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U.S. Department of Energy

Welcome to the EVs@Scale Lab Consortium Bi-Annual Stakeholder Meeting

We will begin at 9 a.m. MT

EVs@Scale Bi-Annual Stakeholder Meeting Plenary / Introduction

9:05 a.m. – 9:15 a.m. MT	**Opening Remarks** *Michael Berube*
9:15 a.m. – 9:30 a.m. MT	**Overview of Consortium Process** *Lee Slezak*
9:30 a.m. – 9:45 a.m. MT	**Consortium Structure and Scope** *Andrew Meintz*

Meeting Objectives

1. Present perspectives, priorities, and insights from key stakeholders in the electric vehicle industry and senior representatives from DOE and national laboratories on near- and long-term R&D priorities

2. Assess the status, challenges, technology gaps, and prospective R&D collaborations to electric vehicle integration with the grid at-scale

3. Identify opportunities to refine Consortium research areas and support common understanding and direction across the Consortium

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Opening Remarks

Michael Berube

Deputy Assistant Secretary for Sustainable Transportation in the U.S. Office of Energy Efficiency and Renewable Energy

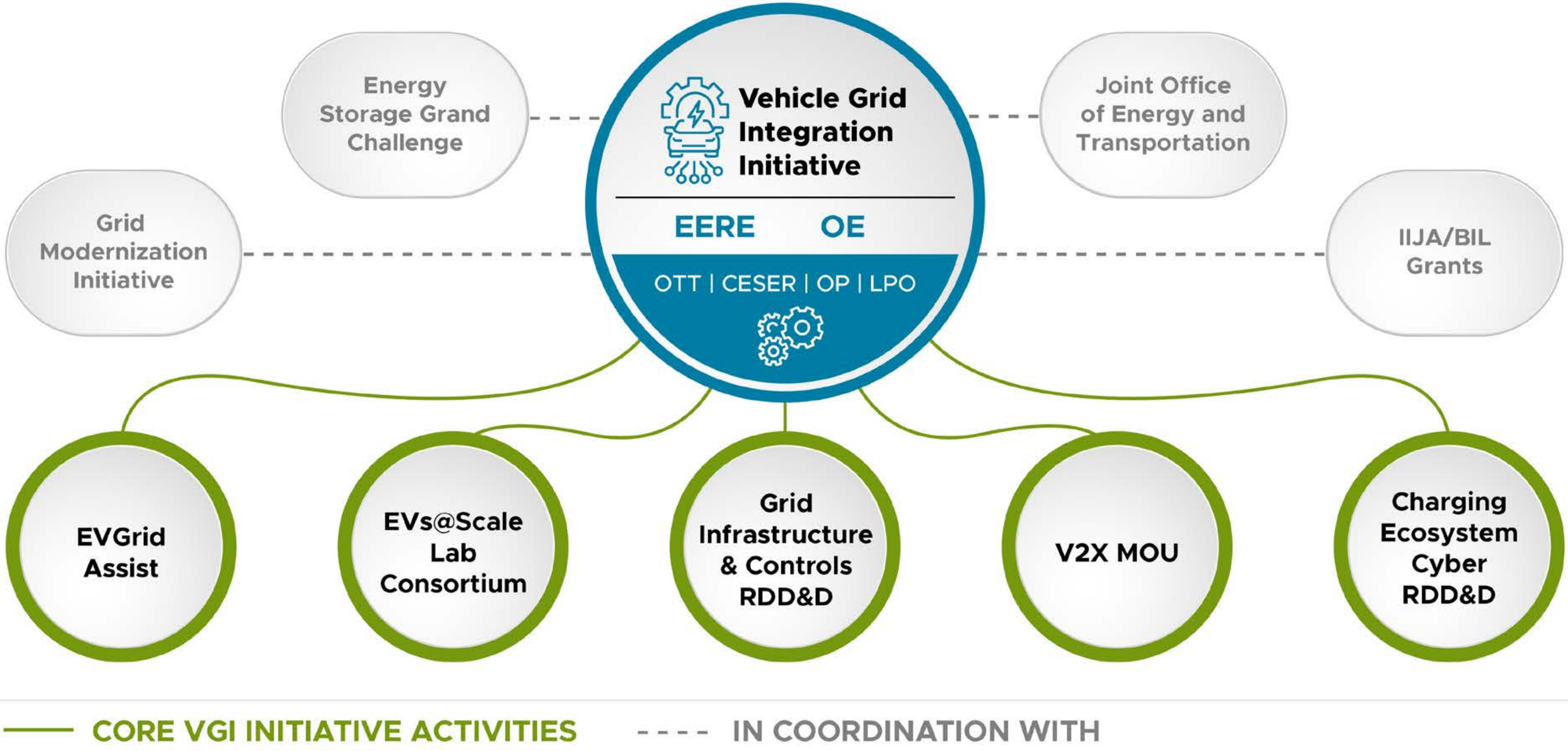
A COORDINATED APPROACH

Close coordination accelerates transportation decarbonization:

- Consistent and broader stakeholder outreach
- Clear signal to industry
- Coordination at all staff levels:
  - R&DD planning and execution
  - Infrastructure deployment
  - Policy & regulation development
  - Data, tools, education and training

Underpinned by a singular aligned transportation decarbonization vision/blueprint

Vehicle Grid Integration



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Consortium Overview

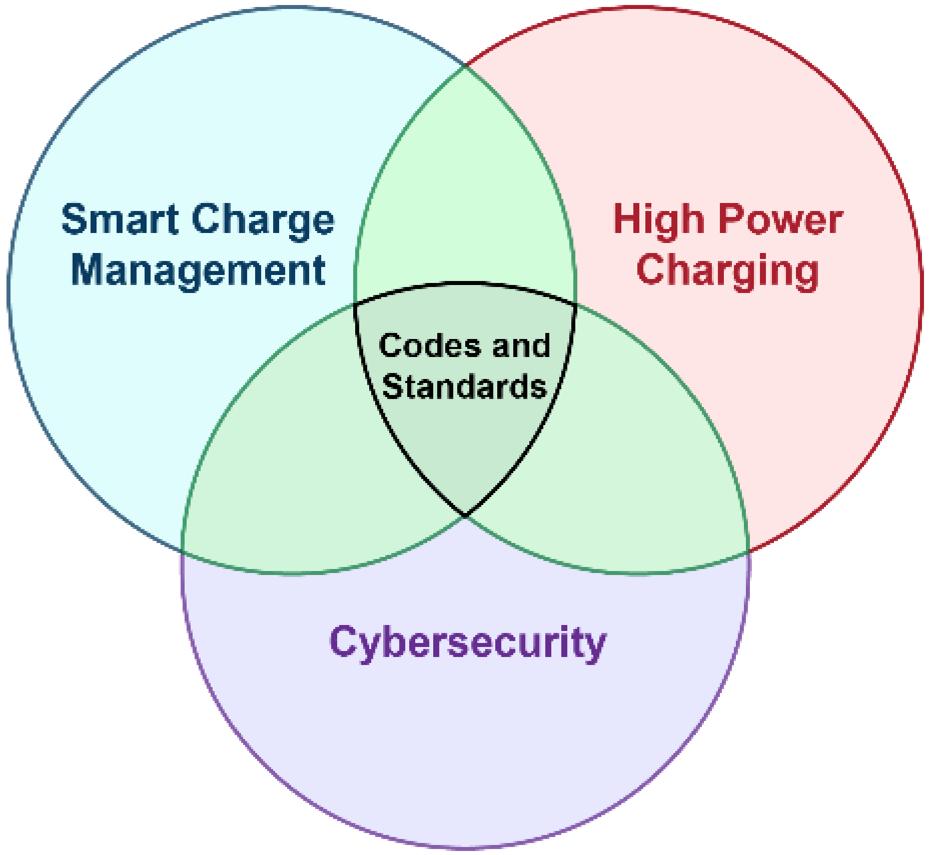
Lee Slezak

GOAL:

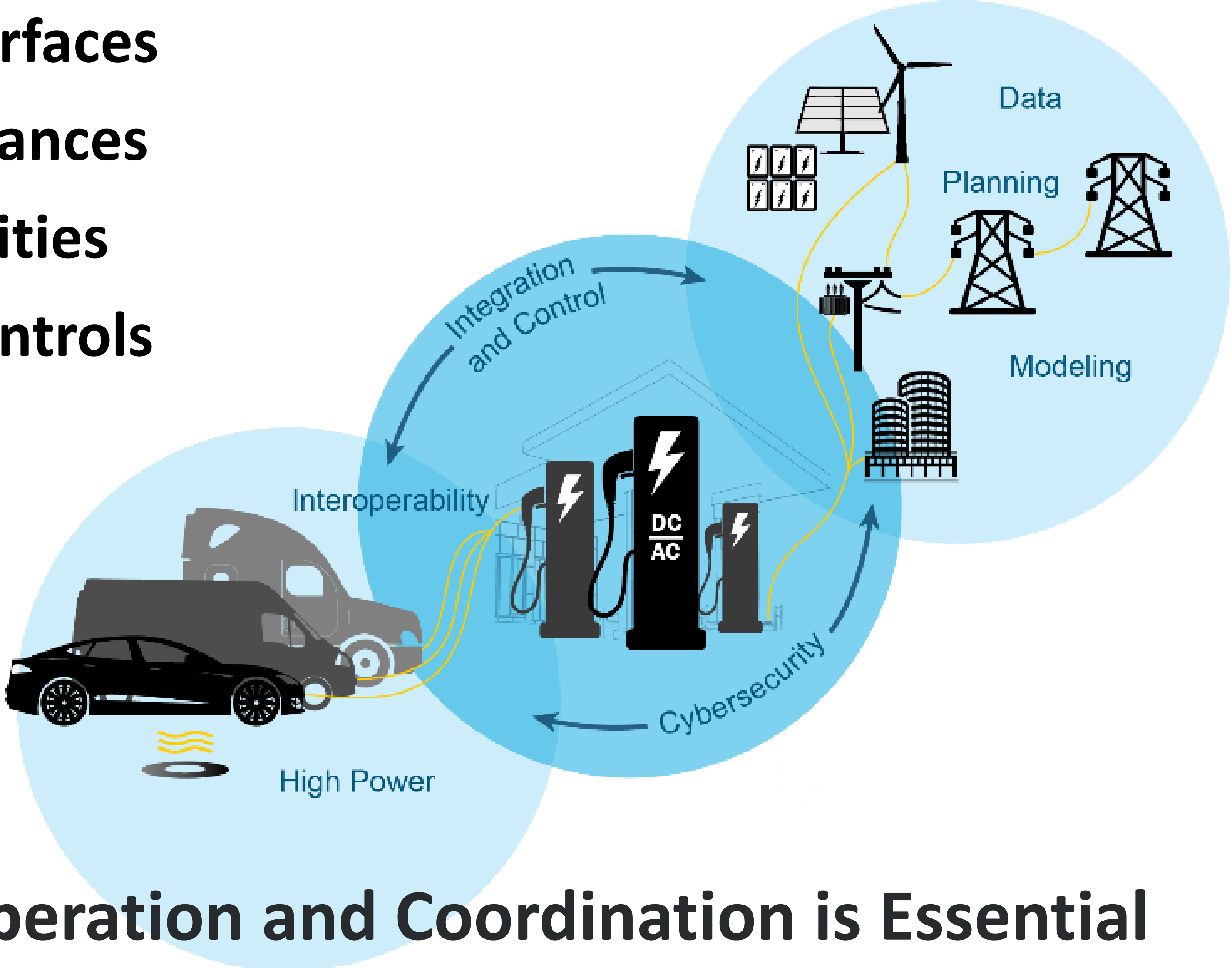
Facilitate development and harmonization of a robust, interoperable, economically vibrant, resilient, cybersecure EV charging infrastructure that is integrated with a decarbonized modern grid

FOCUS:

- **EVs@Scale Lab Consortium**
- **Industry and University FOA Projects**



- Transportation-Grid Interfaces
- Rapid Technological Advances
- High Load Charging Facilities
- Communications and Controls
- Security and Resilience
- Codes and Standards
- Grid Capacity
- Optimizing DERs



Cross-sectoral Cooperation and Coordination is Essential

EVs@Scale Lab Consortium

Objectives

- **Adapt to rapidly evolving technology landscape**
- **Maximize multi-lab coordination**
- **Identify and prioritize long-and short-term RD&D**
- **Timely support to address urgent challenges**
- **Support Administration and IIJA (BIL) transportation electrification objectives**

Consortium Features

- **Six Labs – ANL, INL, NREL, ORNL, PNNL, SNL**
- **5 R&D pillars aligned with G&I R&D pillars**
- **Stakeholder Engagement and Outreach**

5 Pillars of EVs@Scale Lab Consortium

Smart Charge Management

Develop SCM and VGI strategies and tools suitable across transportation vocations

High Power Charging

Expand understanding of HPC characteristics and develop technologies to meet concentrated EV HPC demands and improve grid connectivity

Wireless Power Transfer

Develop and validate high-power dWPT from proof-of-concept to a practical roadway-integrated system

5 Pillars of EVs@Scale Lab Consortium (continued)

Cyber-Physical Security

Identify and address challenges to high-power charging security, safety, infrastructure and grid operations reliability, and consumer confidence

Codes and Standards

Address standards challenges for high-power EV charging, grid impacts, interoperability, and safety

EVs@Scale Lab Consortium Stakeholder Engagement and Outreach

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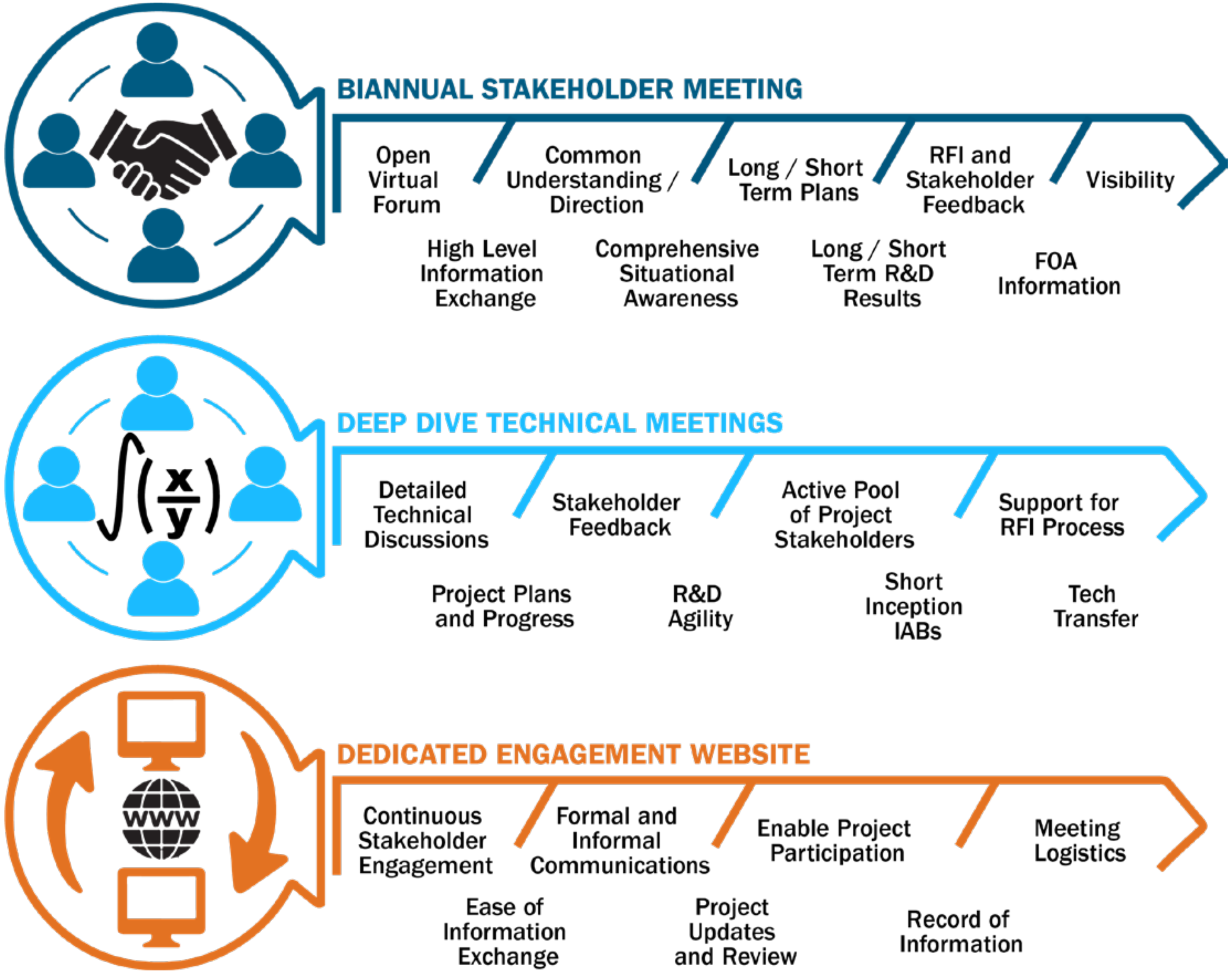

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Consortium
Scope and Structure

Andrew Meintz

Impact

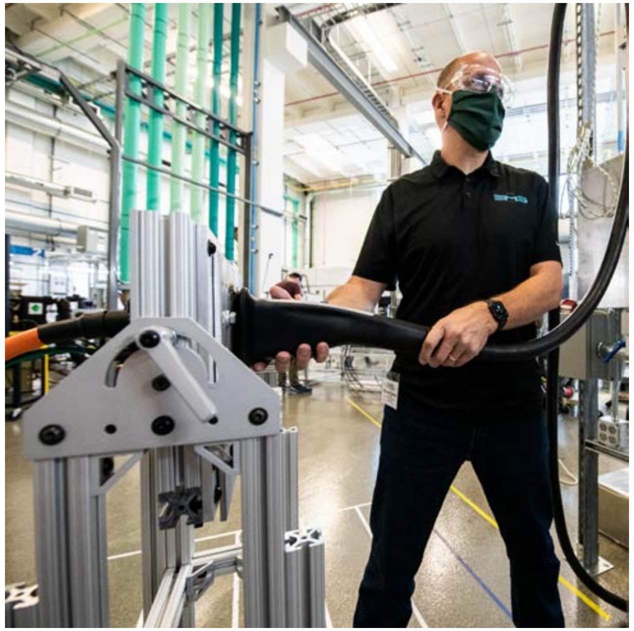
- Transportation is key for America's economy: annually vehicles transport 18 billion tons of freight[1] and moved people more than 3 trillion vehicle-miles[2]
- Presently, the transportation sector derives < 1% of its energy from electricity but accounts for nearly 30% of primary energy consumption in the U.S.[3]
- Considering a case where adoption of EVs reaches about 2/3 of the light-duty fleet in 2050 would result in 16% of annual electricity consumption.

Installation of smart charging system at NREL's Flatirons Campus (Dennis Schroeder / NREL)

[1] Bureau of Transportation Statistics, DOT, Transportation Statistics Annual Report 2020, Table 4-1. https://www.bts.gov/tsar.
[2] Transportation Energy Data Book 39th Edition, ORNL, 2021. Table 3.8 Shares of Highway Vehicle-Miles Traveled by Vehicle Type, 1970-2018.
[3] Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. NREL/TP-6A20-71500

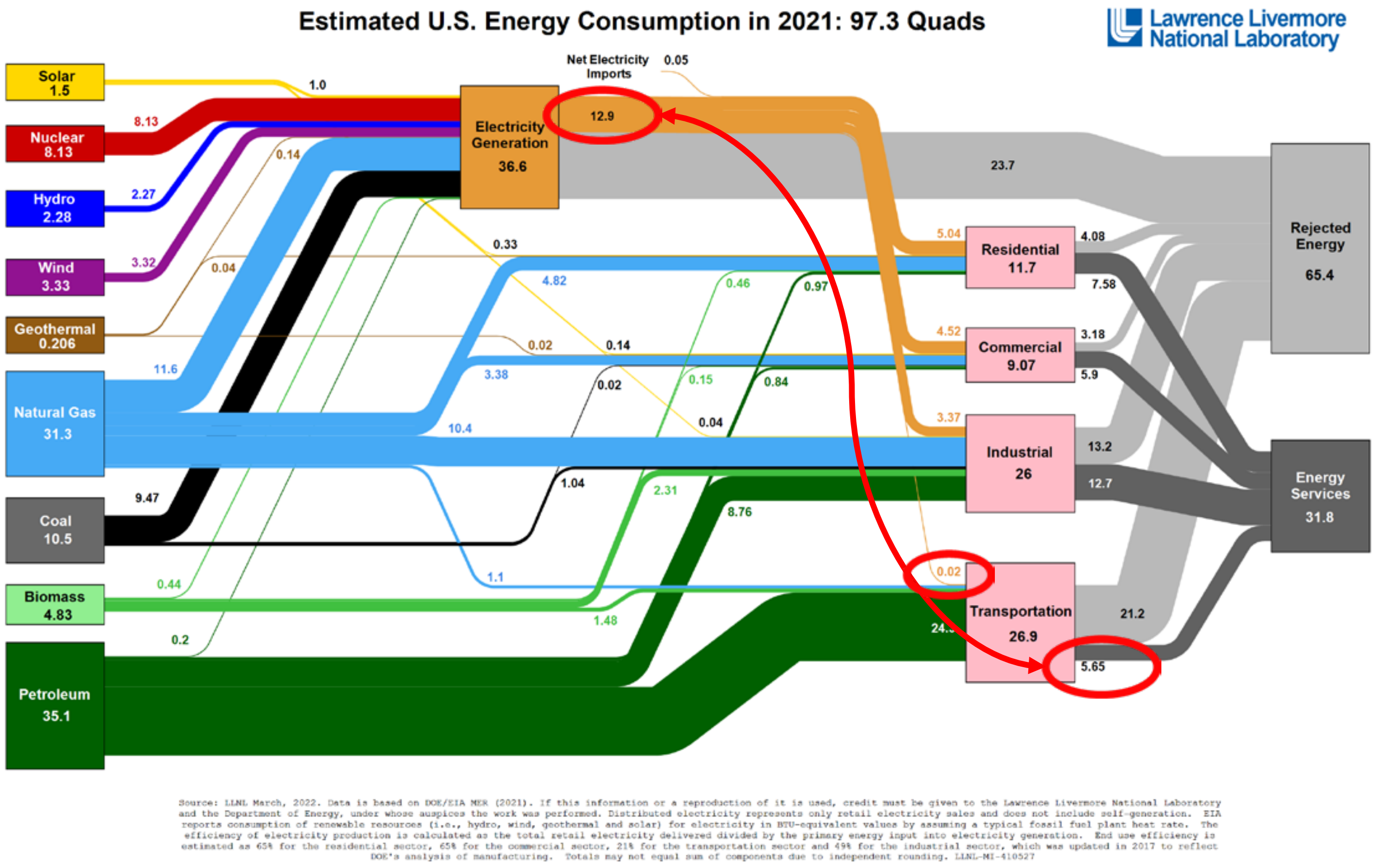
Objectives

- Develop charging technologies and standards needed to meet U.S. goals of transitioning to a nationwide fleet of on-road vehicles powered by electricity, bringing the transportation sector closer to a net-zero-emission future
- Bring together the national laboratories' hardware and software expertise, capabilities, and facilities related to EV charging, charge management, grid services, grid integration, and cyber-physical security.
- Enable highly coordinated, targeted research to be initiated and successfully conducted that is in step with rapid changes in the EV charging

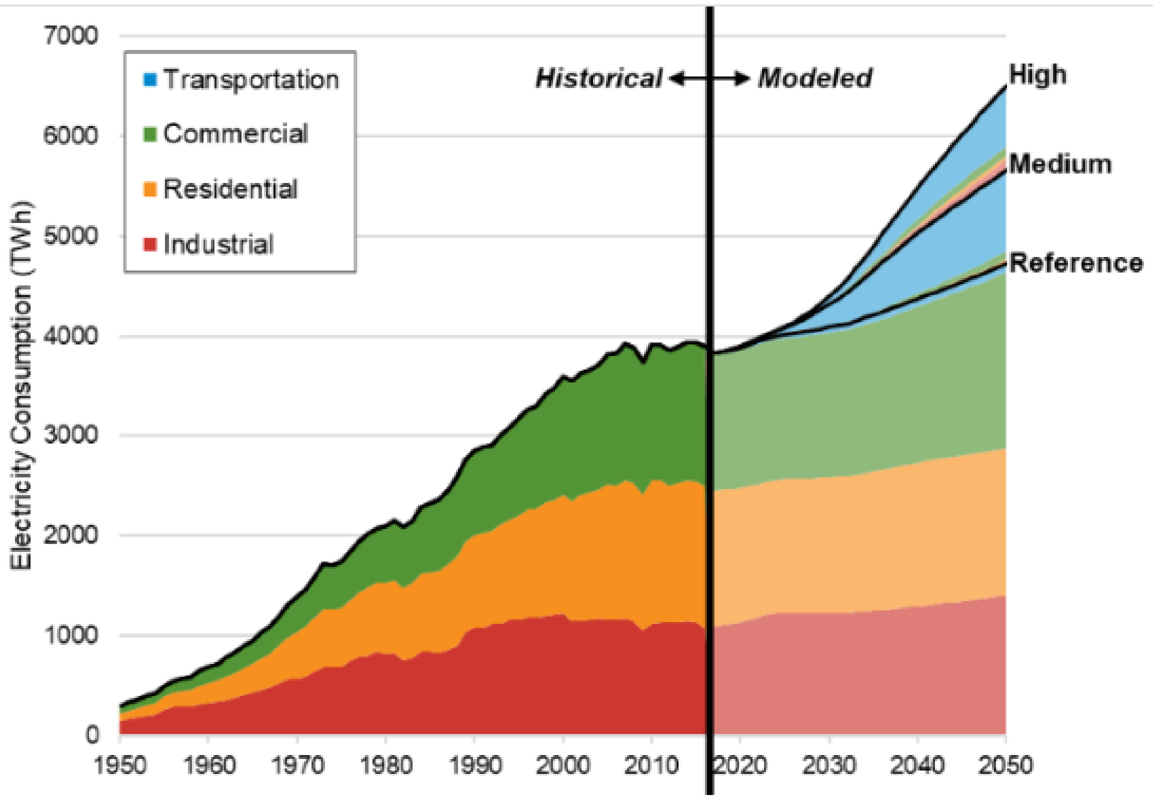


Industry engagement with Consortium members to support development of Megawatt Charging System (Dennis Schroeder / NREL)

Electricity Generation and Transportation are two sectors that traditional have been very distinct and not connected



Sector Coupling



Historical and Projected annual electricity consumption[3]

How will electricity generation and the transportation sectors work together?

What research can we do to ensure a safe, smooth, and seamless transition?

How could a grid-integrated charging network support intermittent generation?

[3] Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. NREL/TP-6A20-71500

Consortium Scope and Structure

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Scope

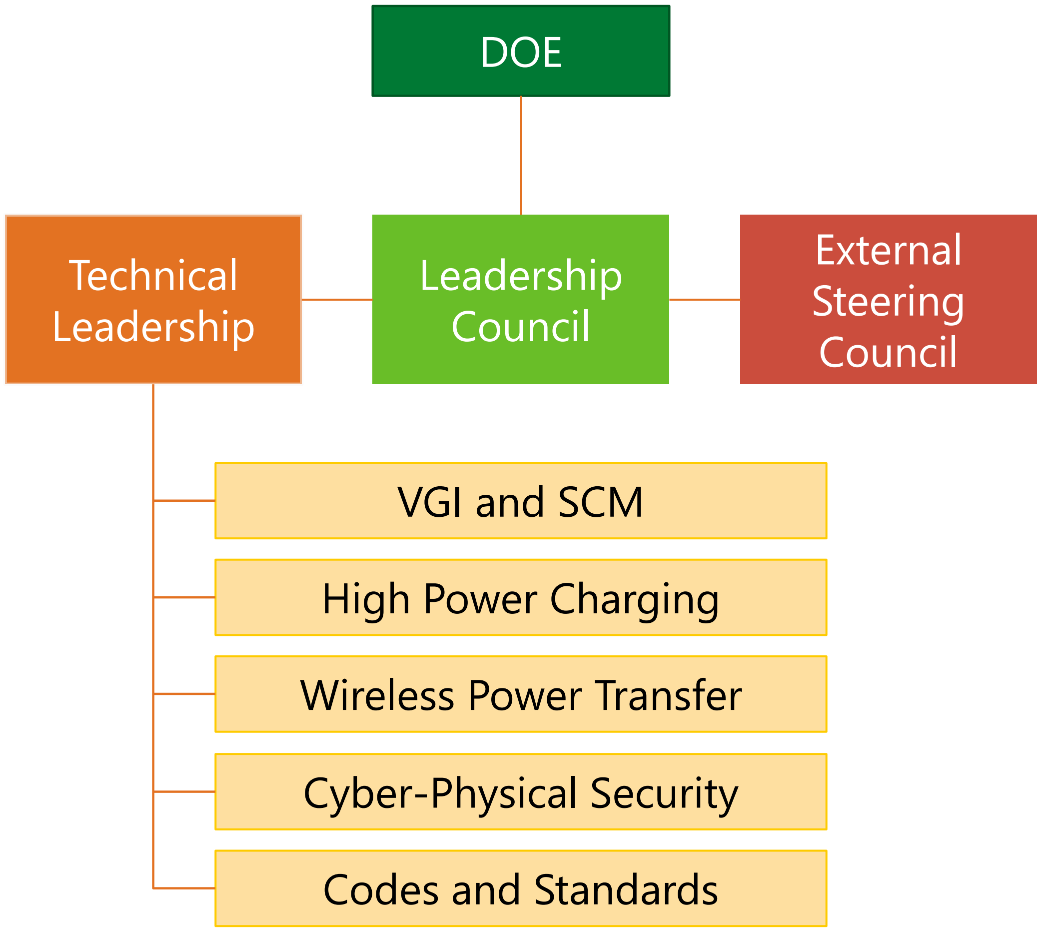
Precompetitive research, development, and demonstration to supports a nationwide network of electric vehicle charging that is harmonized with the grid

Structure

- Smart Charging and Vehicle Grid Integration
- High-power Charging
- Wireless Power Transfer
- Cyber-Physical Security
- Codes & Standards

Consortium Structure

- Leadership Council
  - Andrew Meintz (NREL, chair), Keith Hardy (ANL, rotating co-chair), David Smith (ORNL), Summer Ferreira (SNL), Rick Pratt (PNNL), Tim Pennington (INL)
- External Steering Council
  - Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure
- Consortium Pillars and Technical Leadership
  - Vehicle Grid Integration and Smart Charge Management (VGI/SCM): Jesse Bennett (NREL), Jason Harper (ANL)
  - High Power Charging (HPC): John Kisacikoglu (NREL)
  - Wireless Power Transfer (WPT): Veda Galigekere (ORNL)
  - Cyber-Physical Security (CPS): Richard "Barney" Carlson (INL), Jay Johnson (SNL)
  - Codes and Standards (CS): Ted Bohn (ANL)



Housekeeping for Today's Discussion

- We are using PollEV to ask for your input during each of our presentations
  - Pillar Presentation
  - Continuing VTO Activities
  - Consortium Interaction and Roundtable
- Please be thinking during the discussions
  - "Are the principal thrusts proposed within this pillar on target and appropriate for DOE to be pursuing?"
  - "Are there additional barriers / challenges within this pillar that DOE should be addressing?"

EVs@Scale Bi-Annual Stakeholder Meeting Pillar Presentations

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9:45 a.m. – 10:05 a.m. MT	**Vehicle Grid Integration & Smart Charge Management** *Jesse Bennett*
10:05 a.m. – 10:25 a.m. MT	**High-Power Charging** *John Kisacikoglu*
10:25 a.m. – 10:35 a.m. MT	**Break** *All attendees and presenters*

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Flexible charging to **U**nify the grid and transportation **S**ectors for **E**Vs at scale (FUSE)

Jesse Bennett, NREL

EVs@Scale FUSE - Overview

Objective:

- Develop an adaptive ecosystem of smart charge management (SCM) and vehicle grid integration (VGI) strategies and tools relevant to assess and reduce barriers to electrification throughout a wide geographic area and across numerous vocations

Outcomes:

- Broadly identify limitations and gaps in the existing VGI and SCM strategies to strategically shift PEV charging in time across a wide range of conditions
- Develop enabling technologies and demonstrate VGI approaches to reduce grid impacts throughout the entirety of the LD, MD, and HD on-road electric fleet while accounting for vehicle operational and energy requirements.
- Determine SCM and VGI benefits for consumers and utilities for EVs@Scale across the range of conditions (geographies and seasons) found in the US

EVs@Scale FUSE - Team and Partners

Team:

- **National Renewable Energy Laboratory (NREL)**
  - Vehicle Charging, Grid Impact Analysis, SCM/VGI Development and Demonstration
- **Argonne National Laboratory (ANL)**
  - SCM/VGI Development and Demonstration
- **Idaho National Laboratory (INL)**
  - Vehicle Charging Analysis, SCM/VGI Development
- **Sandia National Laboratories (Sandia)**
  - Grid impact Analysis

Industry Partners/Data Sources:

- **Electric Distribution Utilities**
  - Dominion Energy (100+ distribution feeder models throughout VA)
- **Vehicle Travel Data**
  - Wejo (~400 million trips throughout VA for Sept. ‘21 and Feb. ’22)

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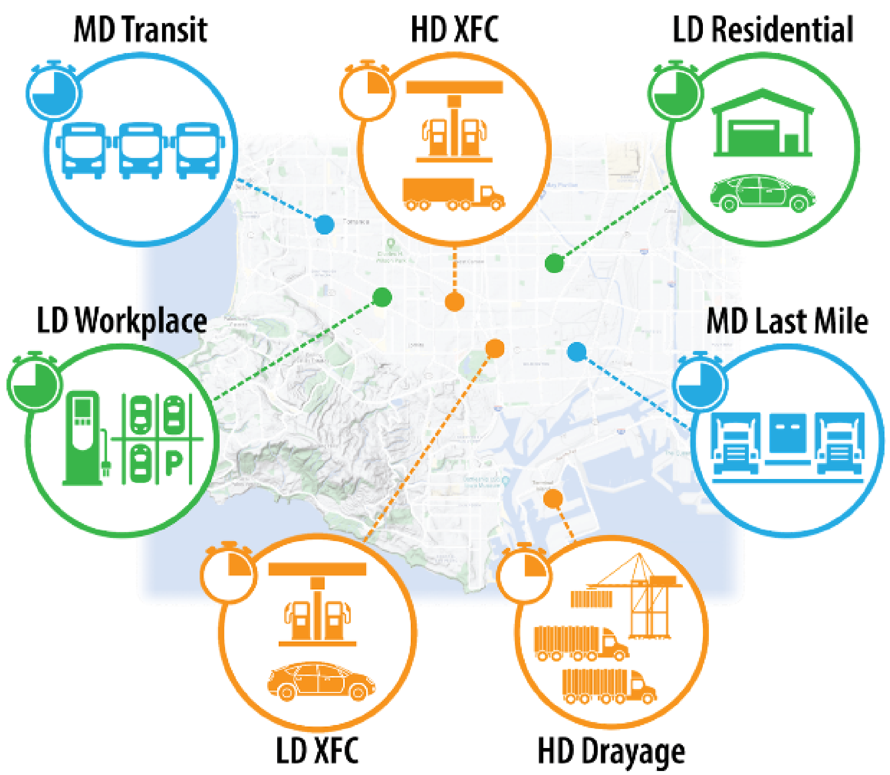
- **This project will analyze and demonstrate SCM and VGI approaches to reduce grid impacts from EVs@Scale as a result of the charging needs of the LD, MD, and HD on-road electrified fleet.**

- **SCM/VGI Analysis**
  - Assess the potential charging demand for EVs@Scale and determine the uncontrolled charging grid impacts.
  - Develop and analyze the effectiveness of various VGI and SCM strategies at mitigating the grid impacts of charging EVs@Scale

- **SCM/VGI Demonstration**
  - Expand on existing SCM/VGI strategies to adapt to the evolving needs EVs@Scale throughout a wide range of vehicles and vocations.
  - Develop enabling technologies to demonstrate the potential for new and existing SCM and VGI in a laboratory and real-world environment.
  - Coordinate with Codes and Standards Pillar to determine the potential of existing technologies and need for future developments.



EVs@Scale FUSE - Tasks and Milestones (Years 1 and 2 only)

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- **Task 1: Scoping, requirements, and industry/stakeholder engagement**
  - Coordinate with industry partners to support both analysis and demonstration tasks
- **Task 2: Assessment of travel, charging energy, and grid impacts**
  - Assess charging demand for EVs@Scale
  - Analyze grid impacts with and without SCM
  - Broadly assess SCM strategies across wide regions
- **Task 3: Demonstrate appropriate SCM strategies, systems, and tools to reduce the potential grid impacts of EVs@Scale charging**
  - Define SCM strategies and demonstration needs
  - Develop enabling technologies
  - Demonstrate SCM in lab and real-world environments

Milestone	Description	Date	Lab
A.1.1.1	Identify areas of study and necessary partners.	FY22 Q2	NREL ANL INL
A.1.1.2	Acquire necessary transportation data and distribution models in regions of study.	FY22 Q3	NREL
A.1.1.3	Provide requirements and support for real world implementation of SCM strategies.	FY22 Q3	NREL ANL INL
A.1.1.4	Broadly identify limitations and gaps in the existing VGI and SCM strategies across wide regions.	FY22 Q4	INL
A.1.1.5	Develop EV charging load datasets and verify utility grid models in regions of study.	FY22 Q4	NREL
A.1.1.6	Identify high-capacity locations for concentrated charging throughout regions of study.	FY22 Q4	SANDIA
A.1.1.7	Identify lab demonstration opportunities and partners necessary to support Task 3.3	FY22 Q4	ANL NREL
A.1.2.1	Complete proof of concept smart interop EVSE hardware.	FY23 Q1	ANL
A.1.2.2	Finalize EVRest internal testing and prepare for alpha pilot of EVRest at Argonne.	FY23 Q1	ANL
A.1.2.3	Perform hosting capacity analysis to determine optimal interconnection points for HPC and depot charging locations.	FY23 Q1	NREL
A.1.2.4	Complete development of new VGI and SCM strategies to address limitations and gaps.	FY23 Q2	INL NREL
A.1.2.5	Develop MD/HD EV charging load dataset for EVs@Scale in region(s) of study	FY23 Q2	NREL
A.1.2.6	Perform simulations that consider incentives for charging to avoid excessive high power or distributed charging.	FY23 Q2	SANDIA INL
A.1.2.7	Demonstration of charge scheduler bridge at smart energy plaza.	FY23 Q2	ANL
A.1.2.8	Assess effectiveness of new VGI and SCM strategies to alleviate issues on distribution feeders and bulk transmission across a wide range of conditions including XFC reservations and price incentivized charge scheduling.	FY23 Q4	NREL INL

EVs@Scale FUSE - Analysis Overview

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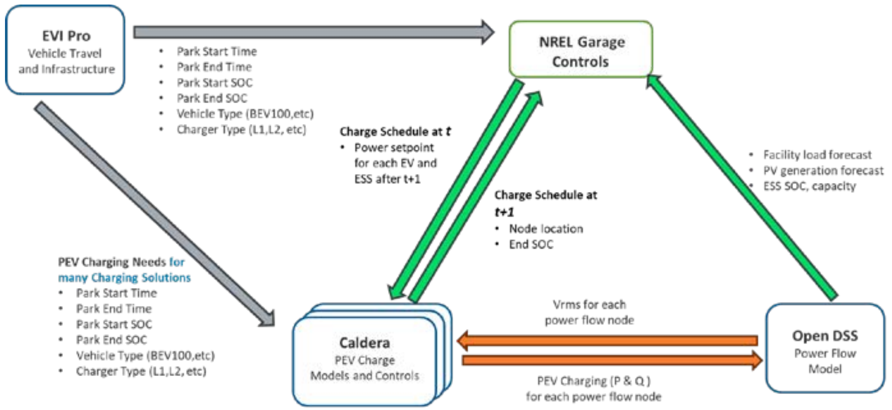
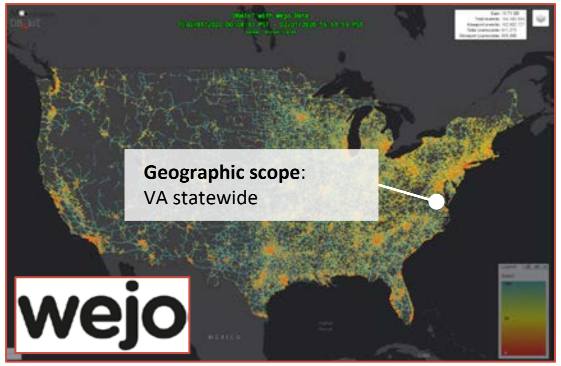
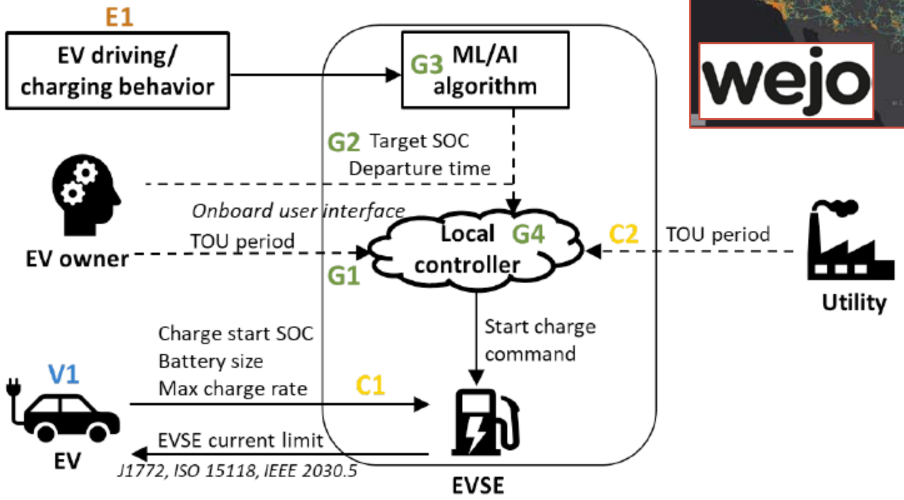
- **Assess charging demand for EVs@Scale**
  - Acquire travel data for existing vehicle operations
  - Develop EV adoption scenarios using NREL's TEMPO
  - Leverage NREL's EVI tools to determine charging needs
- **Analyze grid impacts with and without SCM**
  - Acquire grid models from partner utility
  - Leverage INL's Caldera to assess grid impacts with and without SCM
  - Refine and update SCM strategies for EVs@Scale
- **Broadly assess SCM strategies across wide regions**
  - Acquire transportation, utility, and other necessary data across wide regions
  - Assess gaps and limitations in SCM strategies throughout large regions or utility service territories

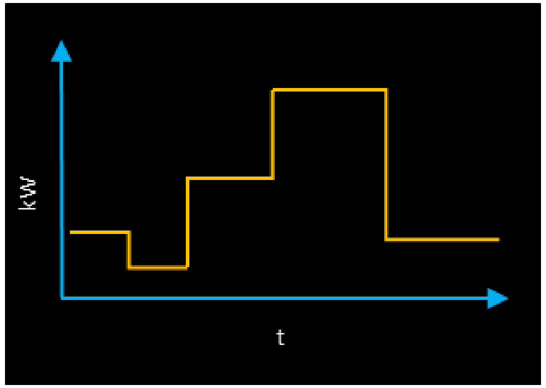


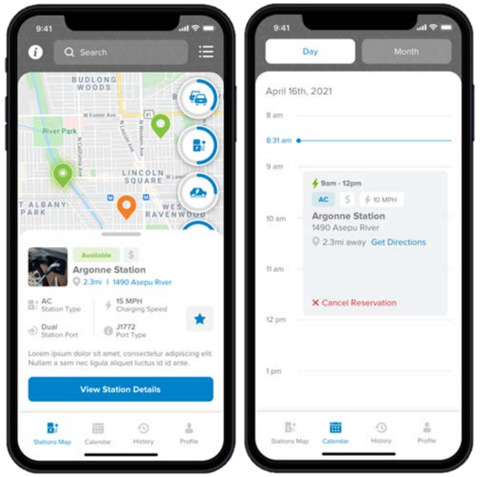


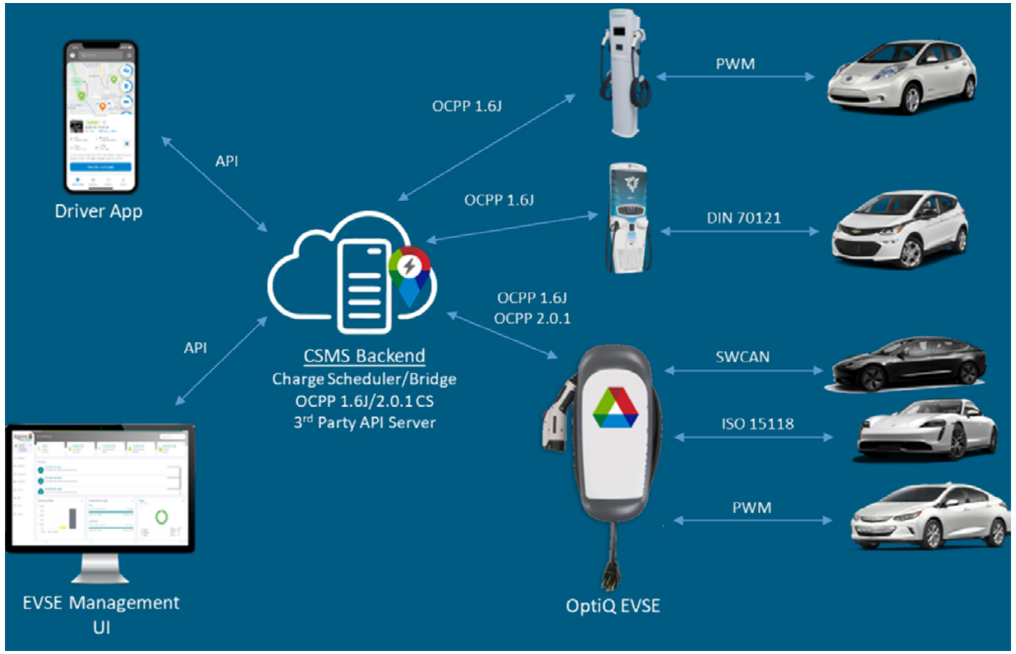


EVs@Scale FUSE - Demonstration Overview

- **Define SCM strategies and demonstration needs**
  - Define/refine SCM objective functions for EVS@Scale
  - Review SCM requirements for simulation/analysis
  - Assess current standards and hardware requirements
- **Develop enabling technologies**
  - Develop Smart Interop EVSE (hardware and firmware)
  - Refine ISO-15118 Charge Scheduler
  - Develop Smart Interop EVSE (hardware and firmware)
  - Develop Charge Reservation System - EVRest
- **Demonstrate SCM in lab and real-world environments**
  - Demonstrate SCM at ANL's Smart Energy Plaza and NREL's EV Research Integration (EVRI) Lab







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High-Power Electric Vehicle Charging Hub Integration Platform (eCHIP)

John Kisacikoglu, NREL

Outline

- Project Overview
- Status Review for High-Power Charging Technology
- Charging Hub Hardware Demonstration Plan at NREL
- DC Charging Hub Applications and Use Cases
- Conclusion and Next Steps

Project Overview

Objective: Develop plug-and-play solution allowing charging site to organically grow with additional chargers and distributed energy resources through predefined compatibility with standards that will ensure interoperability and reduce upfront engineering expense

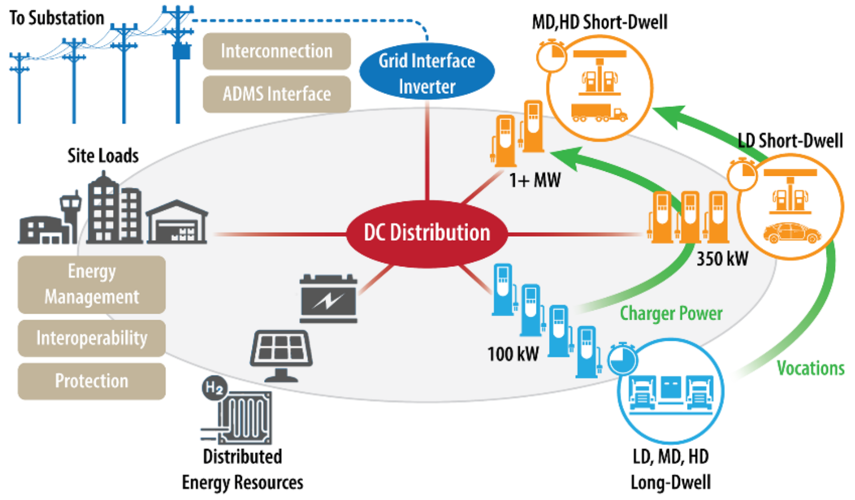
Outcomes:

- Develop and demonstrate solutions for efficient, low-cost, and **high-power-density DC/DC** for kW- and MW-scale charging
- **Broadly identify limitations and gaps** in DC distribution and protection systems that allow for modular HPC systems
- Determine interoperable hardware, communication, and control architectures for high-power charging facilities that support **seamless grid integration and resilient operation**

NREL
- John Kisacikoglu (PI)
- Myungsoo Jun
- Shafquat Khan
- Rasel Mahmud
- Partha Mishra
- Manish Mohanpurkar
- Emin Ucer
- Ed Watt

Argonne National Laboratory
- Jason Harper
- Keith Hardy
- Bryan Nystrom
- Akram Ali

Oak Ridge National Laboratory
- Prasad Kandula
- Madhu Chinthavali



Review on DC Microgrids/Charging Hubs

Architecture	Power Electronics Interface	Control and Energy Management	Protection
• Grid topology • Voltage polarity • Islanding • Switching • Reconfiguration • Source/load types	• AC/DC inverter selection ➢ Diode-bridge, AFE, SST, etc. • DC/DC converter selection • Power flow direction ➢ Uni-directional ➢ Bi-directional • Circulating current issues • Filtering (EMI etc.)	• Control structure ➢ Centralized, decentralized, etc. • Control level ➢ Primary, secondary, tertiary • Method ➢ Droop, non-linear, etc. • Voltage and current stability • Islanding control • Coordination of different controllers	• Grounding ➢ TT, TN-S, TN-C, TN-S-C • Fault detection • Fault isolation • Fault handling • Protection devices ➢ Circuit breakers ➢ Fuses • Device ratings

Communication Interface	Power Quality	Standards
• Communication network • Protocol • Coverage • Medium ➢ Wired, wireless • Latency • Bandwidth • Security	• Voltage transients • Harmonics • EMC Issues • Inrush currents • Voltage imbalance • DC bus faults • Circulating currents	• IEEE P2030.10 • IEEE 1547-2018 • IEEE 1547 • IEEE 946-2004 • IEEE SEG-4,6,9 • IEEE P946

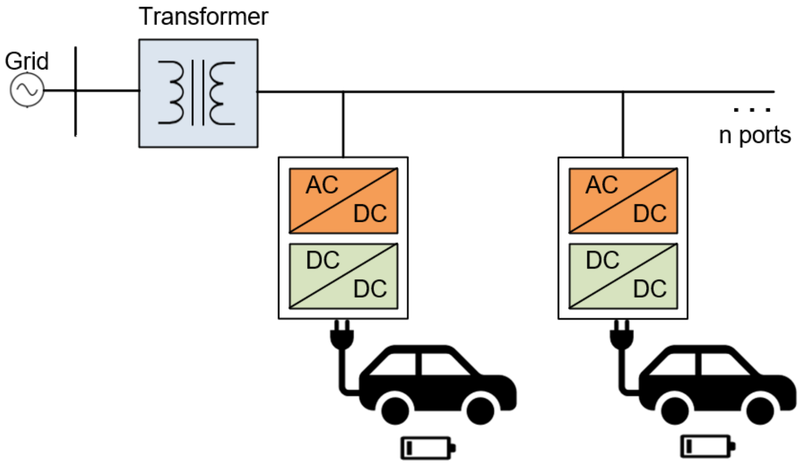
Technology Status

- Applications in homes, hospitals, businesses and factories, shipboard power systems, aircraft and automobile systems, and EV charging stations.
- Most DC microgrids operate between **24V and 1500V DC.**
- Instantaneous overcurrent protection requires wide-bandwidth measurement sensors and ultrafast sampling rates to avoid missing the initial fault current peak.
- Most standards and technologies are available for AC/DC interface for PVs.

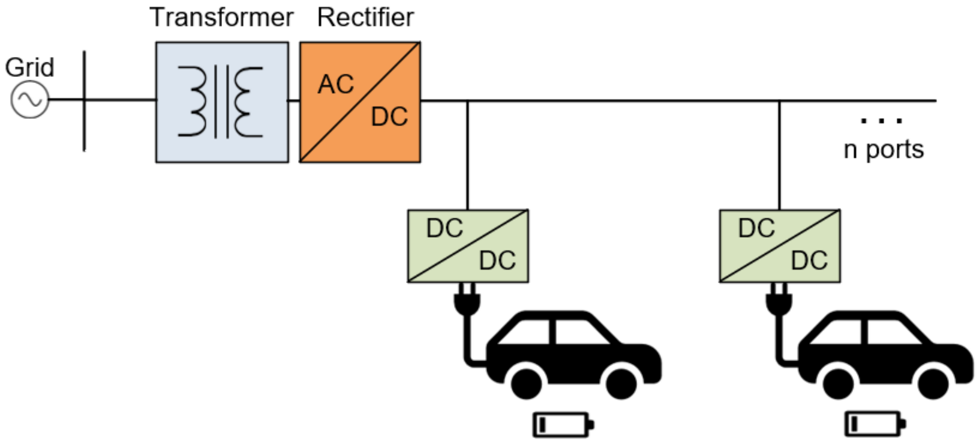
Some DC Microgrid projects around the world

- Alliance Center: DC Microgrid Project
- Sandia/Emera DC Microgrid
- Center for Research on Microgrids (CROM)
- AEG DC Microgrid Solutions
- ARDApower EV Charging Microgrid
- ABB On-board DC microgrid (for ships)
- Livingston & Haven Bosch DC Microgrid
- GLEAMM Project Prototype Microgrid
- CESI RICERCA DER test microgrid (Italy)
- Chinese-Danish DC Microgrid Project: iDClab
- Dunkung DC Microgrid (Taiwan)
- Eaton DC Microgrid and Current OS Protocol

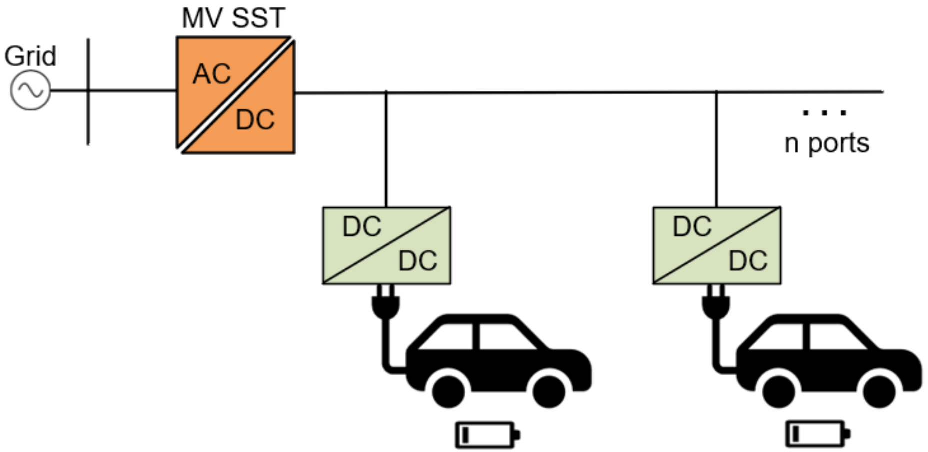
HPC Power Electronics Architectures



AC-Hub option



DC-Hub option w/ LF Transformer



DC-Hub option w/ MV SST

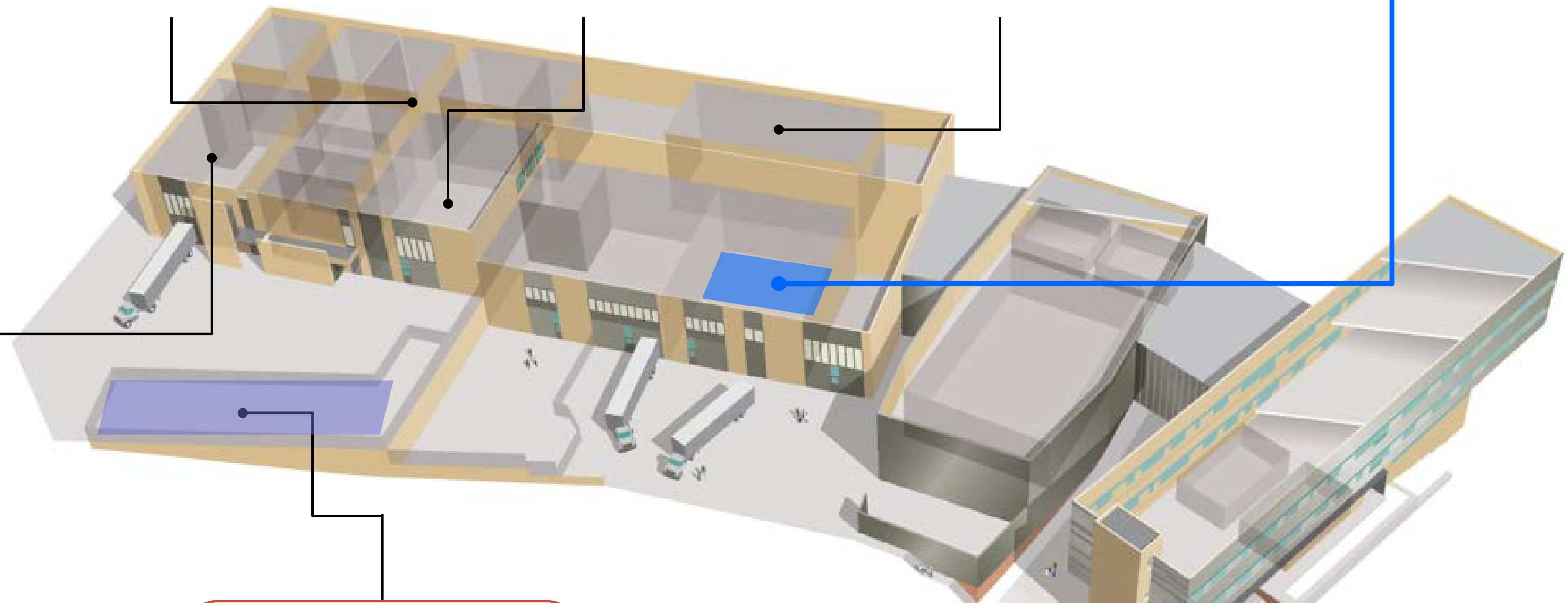
Energy Systems Integration Facility

Rooftop Experiment Area
Wind & Solar

Energy Storage Lab (BTMS)
Batteries & Thermal Energy Storage

Systems Performance Lab
Residential Buildings & Loads

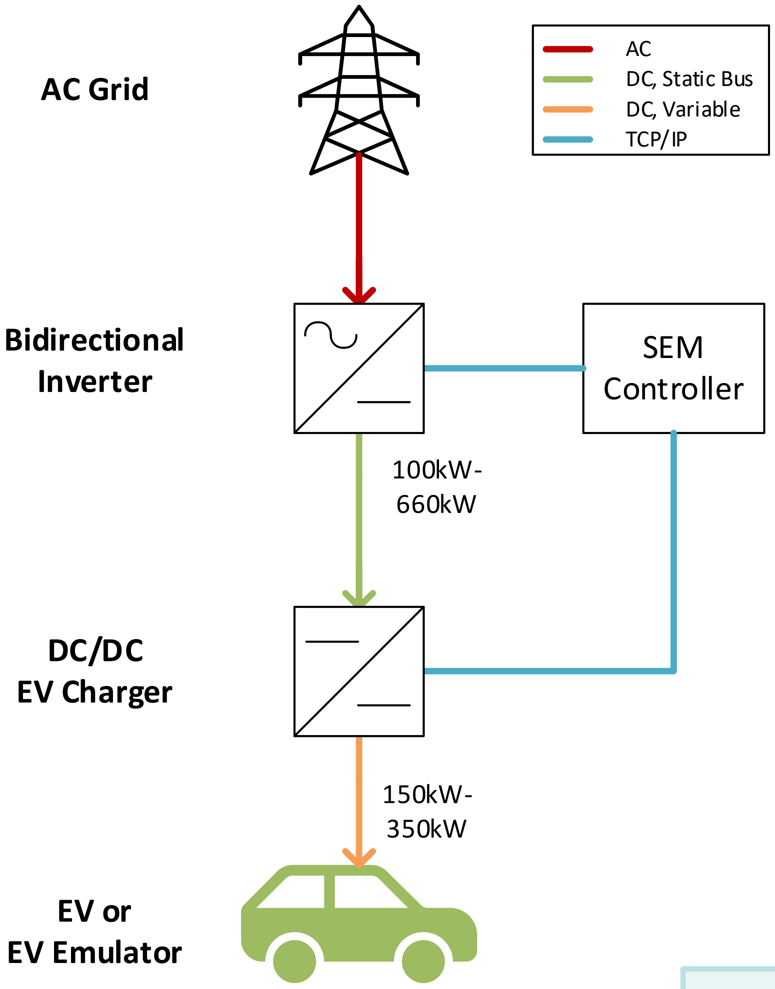
EVRI



Hydrogen Systems Integration Lab
Fuel Cells & Electrolyzers

MVOTA
EVs, Power Transformers, Microturbines, & Generators

Charging Hub Demonstration - Phase 1



Initial SEM development
No grid-side control

Location

ESIF Building – EVRI

To be completed by January 2023

Inverter

- Anderson AC2660P
  - Bi-directional power flow
  - 660kW capability
  - Similar rated inverters available

EV Charger (DC/DC)

- Tritium PKM150
  - 150kW, 950V DC Input, 150-920V DC output

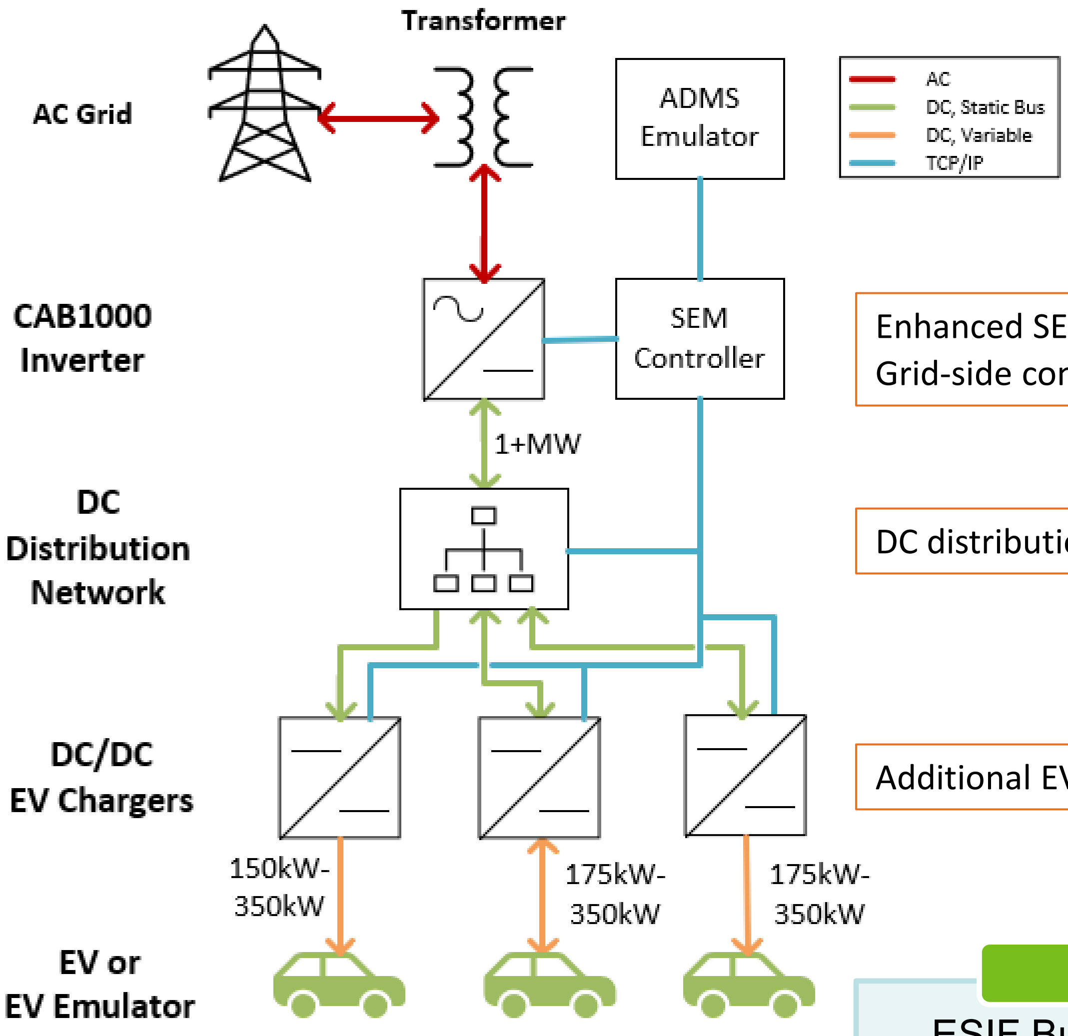
Electric Vehicle

- Hyundai Ioniq 5
  - 800V, 77.4kWh

Electric Vehicle Emulator

- Custom design for control and communication
- AV900: 250kW Battery Emulation

Charging Hub Demonstration - Phase 2



Enhanced SEM development
Grid-side control functionality

DC distribution bus design

Additional EVs

Location

ESIF Building – MVOTA

To be completed by March 2024

Inverter

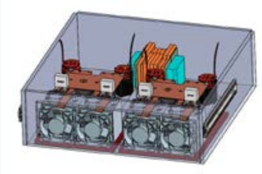
- CAB1000 - Utility Grade Inverter
  - Bi-directional power flow
  - Capable of 1043kW
- Required transformer - ETA Jan 2023

DC Load Center

- Under development

EV Chargers

- ORNL/ANL UPER - 175kW
- Tritium PKM150 - 150kW
- COTS - 350kW



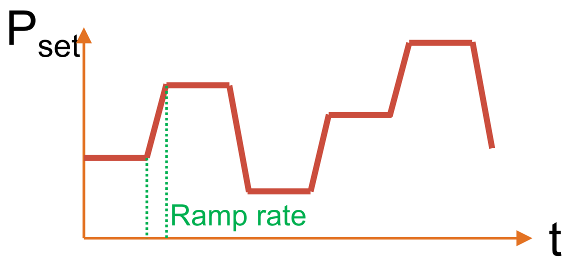
Other (same as Phase 1)

- Electric Vehicle
- Electric Vehicle Emulator

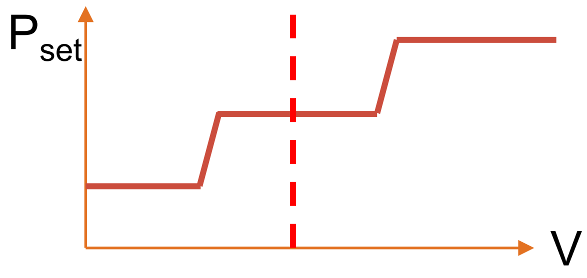
Baseline Cases for Controller Development

1) Open-loop tests. No-control over charging.
   - Charging EV at rated power level

2) Pre-defined, time-based charging profile set by SEM
   - Ramp-rate adjustments
   - Observing DC voltage changes



3) Implementation of voltage-based (rule-based) control
   - Adjusting P_{set} based on voltage (e.g., droop control)



4) Optimization-based operational control
   - $P_{set} = f(E, t, V)$ power response of a vehicle needing *E* amount of energy within time *t* given all other constraints
   - Control policies among multiple ports

Operational Use Cases

1) Application use-cases for LD/MD/HD vehicles
   - Product distribution warehouse
   - Truck stop location
   - Airport

2) DC charging hub operational use-cases
   - DC Power vs. DC voltage balance control
   - Stand-alone operation with on-site storage
   - Transition between stand-alone and grid-connected operations
   - Bidirectional power support to grid (V, P, and Q)
   - Communication failure scenarios
   - Fault recovery
   - Cyber attack

Control Hardware-in-the-Loop (C-HIL) Demonstration

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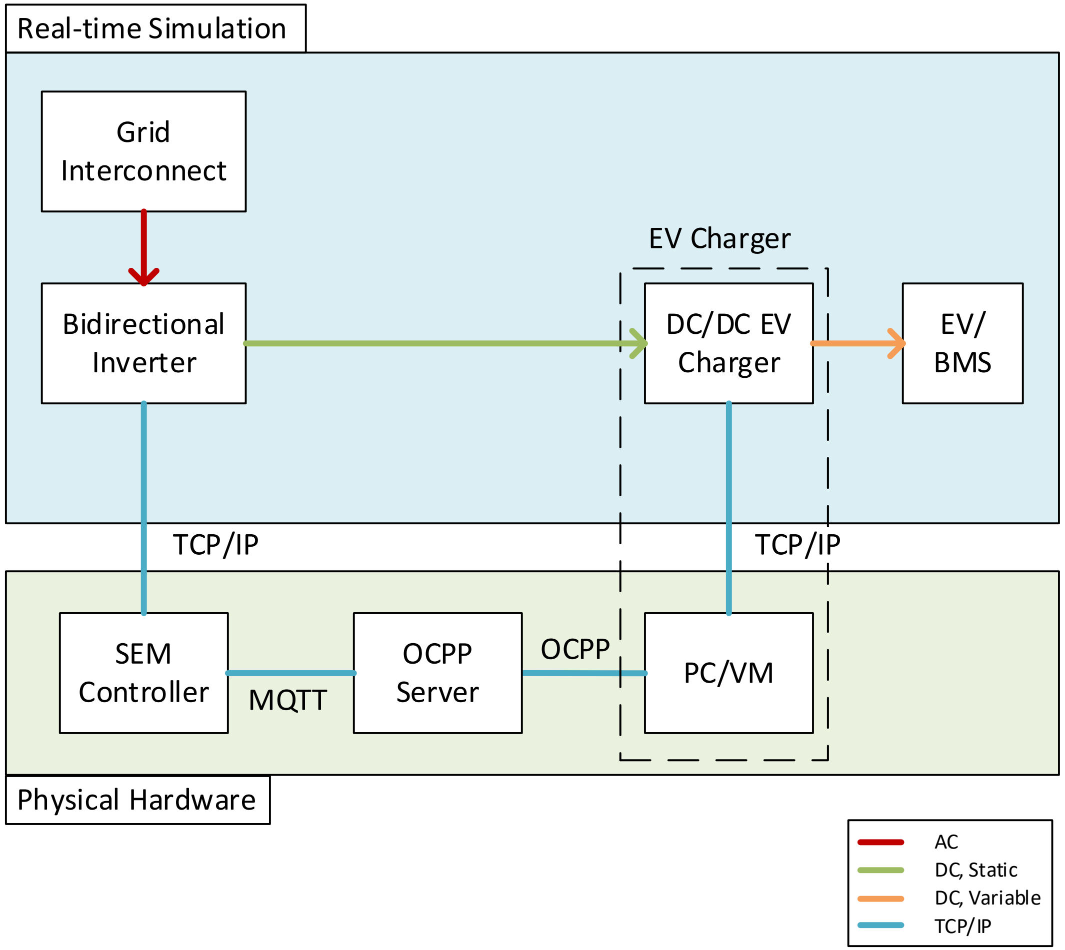
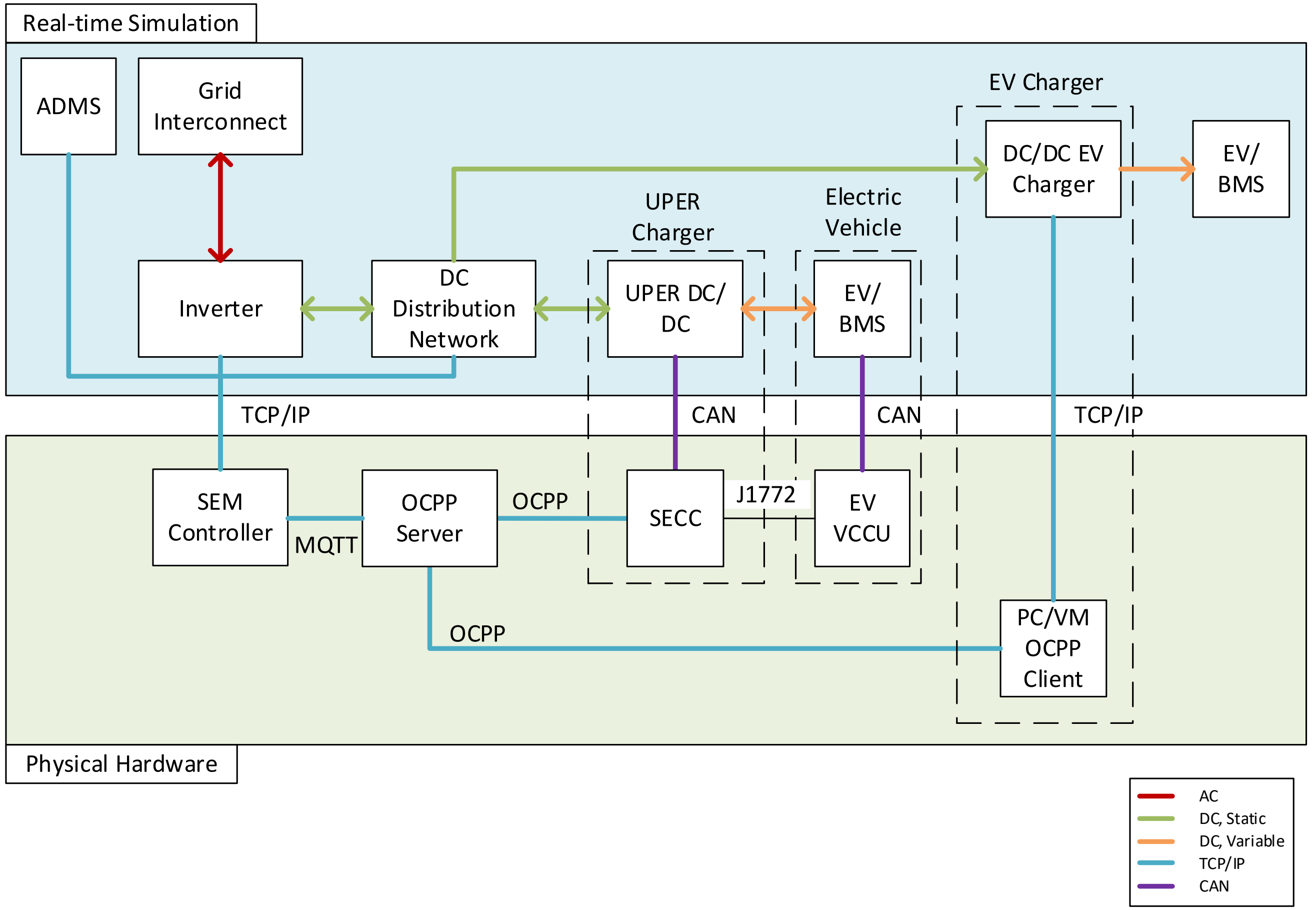
C-HIL Phase 1



To be completed by December 2022

C-HIL Phase 2



To be completed by September 2023

Overview of Demo Plan

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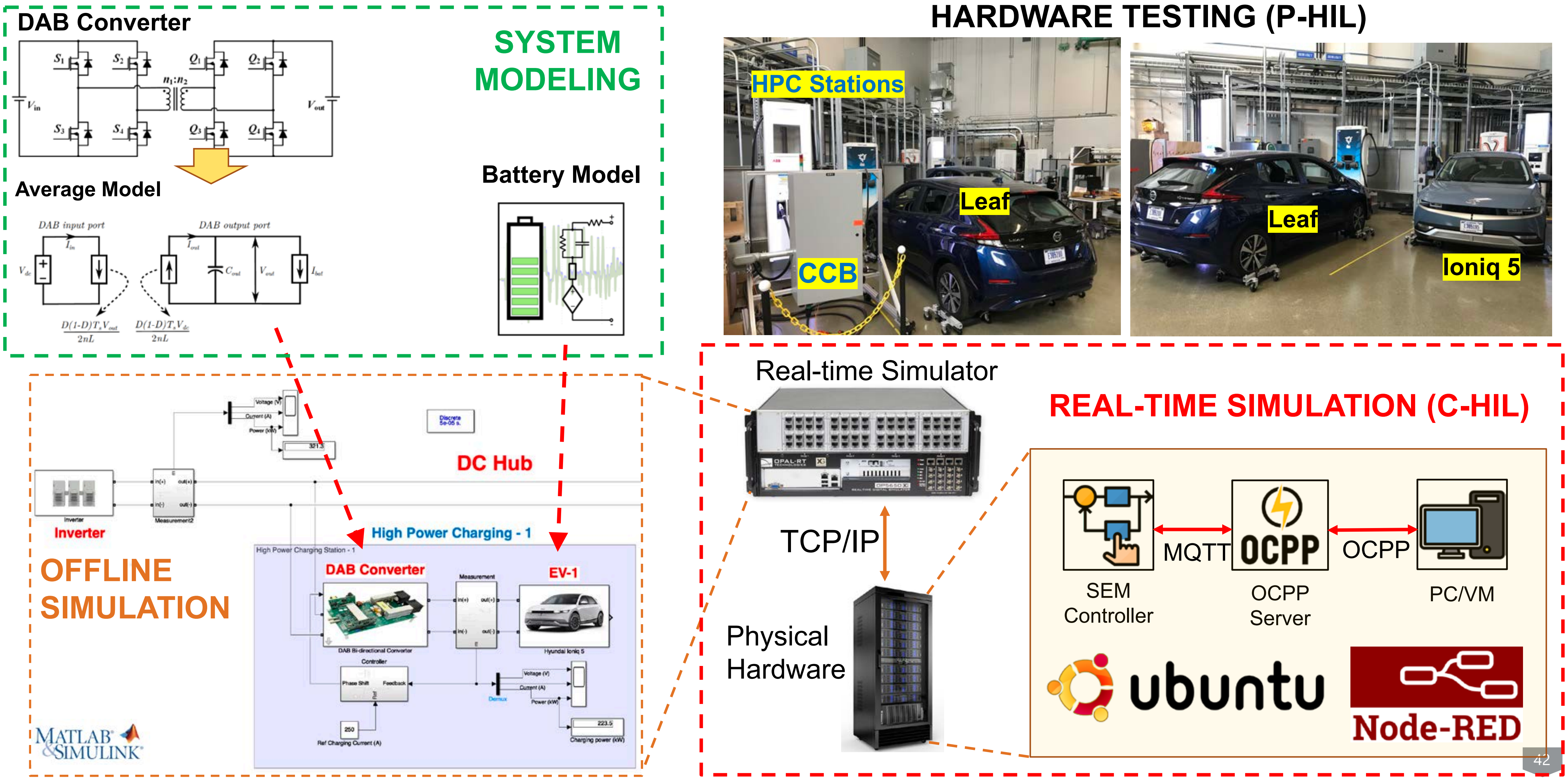
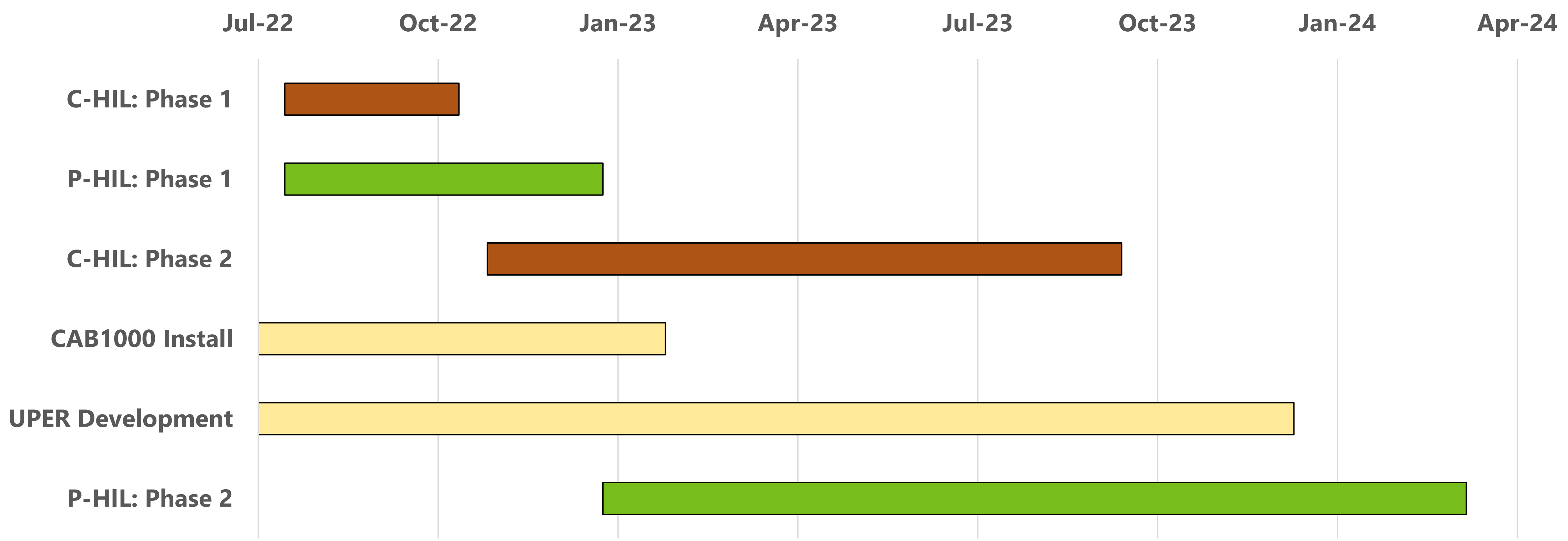


Charging Hub and C-HIL Timeline



Conclusion and Next Steps

Review

- Project Overview
- Technology Status
- Charging Hub Demonstration Plan at NREL
- Controller Hardware-in-the-Loop (C-HIL) Demonstration Plan at NREL

Next steps

- Detailed planning, preparation, and execution for Phase 1 Hardware Demonstration
- Designing and commissioning C-HIL test bed
- Modeling and code development for initial SEM software
- Developing Spec-II module integration requirements with UPER and SEM controller
- UPER DC/DC development and integration

10:25 a.m. – 10:35 a.m. MT	**Break** *All attendees and presenters*
10:35 a.m. – 10:55 a.m. MT	**Dynamic Wireless Power Transfer** *Veda Galigekere*
10:55 a.m. – 11:15 a.m. MT	**Cyber-Physical Security** *Barney Carlson*
11:15 a.m. – 10:35 a.m. MT	**Codes and Standards** *Ted Bohn*

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Dynamic Wireless Power Transfer

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Oak Ridge National Laboratory (ORNL)

Dynamic Wireless Power Transfer

- **Objective:** Develop and validate technologies and solutions to transition high-power dynamic wireless (HPDW) charging of electric vehicles (EVs) from an early-stage proof-of-concept system to a practical roadway-integrated dynamic wireless power transfer (DWPT) system suitable for deployment at-scale.
- **Outcomes**:
  - Evaluation of comprehensive data from dynamic wireless charging system including
    - Real-world data from dynamic charging system installed at ACM
    - Safety and inter-operability
    - Life-cycle and accelerated aging impact on coupler and roadways using heavy-vehicle simulator
  - Solutions to system- and component-level barriers for real-world deployment of HPDW systems.
  - Validated HPDW coil architectures and embedding techniques suitable for different roadways, environmental conditions, use cases, and system life-cycle.
- **Team and Funding:**
  - ORNL, INL, NREL
  - $2.70 M/yr
- **Collaboration:**
  - Virginia Tech. Transportation Institute, American Center for Mobility, TDOT, MDOT, VDOT, FWHA, OEMs (Stellantis and Hyundai), and Utilities (TVA, DTE).

Considerations for at-scale deployment of high-power DWPT system

Dynamic Wireless Power Transfer: Prior Work

FY19:

Analytical and simulation studies

FY20:

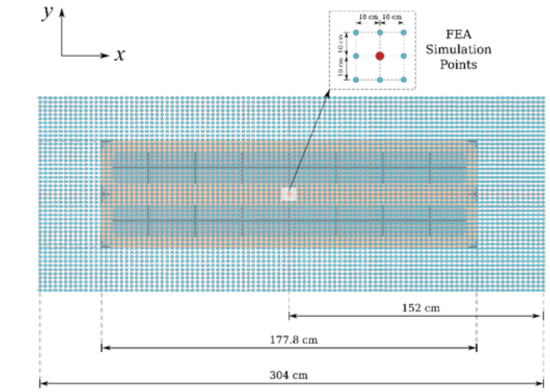
Hardware design and development

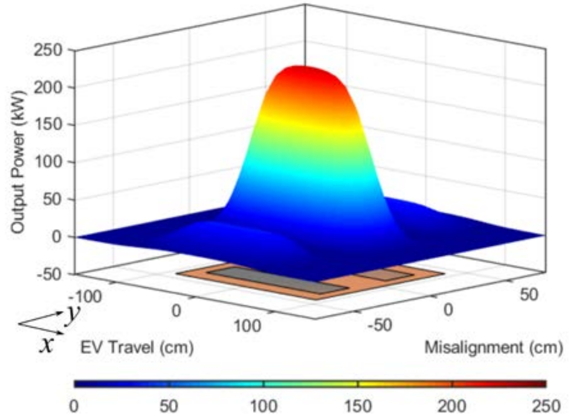
FY21:

Laboratory validation of 200 kW DWPT

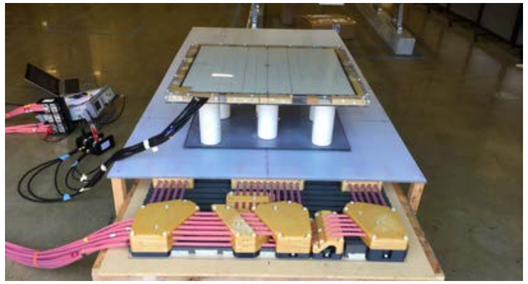
FY22:

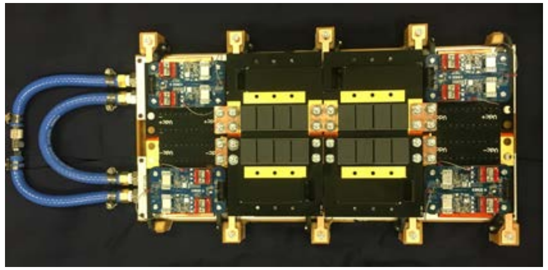
Real world validation of 200 kW DWPT



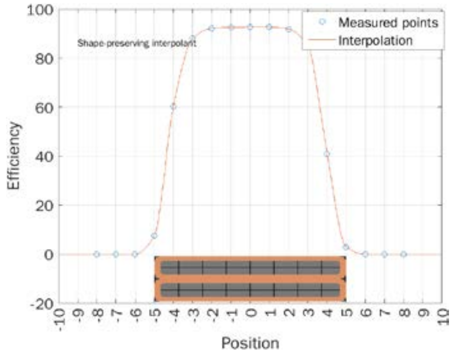


Detailed simulation and analytical design-oriented study

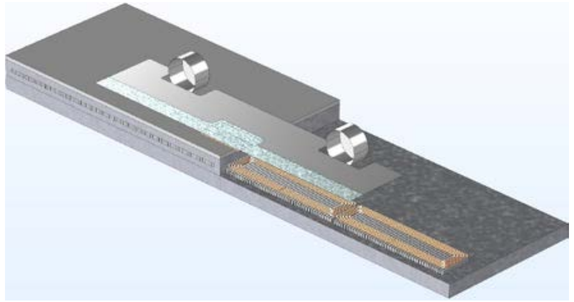




Hardware development and benchtop validation

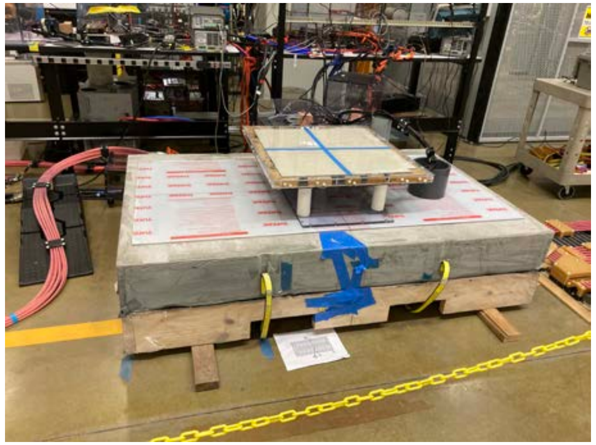


Laboratory validation of 200 kW DWPT using dynamic inductive charging emulator



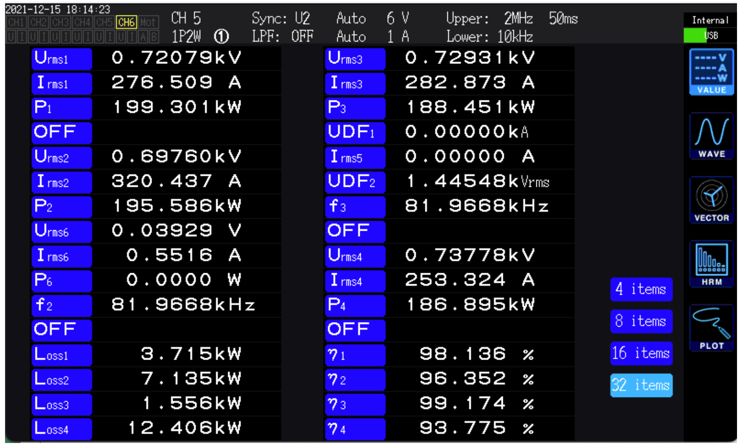
Planned 200 kW 55 mph DWPT validation at ACM

Status of 200 kW DWPT System Validation in Laboratory

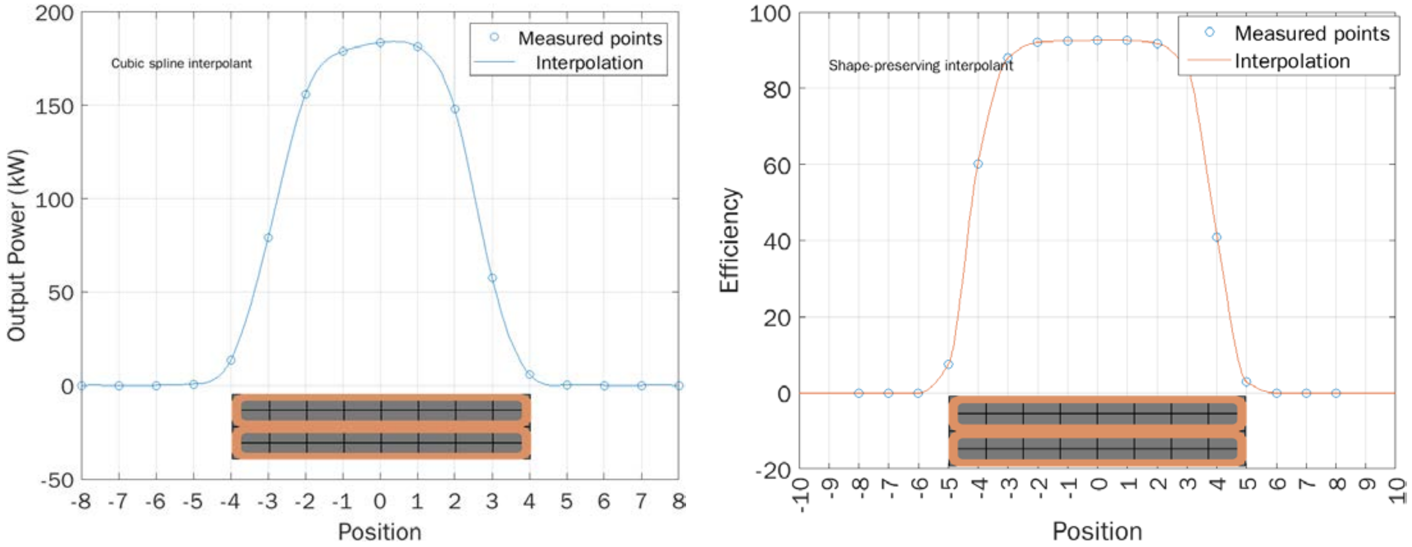


200 kW DWPT system with transmitter set in precast Master flow Epoxy Grout

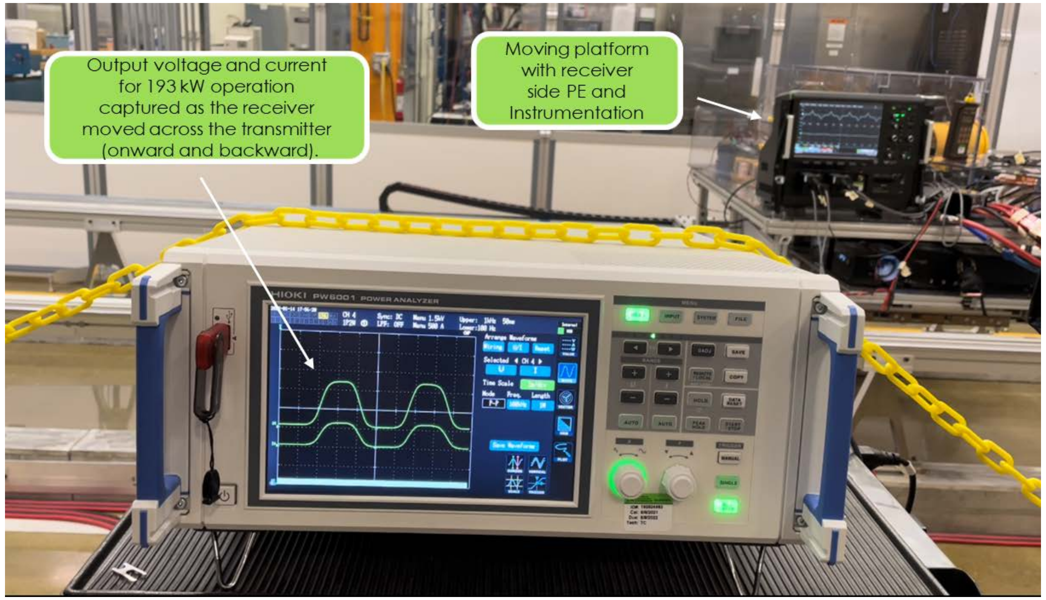
200 kW DWPT system with the receiver coil mounted on Hyundai Kona



Power analyzer reading for 186 kW output without vehicle coil mounted.

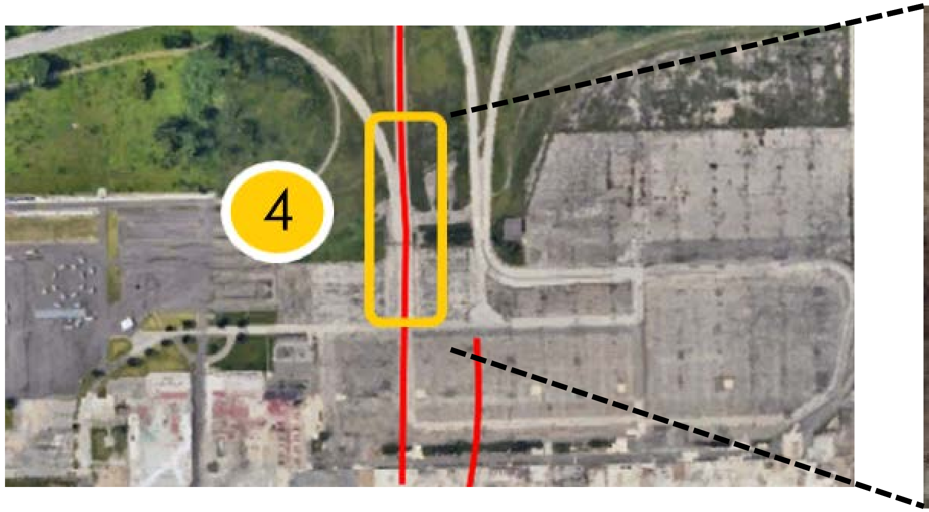


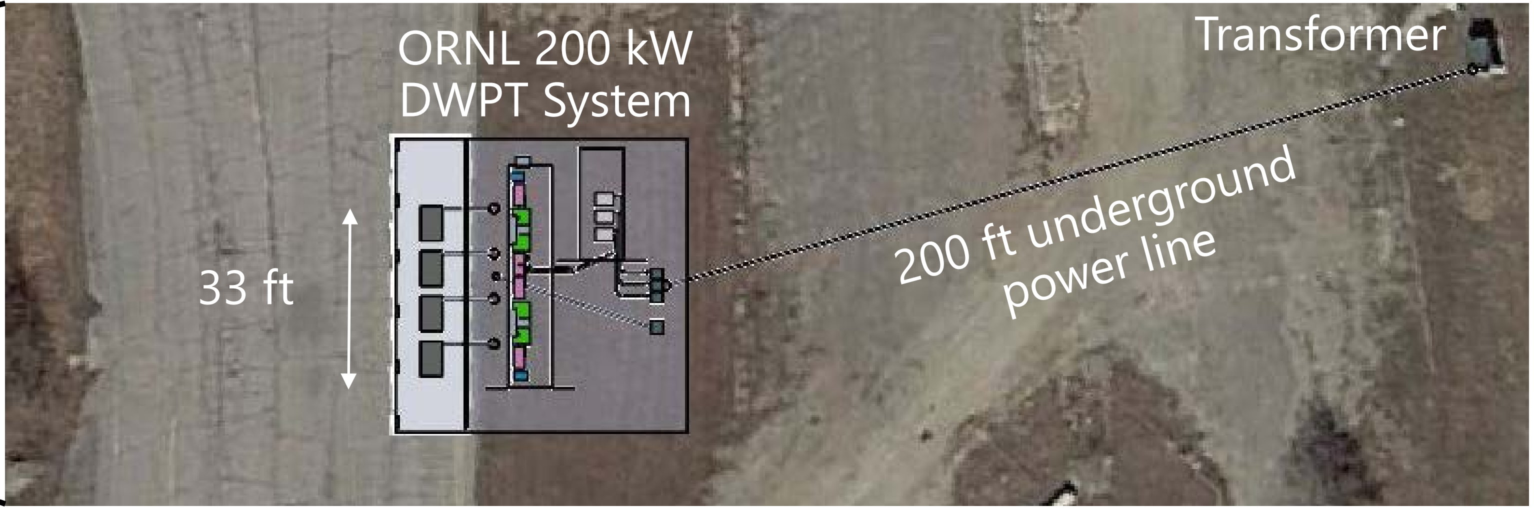
Profile of measured output power and efficiency of 200 kW dynamic charging system measured along the length of the transmitter at discrete points



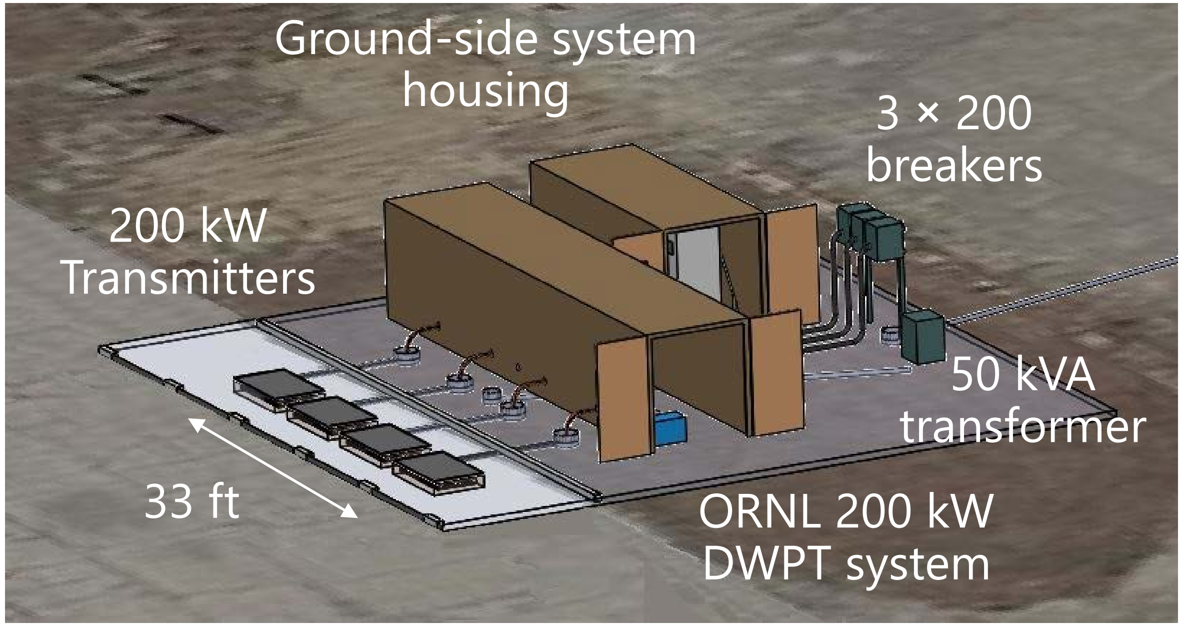
Dynamic inductive charging setup in the laboratory

200 kW DWPT System Validation Planned at ACM





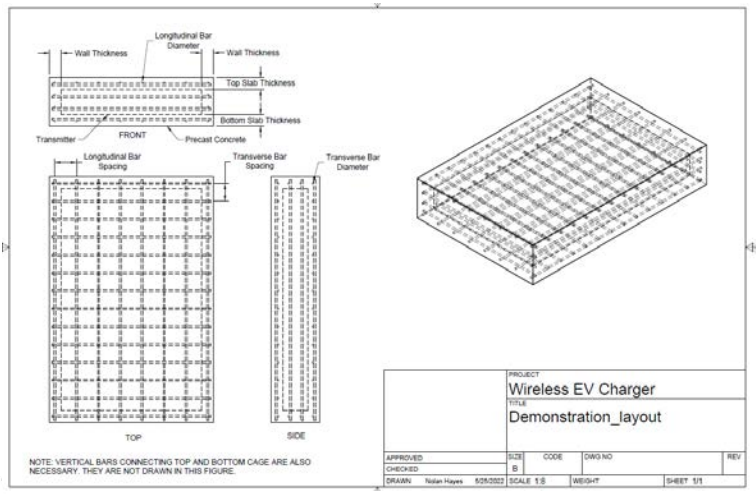
- Characterize HPDW charging system **on the road at ACM**
- Analyze the power transfer characteristics, including the following:
  - Efficiency, power, and energy profiles
  - Misalignment tolerance
  - Thermal profiles
  - Emissions and shielding
  - Use cases
  - **Environmental factors**



Next Steps for R&D to Transition DWPT to Real-World

System level challenges to enable deployable DWPT solution

- Are we going to need full depth reconstruction or just modify partial depth?
- What are the appropriate embedment techniques (Installation and maintenance)?
- What design changes are needed to the DWPT system to meet the structural and life-cycle requirements?



To determine practically viable solution suitable for deployment:

- Accelerated aging tests of DWPT system embedded in roadway using Heavy Vehicle Simulator (<15000 Lbs and 3000 Hrs).
- Different installation and maintenance scenarios to be considered.
- Iteratively identify failure modes and modify DWPT design to meet the structural requirements.

- Independent variables for consideration
  - Electronic packaging
  - Installation methods
  - Temperature
  - Depth of installation
  - Road construction
  - Surface treatments
  - Power and duty cycle of charging system

Full scale accelerated aging testing using Accelerated Pavement Testing Facility (VTTI).

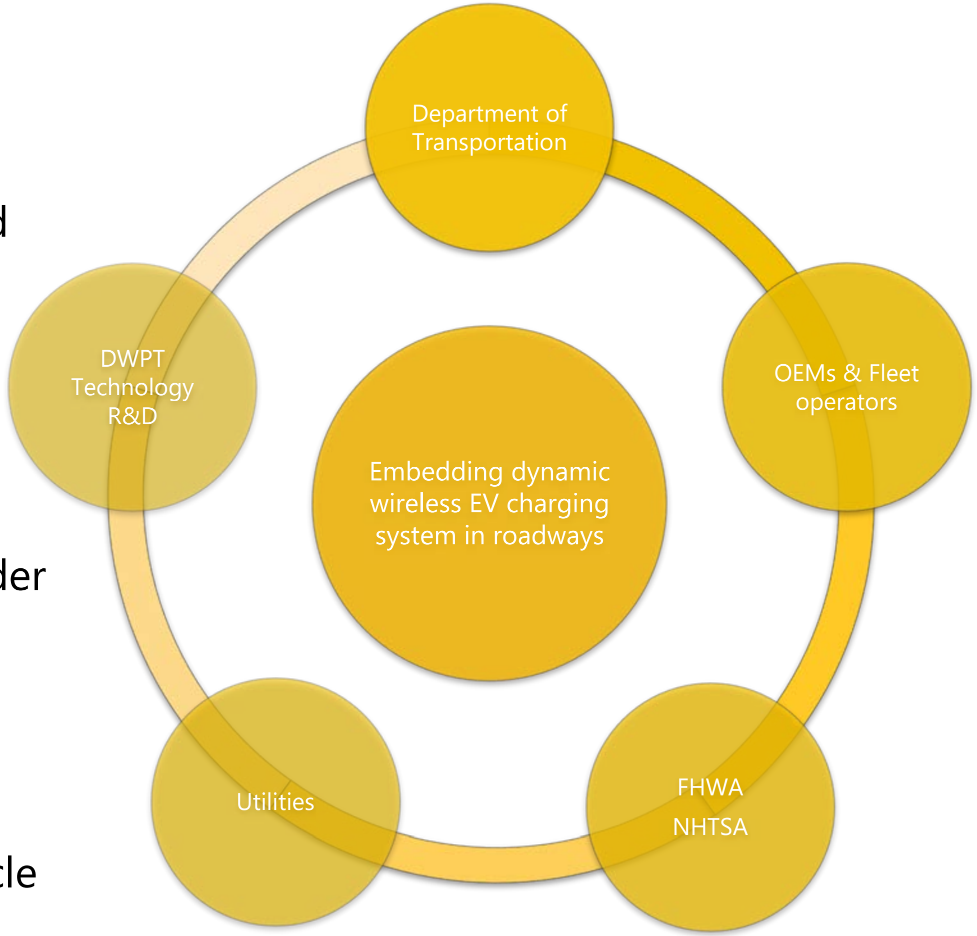
A structurally durable DWPT system with cost-effective and validated embedment techniques considering existing roadway practices is essential to evaluate realistic installation, operation and life-cycle cost.

Functional and Regulatory Requirements

Goal: Identify the practical functional and regulatory requirements to embed DWPT in roadways
Challenge: Satisfying roadway and safety related compliances while keeping DWPT system performance and form-factor applicable

Approach:

- Extensively engage with all relevant stake holders to understand implications and concerns
  - GDOT – Savanah to Atlanta Freight corridor
  - TDOT and FDOT
  - Hyundai, Stellantis, HEVO, Convalt Energy
  - SAE J 2954
- Installation, servicing, and maintenance requirements for in/under and around the roadway
  - Safety vehicle and emergency vehicle requirements
  - Compliance to multiple agencies and standards
  - Utility/grid interface requirements
- Developed modular and scalable solutions to serve across vehicle platforms and duty-cycles (stationary, quasi-dynamic, dynamic)



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CyberPUNC (Cybersecurity Pillar for Unified National Lab Collaboration)

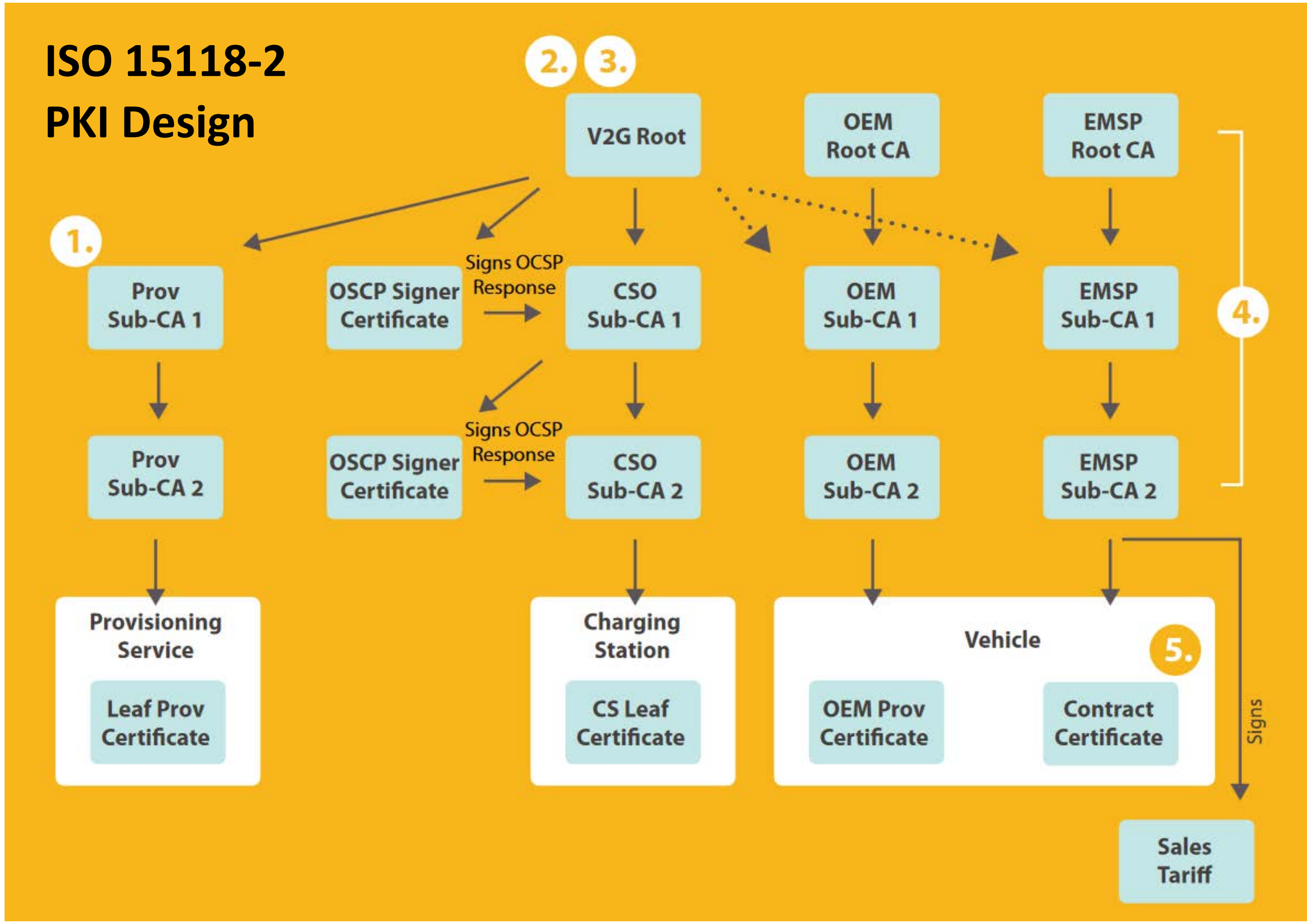
Barney Carlson, INL

Overview: *CyberPUNC* EVs@Scale Pillar

- **Objective:**
  - Contribute to the continuously evolving cyber-physical security methods and solutions needed to ensure EV charging infrastructure safety, reliability, & resiliency.
- **Six National Labs: INL, SNL, PNNL, ANL, NREL, ORNL**
- **Four main project areas that focus upon challenges and barriers:**
  1. Implementation and utilization of the latest security methods
  2. Identify vulnerabilities in new technology features and standards
  3. Methods to identify, protect, detect, respond, and recover from cyber-physical security events impacting EV charging infrastructure
  4. Training for the EV charging infrastructure cybersecurity workforce

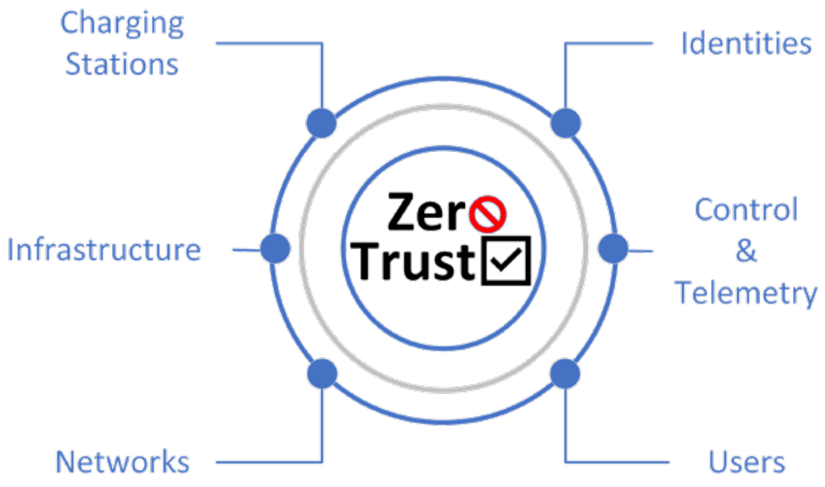
PKI Implementation and Vulnerability Assessment

- **Aid implementation of PKI architectures**
  - Host SAE-led industry working group testing events
  - Map cross-platform interoperability for PKI architectures to reduce adoption barriers
- **Investigate PKI vulnerabilities and scaling challenges**
  - Test scalability with 1000s of virtual machines in HPC environment
  - Transfer design weaknesses to industry for enhancement



Demonstrate Zero Trust Architecture for EV Charging Infrastructure

- ***"Trust no one, verify everything"* – Zero trust security model is based on principles to reduce or eliminate implicit trust from systems**
  - Architect, design, and implement zero trust prototype components to address selected high consequence use cases
  - Develop assessment criteria for evaluation of zero trust technologies
  - Assess prototype components against use cases using assessment criteria; report on results



Post Quantum Encryption

- **Quantum computing poses a threat to classical PKI**
  - PKI is used extensively throughout the EV charging infrastructure to secure communications and transactions
- **NIST is in the process of standardizing post quantum cryptosystems (PQC)** (draft standards expected in 2023), **which are secure against both quantum and classical computers**
- **Goal: assess potential impacts of NIST PQC on EV charging infrastructure security in preparation for the PQC transition**
  - PQC application will also influence the design of the zero-trust architecture

Identify Vulnerabilities in New Features & Standards

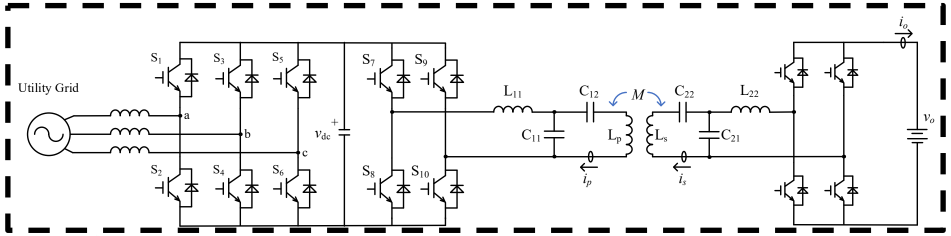
Supply Chain Security

- **Lead an industry working group to identify and enhance the EV charging infrastructure supply chain security**
  - Leverage insights from EVSE vulnerability assessments
  - Target common specs for securing pre-competitive components and supplies that meet rapidly growing demand
  - Explore SBOM/HBOM management that forms foundation of response

Wireless Power Transfer (WPT) Hardware-in-the-Loop Security Assessment

- **Safe testing of various EV charging power transfer designs using hardware in the loop**
  - Run exploits without damaging to expensive, laboratory power electronics hardware
  - Ensures safe laboratory environment
  - Quick / efficient testing of exploits of numerous designs and architectures

EV charging system power electronics architecture implemented in real-time HIL emulator

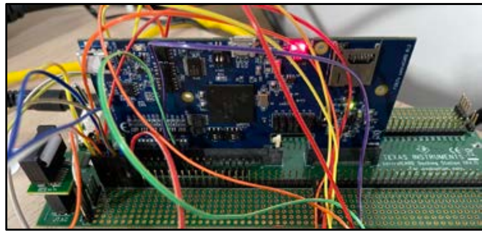


Hardware runs in the emulator while the controls & communications are realized with an external DSP

Power Electronics Real-Time Emulator

Driving Signals

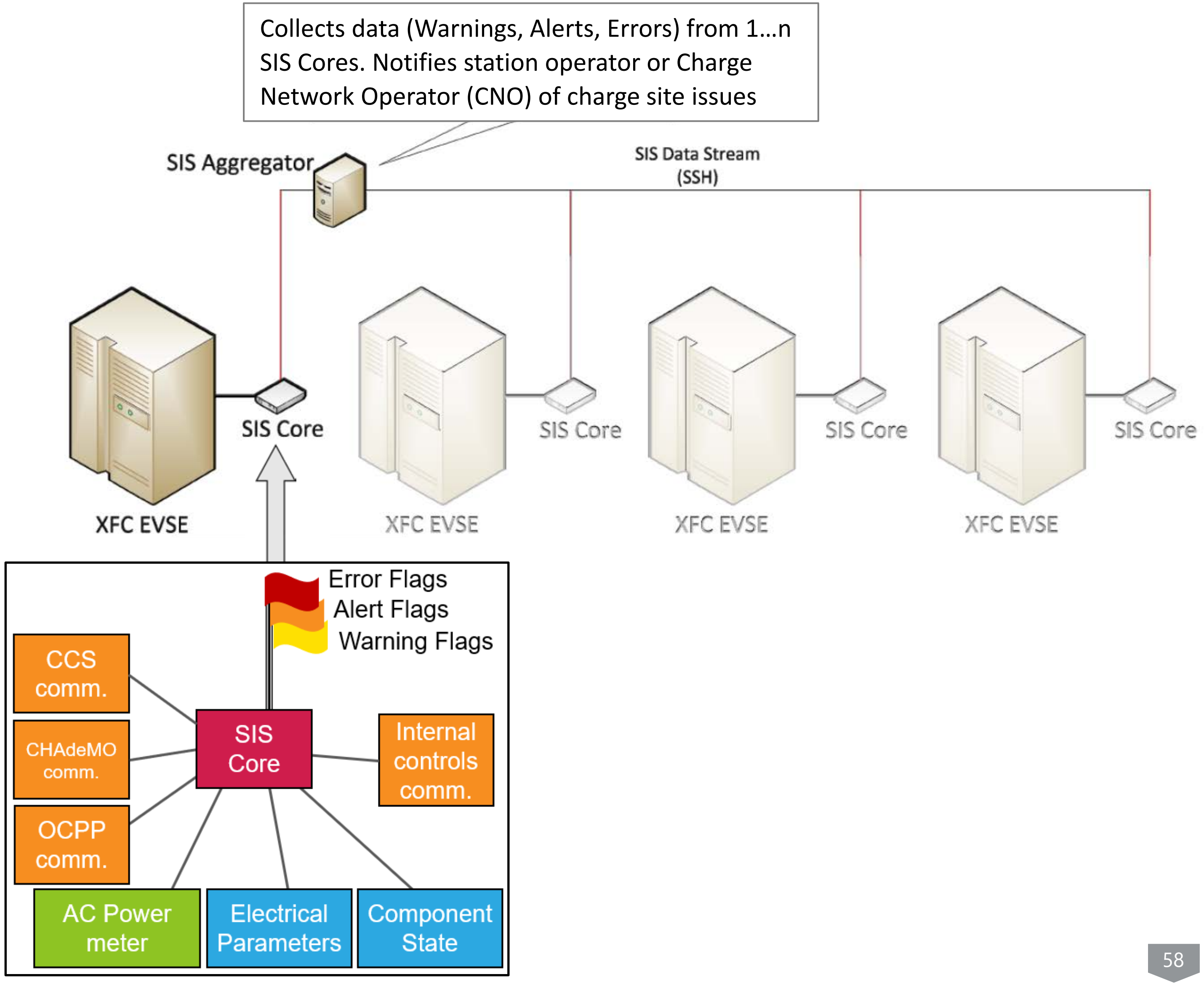
Sampling Signals



Digital Control Board

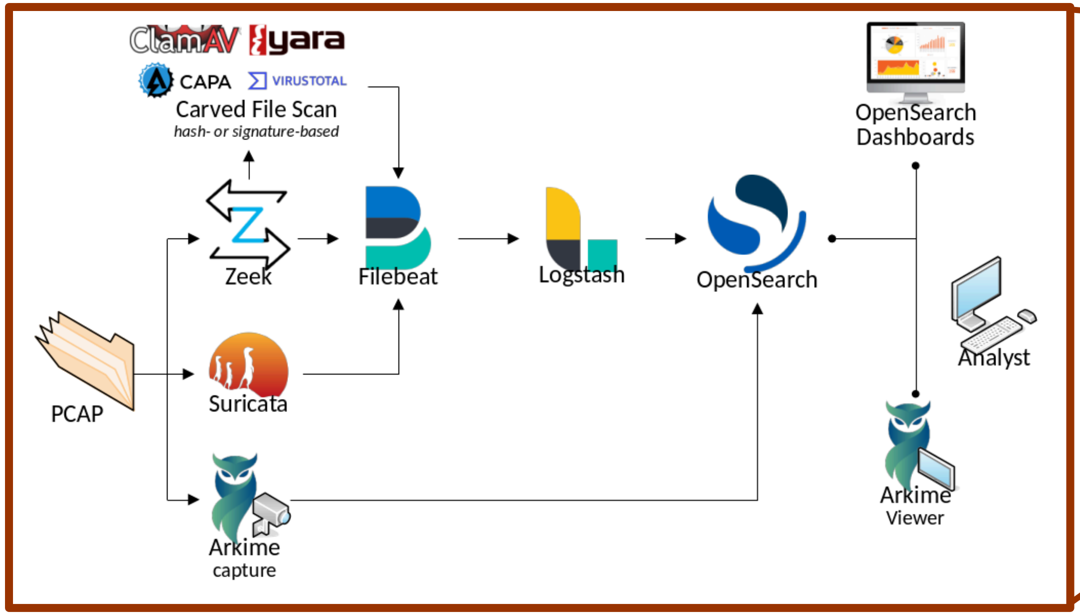
Safety Instrumented System (SIS) for High-Power DC Charging Infrastructure

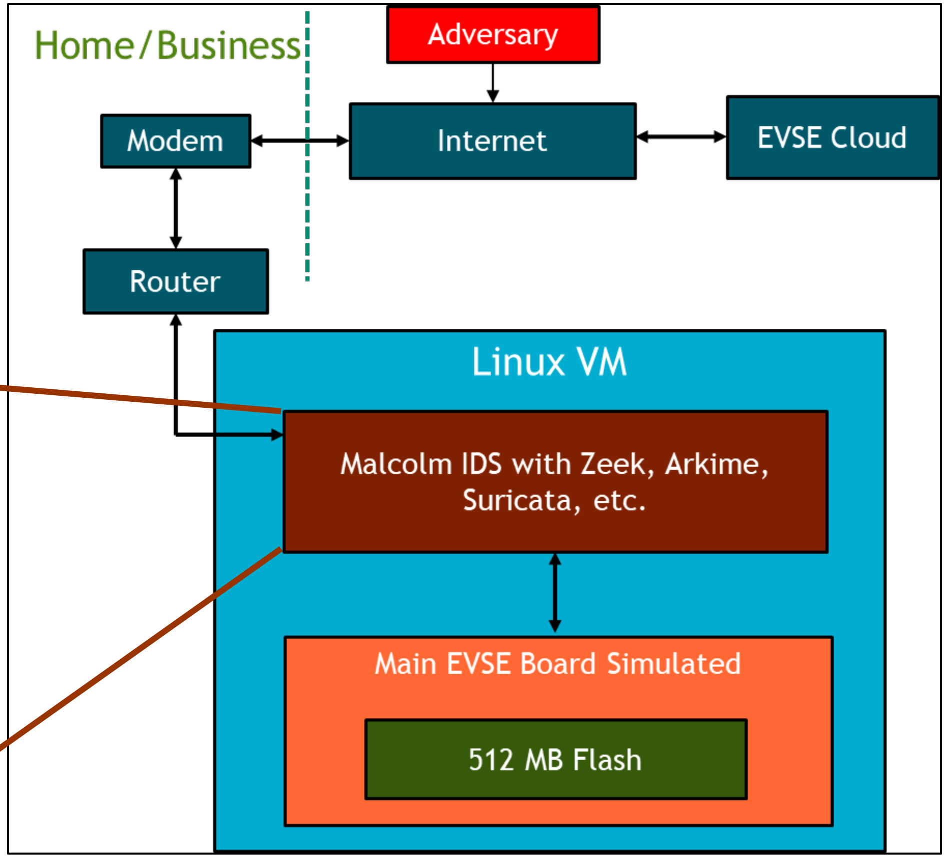
- **Detection & response system integrated into EVSE and charge site**
  - Communications monitoring, physical sensing, and impact severity qualification
  - SIS Core and Aggregator response and recover actions in accordance with impact severity
- **Detects and responds to malicious exploits, natural events, & component failure**
- **Multi-charger site SIS architecture focus: safety and operational resiliency**



Working with major EVSE vendor to create honeypots of their L2 chargers

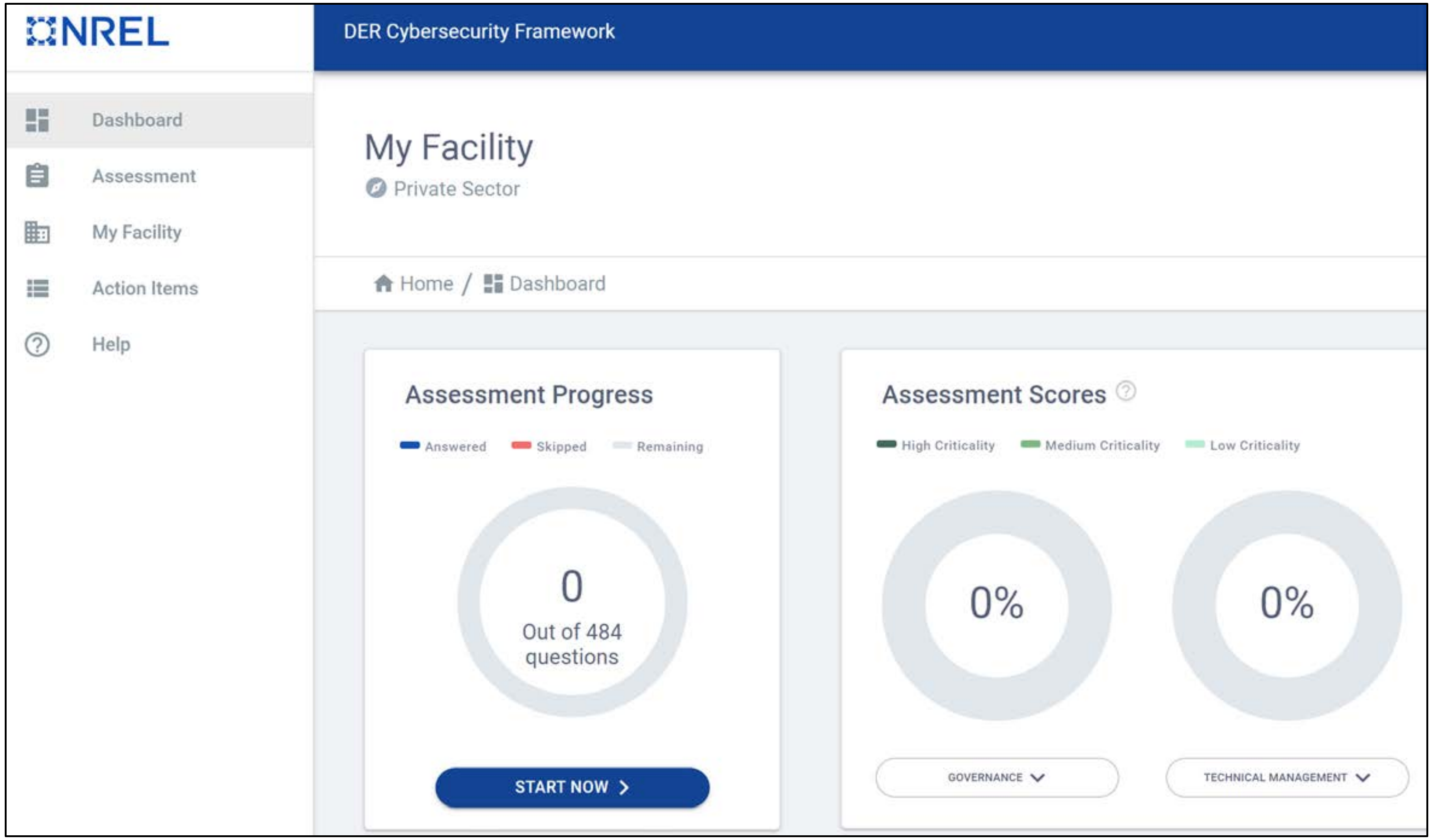
- **Virtualizing EVSE software and adding intrusion detection to VM to quickly build/destroy as necessary**
- **Major challenge with hosting (must look realistic for EVSE installation, but not expose interconnected systems to lateral movement)**





Cybersecurity Tools Application for EV Charging Infrastructure

- Maintain a repository of EVSE cyber tools on open website
- Adding EVSE procurement requirements to DER Cybersecurity Framework (DER-CF)
- Future work: Add EVSE security evaluations to DHS's Cyber Security Evaluation
  Tool (CSET)



CyberAuto Challenge:

- A week-long practicum-based training event
- Help develop the next generation Cybersecurity workforce
- Teaches the basics of "hacking" skills to collegiate & early career professionals using vehicles & charging infrastructure hardware
- 24-hr long 'hands-on' assessment, pen testing, and exploit attempts on state-of-the-art vehicles & charging infrastructure
- Typically, 6 teams of 10-12 participants

CyberAuto Challenge

CyberStrike Training for Network Defenders

- Renewable energy cybersecurity *CyberStrike* training module with Solar, EVSEs, and Wind systems
- 8-hour classes with lectures (slides) and exercises (hands-on training with hardware)
- Plan to also build GridEx EVSE attack scenarios in future years with utility partners
- Typically, 1000 participants per year

CYBER STRIKE
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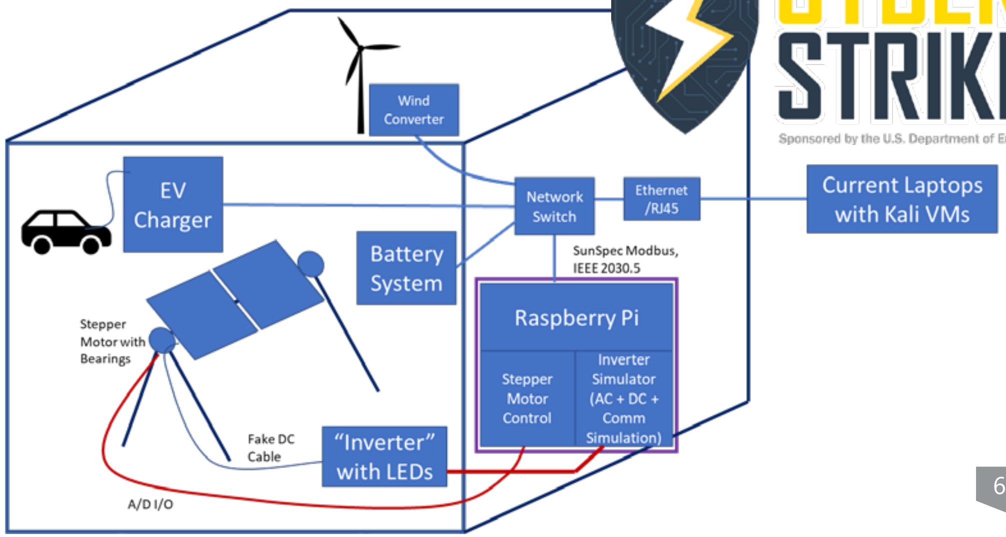

Summary

Numerous *CyberPUNC* on-going and future tasks are focused on:

1. Implementation and utilization of the latest security methods
2. Identify vulnerabilities in new technology features and standards
3. Methods to identify, protect, detect, respond, and recover from cyber-physical security events impacting EV charging infrastructure
4. Training for the EV charging infrastructure cybersecurity workforce

Industry Collaboration and Partnership with EVs@SCALE projects is Highly Encouraged

CyberPUNC Cyber-physical Security EVs@SCALE "Deep-Dive" meeting is Sept. 20-21, 2022

- **Presentations and in-depth discussion with Q&A session**
  - We're looking for technical input and feedback from your organization, to assist this EVs@SCALE effort in providing the maximum benefit for the EV charging industry and ecosystem
- **Sept. 20 from 11AM – 1:30PM (eastern time zone): Cybersecurity Assessments**

  Microsoft Teams meeting Click here to join the meeting Meeting ID: 255 948 253 256 Passcode: qs77xa Download Teams | Join on the web **Or call in (audio only)** +1 208-901-7635,,297341807# Phone Conference ID: 297 341 807#
- **Sept. 21 from 11AM – 1:30PM (eastern time zone): Cyber Tools, Training, Mitigation Solutions, and Codes& Standards**

  Microsoft Teams meeting Click here to join the meeting Meeting ID: 251 020 059 947 Passcode: 4cjrDc Download Teams | Join on the web **Or call in (audio only)** +1 208-901-7635,,220980010# Phone Conference ID: 220 980 010#

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Codes and Standards Support

Theodore Bohn
Argonne National Laboratory

Outline

- Initiative Overview
- Identification of codes and standards activity priorities enabling EVs at Scale
- 'Divide and Conquer' approach by lab teams to cover mulitiple standards areas
- Standards areas covered by each participating laboratory
- Focus areas and progress in standards development in FY2022
- Summary of FY22-23 deliverables/milestones
- Conclusion and Next Steps

Codes and Standards Support Initiative Overview

Objective: Codes & standards support priorities focus on development of the most critical standards for EVs at Scale, i.e., high power DC charging, storage (microgrid, DERMS) integrated with DC charging, vehicle-grid integration, high power scalable/interoperable wireless charging, vehicle-oriented system standards and energy services to support transparent optimized costs/delivery.

Outcomes:

– Establish and complete draft of SAE J3271 Megawatt Charging System (MCS), AIR7357 TIRs
– Create work group to develop EV Standards Roadmap based on 2012 ANSI EVSP roadmap
– Develop and demonstrate a reference DC as a Service (IEEE P2030.13) implementation with off-the-shelf hardware and Open API Energy Services Interface (ESI) implementation
– Complete a study w/summary reports in support of identified high importance standards
– Active participation in SDO standards meetings/committees to close gaps in EVs@S standards

Argonne National Laboratory

- Theodore Bohn
- Mike Duoba
- Keith Hardy
- Jason Harper
- Dan Dobrzynski

Idaho National Laboratory

- Richard Carlson
- Anudeep Medam
- Tim Pennington
- Benny Vargheese

NREL National Renewable Energy Laboratory

- Yashodhan Agalgaonkar
- Jesse Bennett
- John Kisacikoglu
- Jonathan Martin
- Andrew Meintz
- Manish Mohanpurkar
- Vivek Singh
- Isaac Tolbert
- Ed Watt

Oak Ridge National Laboratory

- Veda Galigekere
- Omer Onar
- David Smith

Pacific Northwest National Laboratory

- Brian Dindlebeck
- Lori O'Neil
- Richard Pratt

Filter Criteria: The group of lab team members proposed areas **most** relevant to EVs at Scale

Priority Areas:

- EVs at Scale standards support focus is mostly on scaling charging capabilities. I.e. how to serve more vehicles in more locations without exceeding resource limits, for a spectrum of vehicle sizes/classes (from light to medium to heavy duty; commercial and passenger cars)
  Charging rates from 30A to 3000A for conductive/wireless methods, AC or DC, µgrid, etc

- Electric power delivery oriented standards areas; V2G, local DER, integrated storage, system controls including the Energy Services Interface method of bi-directional information exchange leading to contract based optimization of resources, DC as a Service, communication protocols

- Vehicle Oriented **System Standards** (including non-road, electric aircraft) that include on-vehicle systems (power take-off, refrigeration units, battery management, battery safety, etc.),

- High Power Scalable/Interoperable Wireless Charging (SAE, SWIFTCharge) (up to 1MW)

‘Divide and Conquer’ Diverse Coverage of Standards by Lab Teams

5 Lab Teams in FY2022 Covering ‘Top 10’ Standards Areas:

National Lab participants each proposed support/development within the ‘top ten’ areas for Evs@S

Avoiding alphabet soup/TLA overload, in general coverage shorthand includes:

- **NREL** focus on MCS coupler testing, system architectures/impacts study, P2030.13
- **ORNL** focused on wireless (WPT) topics
- **INL** on WPT, P2030.13 (grid side of charging)
- **PNNL** on EVSP roadmap, heavy vehicle charging stds, P2030.13
- **ANL** on ‘umbrella’ (chair of multiple stds groups) coverage of ongoing W&M stds, ANSI meter stds, IEEE P2030 series (.5, .11, .13, etc), MCS ‘everything’, emphasis on communication and reliability, (see eye chart of SAE standards on EV charging)

Alphabet Soup-TLA Overload; SAE Battery Standards List/Diagram (50+)

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Thermal Management & Adhesives: J3073, J3178

Battery Labeling: J2936

Battery Life Assessment Testing: J240, J2185, J2288, J2801

Truck & Bus Batteries: J3004, J3125,

Battery Safety: J2929, J2464, J3009

Battery Size, Identification & Packaging: J1797, J3124, J2981, J3004

Battery Testing Methodologies: J2758, J2380

Electric Drive Battery Systems Functional Guidelines: J2289

EV / Battery Fuel Economy & Range: J1634, J1711, J2711

Battery Materials Testing: J2983, J3021, J3042, J3159

Battery Vibration: J2380, J3060

Battery Secondary Use: J2997

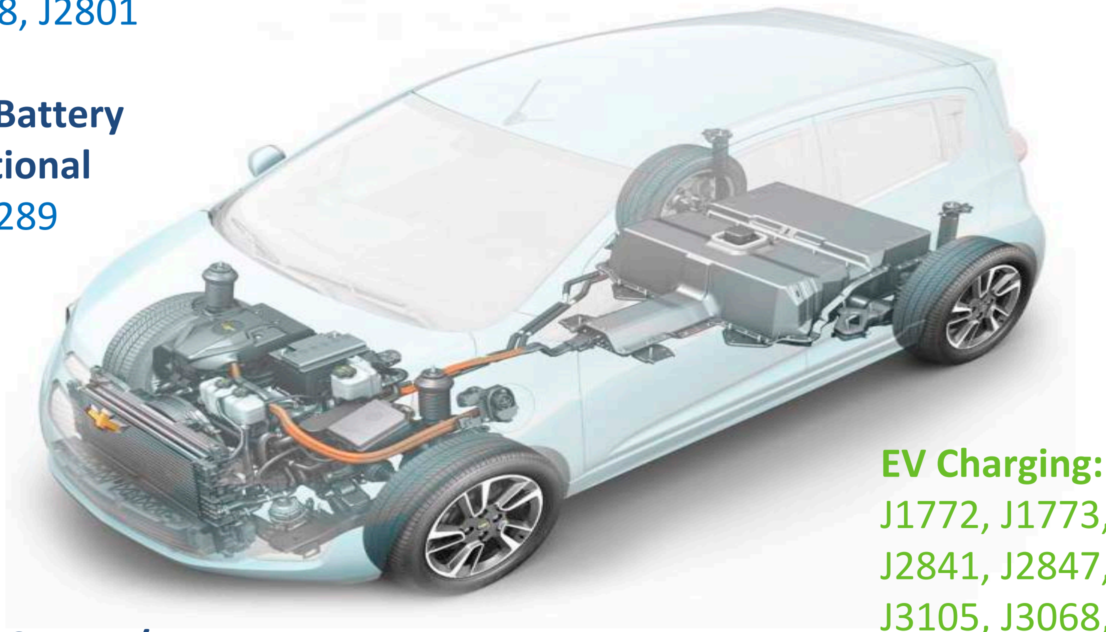
Battery Transport: J2950

EV Charging: J1772, J1773, J2293, J2836, J2841, J2847, J2894, J2931, J3105, J3068, J3271, AIR7357

Capacitive Energy & Start/Stop: J3012, J3051

Battery Recycling: J3071, J2974, J2984

EV Battery Safety: J1766, J2344, J2910, J2990



Starter & Storage Batteries: J1495, J2185, J240, J2801, J2981, J3060,J537, J930

Battery Terminology: J1715/2

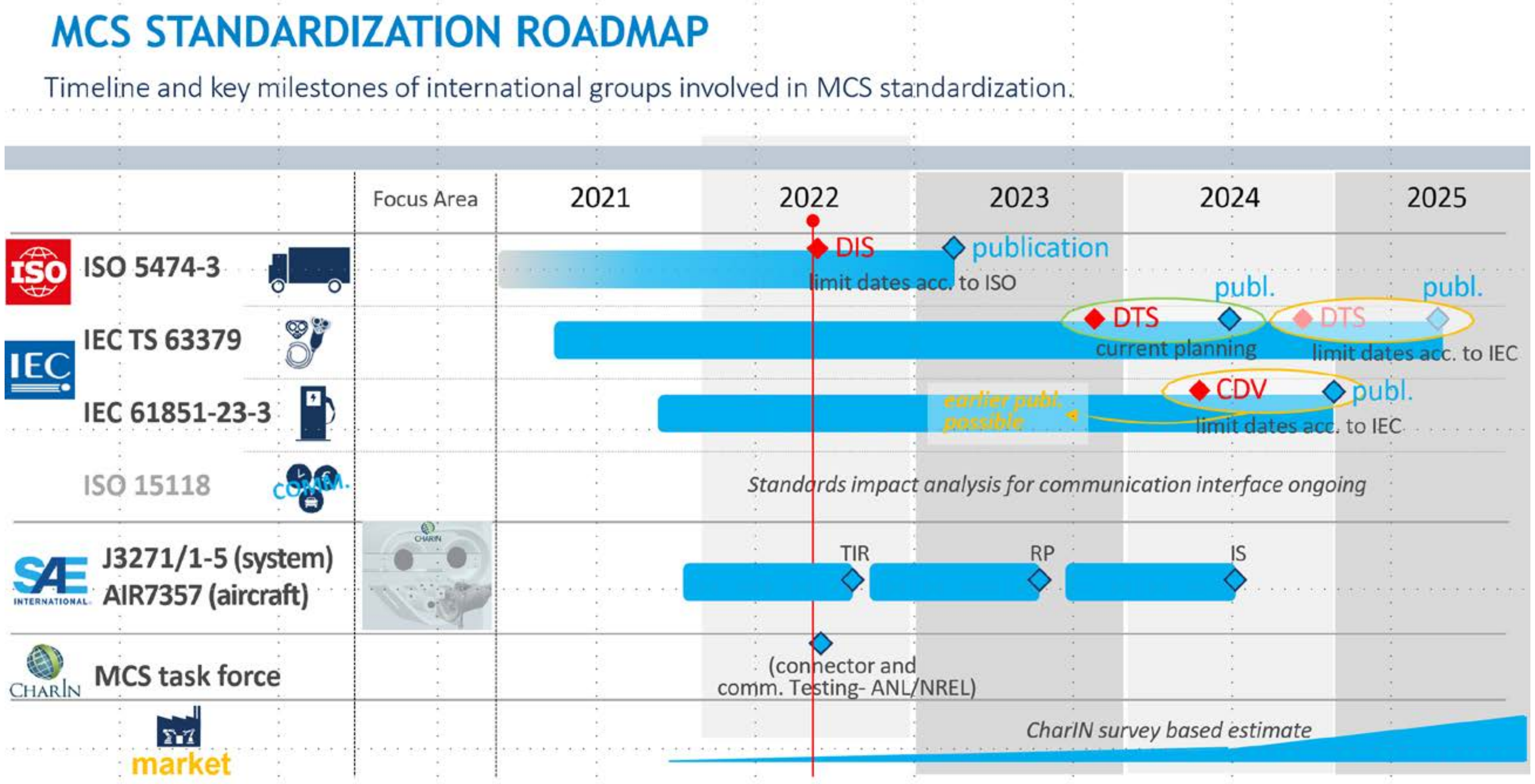
Battery Performance & Power Rating: J1798, J2758

EV Charging Safety: J1718, J2953/1, J2953/2, J2953/3, J2953/4, J2953/5 (CSRP)

Battery Electronic Fuel Gauging & Range: J2946, J2991

Harmonization of High Power Charging SDO Committees/Standards

Working together as a global team: National Lab participants in these and other standards areas need to have consensus between overlapping standards. There is not one 'global' Standards Defining Organization' so all the SDOs have to 'play nice' and create compatible/harmonized standards as a foundation for global interoperability.



Hands-On C&S Support Examples; Demonstrations-partner activities

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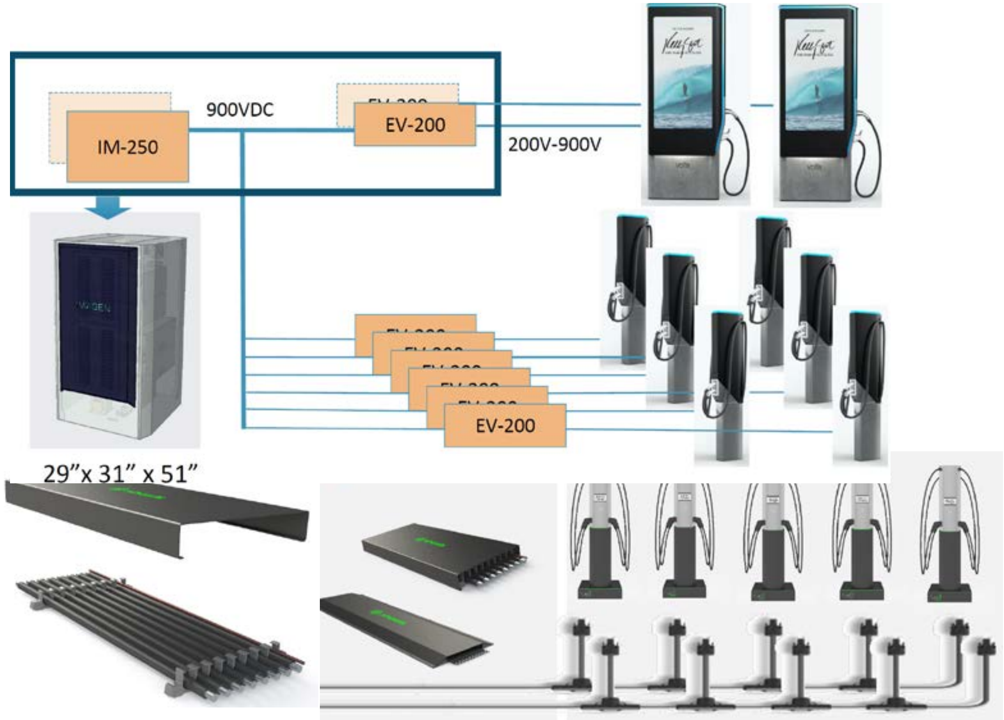
C&S Support Activity Collaborators:

Industry charging stakeholders (manufacturers, operators, planners, researchers, existing projects w/liaison interactions- RHETTA, eTRUC, etc)

Subcontractor subject matter experts (ANSI, University of Delaware, Rema, BTCPower, EVoke)

Standards organizations (SAE, IEC, ISO, IEEE, ANSI), Code panels (NCWM, UL, NFPA)

Hands-on tutorial (training) w/Weights and Measures Examiners (HB44)



Imagen/Shoals DCaaS, 250kW blocks, MCS Ready

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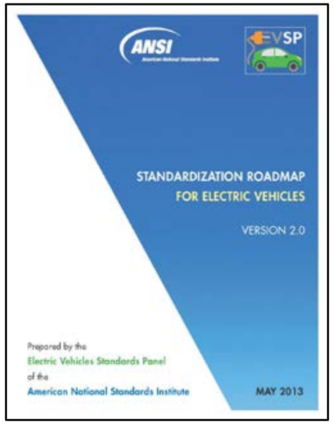
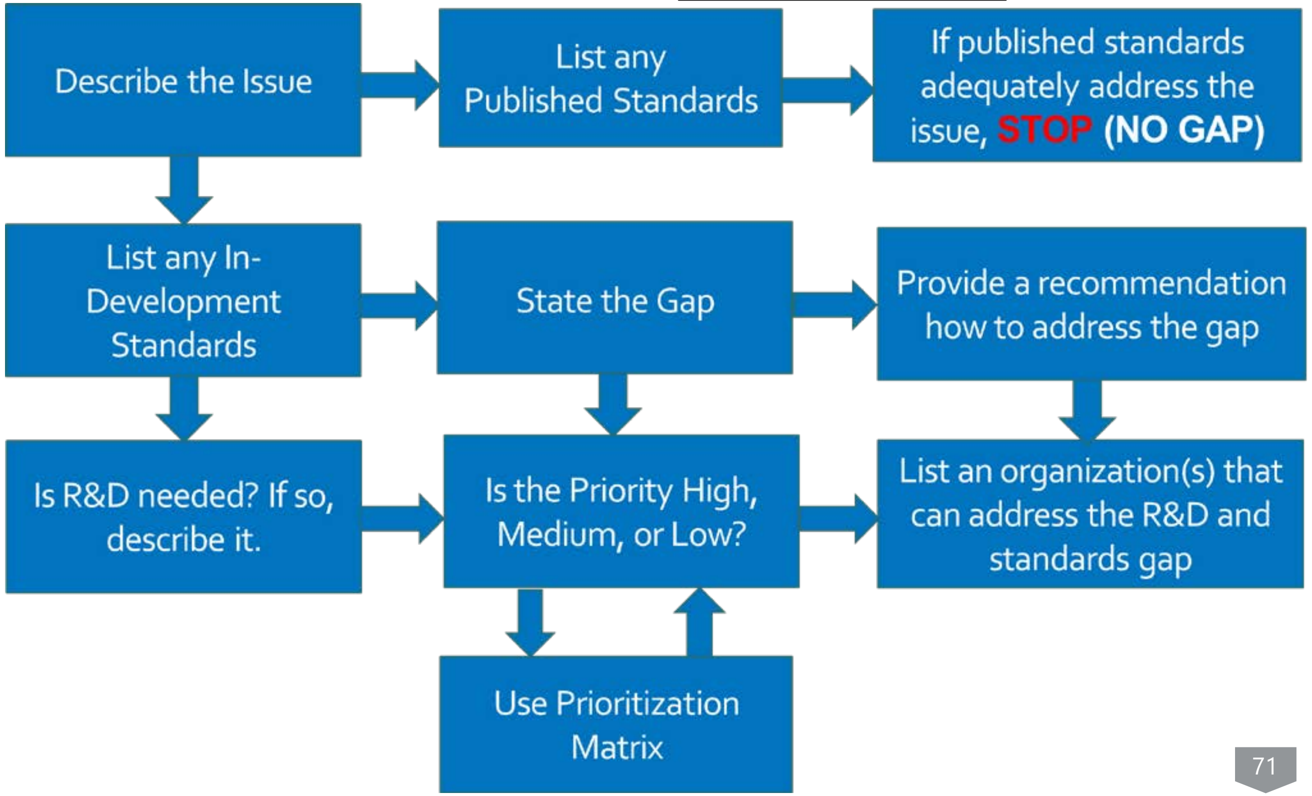
Roadmap Overview

- Identifies issues as well as standards, codes, and regulations that exist or are in development to address those issues
- Identifies “gaps” & recommends development of new or revised standards, conformance and training programs, where needed
- A “gap” means no published standard, code, regulation, or conformance program exists
- Suggests prioritized timeframes for standards development and organizations that may be able to perform the work
- Focus is U.S. market with international harmonization issues emphasized in key areas





FY2022 Milestones/Deliverables

Milestones (shorthand)

- Report on conceptual/functional requirements for P2030.13 w/simulations
- Demo of DC as a Service testbed w/existing components (P2030.13, Shoals)
- MCS physical layer communication robustness test plan; test results (J3271/2)
- ANSI EVSP standards roadmap, draft for peer review; weekly group inputs

Deliverables (shorthand)

- Quarterly/annual progress reports
- MCS coupler thermal-mechanical testing results report
- (critical input to…) First peer review draft of SAE J3271 (part 1-5) MCS TIR
- (critical input to…) first peer review draft of IEEE P2030.13 Functional specs
- Monthly MW+ Charging industry engagement webinar based forum for input

Conclusion and Next Steps

Review

- Initiative Overview
- Standards Support Priority Selection Methodology
- Significant areas of standards development activities
- Implementation/validation of technology-requirements as part of standards

Next steps

- Continued monthly MW+ Charging Industry Engagement interactions/feedback
- Continued weekly SAE J3271(AIR7357) meeting to TIR goal in October 2022
- Continued monthly standards work group participation; drafting standards, etc
- Progress to milestones are studies support WPT and P2030.13 standards
- Engagement in tentative Interoperability (Testival) events in 2022

EVs@Scale Bi-Annual Stakeholder Meeting Cont. VTO Activities

11:35 a.m. – 12:15 p.m. MT	**Lunch & PollEV Pillar Feedback** *All attendees and presenters*
12:15 p.m. – 12:35 p.m. MT	**NextGen Profiles** *Dan Dobrzynski*
12:35 p.m. – 12:55 p.m. MT	**eVISION** *Michael Starke*

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Next-Generation Profiles – High Power Charging Characterization

Dan Dobrzynski
Argonne National Laboratory
ddobrzynski@anl.gov
1-630-252-6440

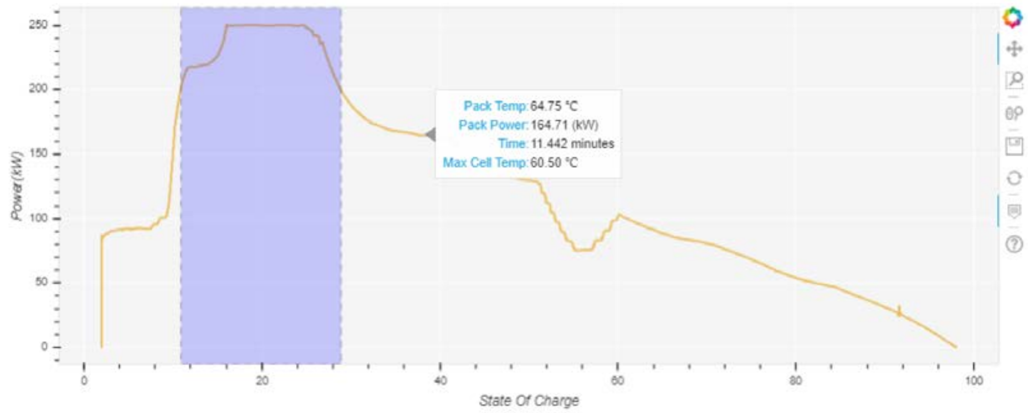
Argonne NATIONAL LABORATORY | INL Idaho National Laboratory | NREL NATIONAL RENEWABLE ENERGY LABORATORY | OAK RIDGE National Laboratory | EVs@Scale U.S. Department of Energy

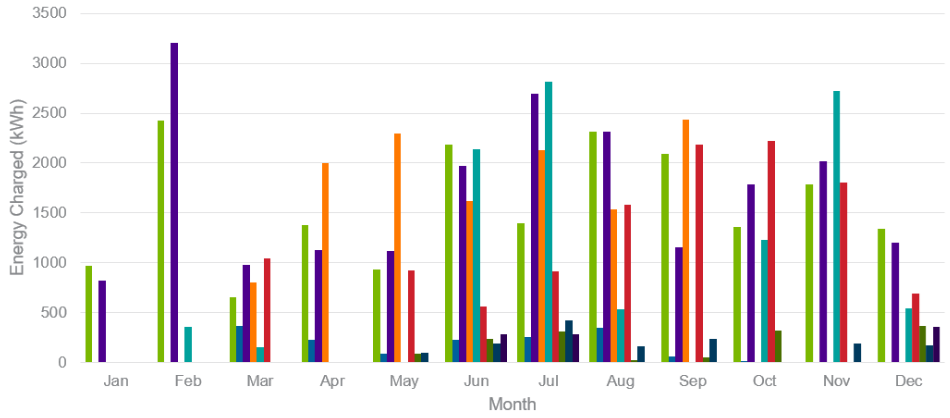
Next-Gen Profiles Objectives

Assess the likely portfolio of EVs and EVSE that are expected to utilize HPC.

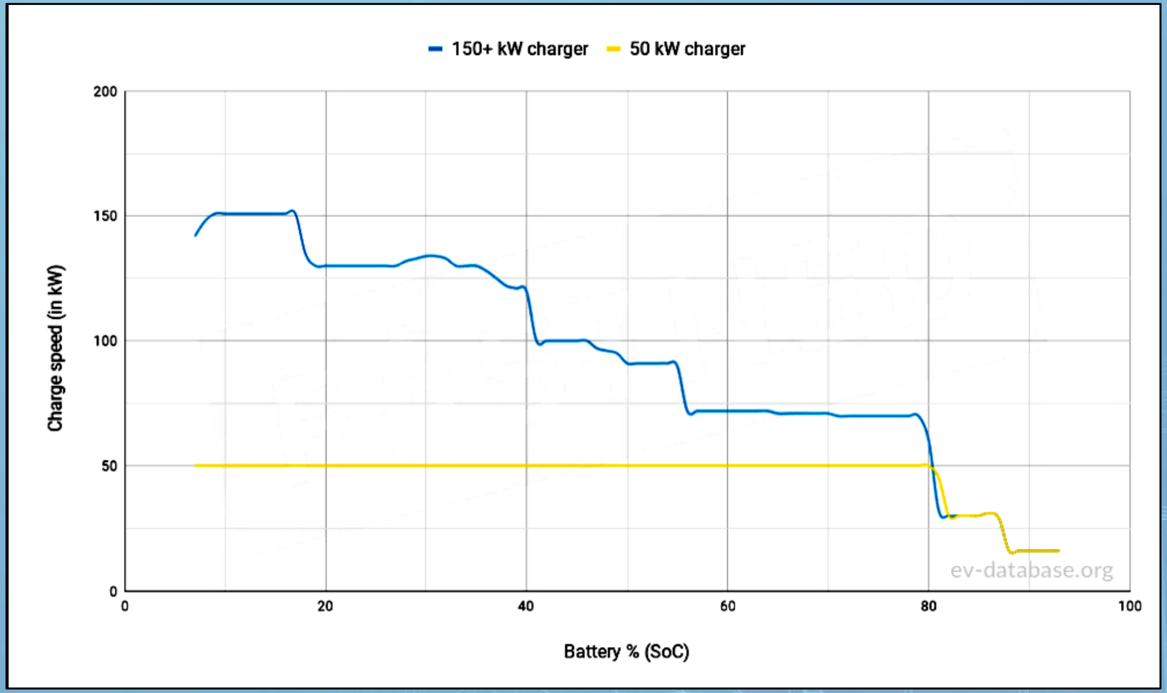
High Power Charging > 200kW

- Assessments at baseline and modified boundary conditions.
- System responses to grid disturbances & charging management.
- Assess conductive and wireless systems
- Perform fleet utilization analysis
- Collaborate with OEMs and industry
  - Testing assets
  - Procedure development





Research Significance



HPC profiles are diverse – and vary across vehicle classes and OEM

- Variances include **peak power draw, ramp-up/down rates, and shape.**
- Profiles are engineered to balance **charge performance, safety** and **battery longevity**.
- Charging performance varies with external factors – **Battery SOC, temperature**, etc.

Open Questions

What are the system limitations and efficiencies of HPC?

What are the HPC demand profiles that the grid will encounter?

How do boundary conditions affect the charging limits, efficiencies, and demand profiles?

Developing a Knowledge Base

Grid planning efforts

Charging depot site sizing

DER/Storage integration

HPC charge management strategies

Technical Approach

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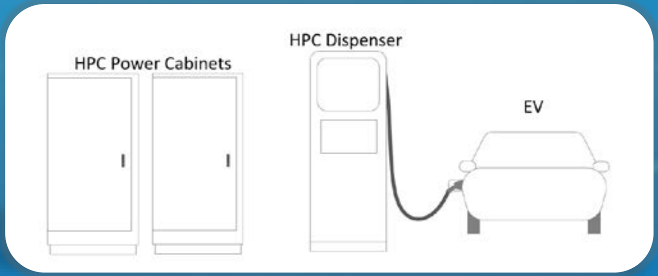
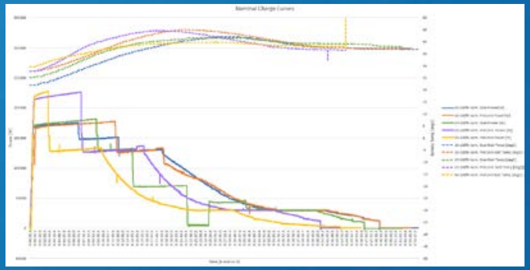
EV Profile Capture

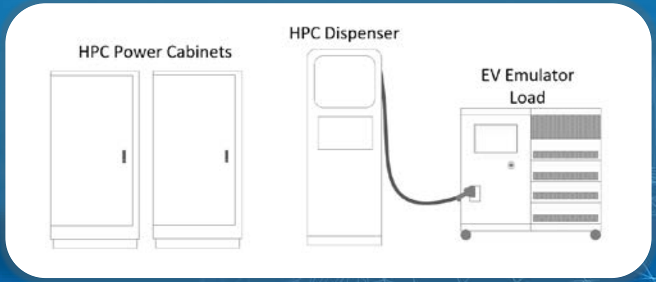


Single Vehicle Boundary Condition Analysis

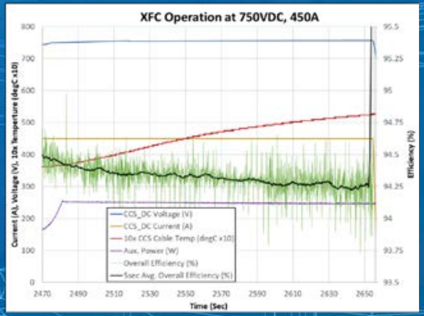


EV Charge Profile Comparison

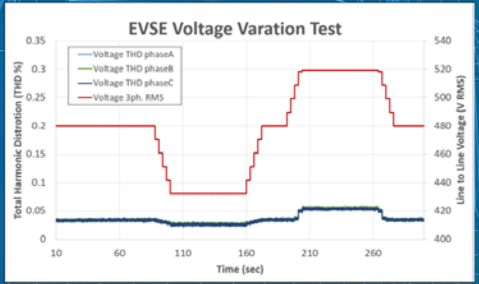
EVSE Characterization



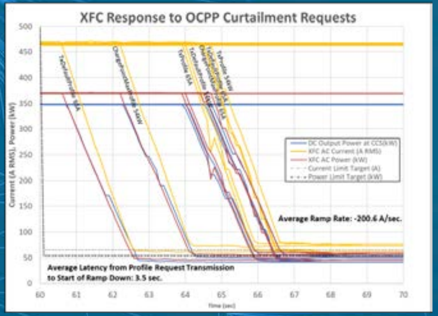
Quasi-steady state Performance Analysis



Grid Disturbance Analysis

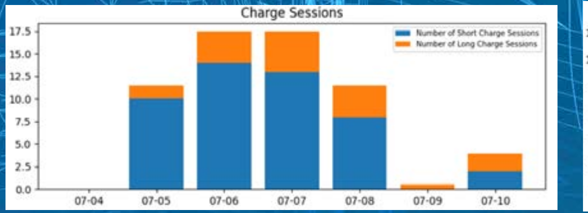


Charge Management Analysis

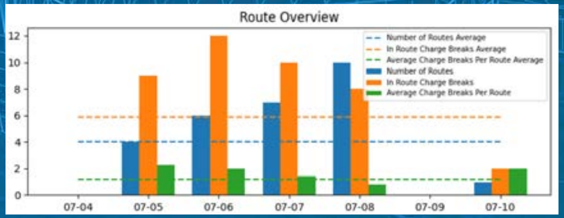


Fleet Utilization Analysis

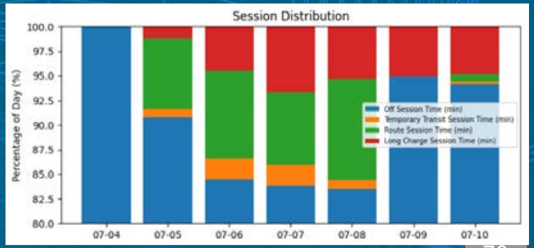
Fleet Session Analysis



Fleet Route Analysis



Temporal Use Analysis

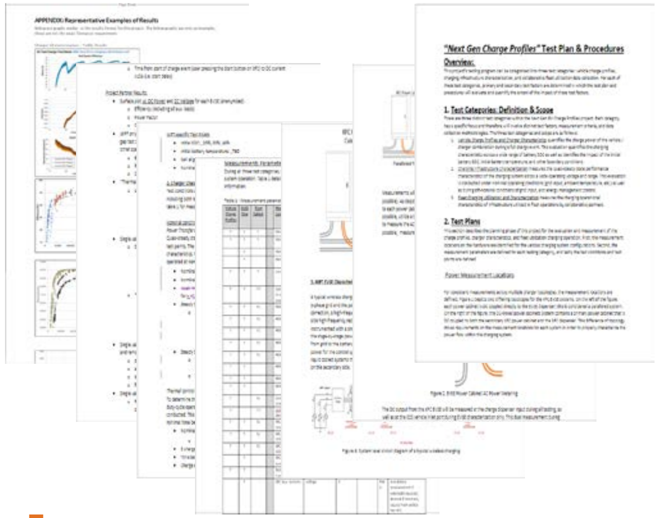


Programmatic Approach

Laboratory Coordination

- Assets
- Capabilities
- Relationships

Process Design



- Test Conditions
- Measurement Points and Metrics
- Procedures

→ Uniform and comparable results

Dissemination Policy

Public

Publicly available report with resulting graphics; high-level analysis between and among test asset groups

Project Partner Group

Anonymized and parsed time series data sets are shared equally among all project partners.

Project Partner

Full-time series data is shared with each project partner pertaining only to their associated research assets.

Accomplishments

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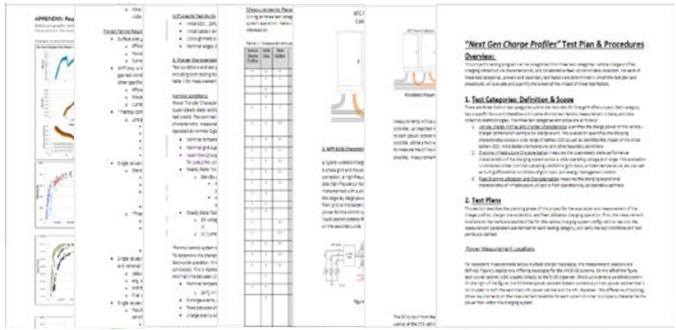
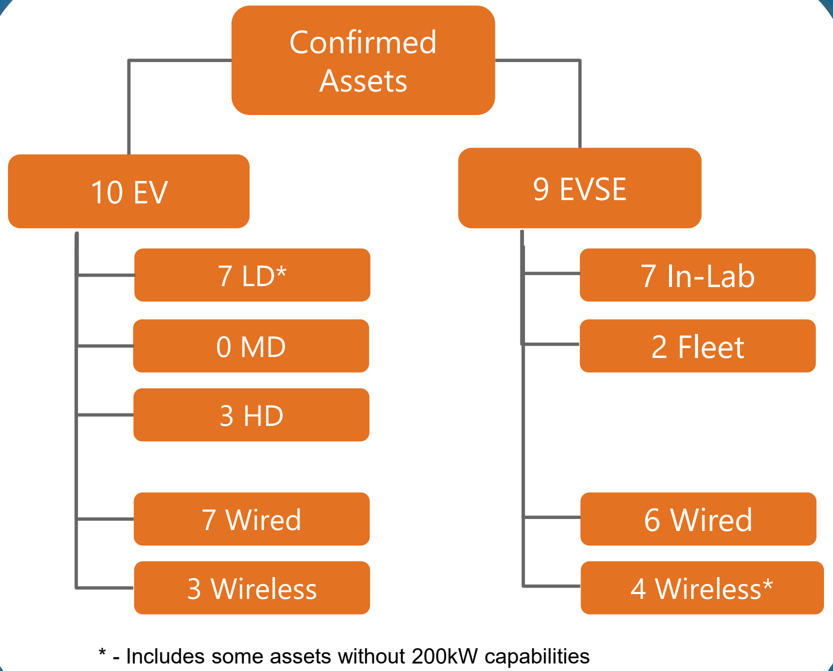
Procedure Development



Commenting Source	Comment Count
DOE and National Laboratories	32
US Research Institutes	12
EVSE OEMs	10
EV OEMs	6
Foreign Research Institutes	26
Total	**86**

Securing Testing Assets



Development Outline

- Draft document completed 08/20/2021
- 2 Month open review period – 86 industry comments
- Resolution of Comments – completed 11/30/2021

Setbacks

- Delays and lack of assets availability
- Lack of interest by some OEMs
- Acceptance of assets capable of less than 200kW charging

Project Timeline

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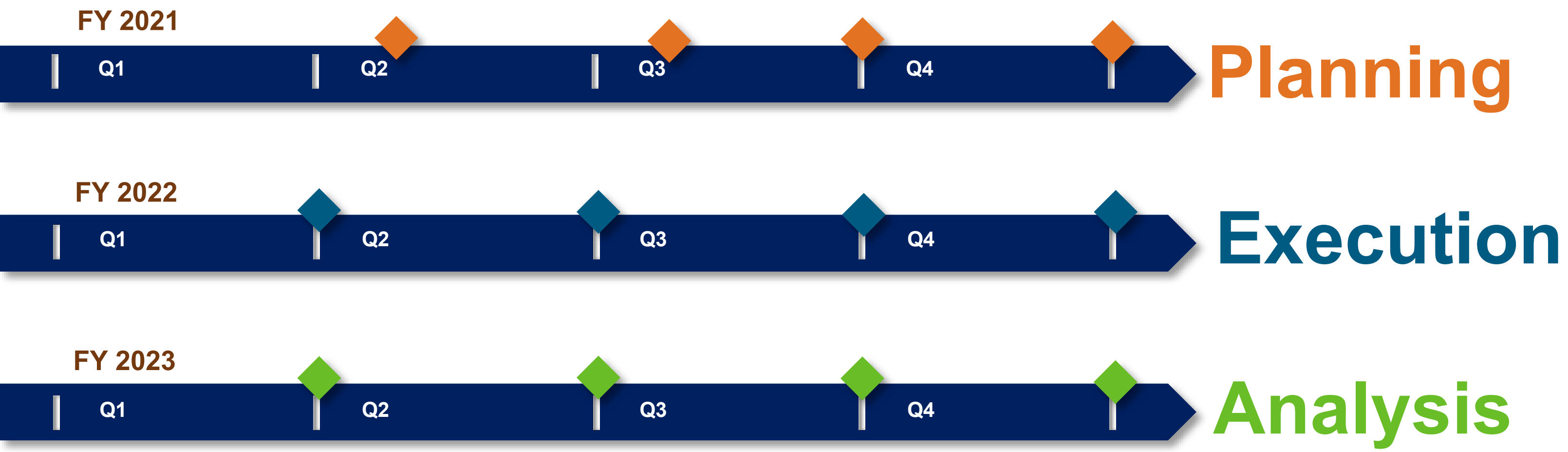

- Completed
- Ongoing
- Future Work

Year 1 Milestones

- Solidify collaborator agreements
- Parameter definitions/draft procedure
- Procedure performance - refinement
- Finalized project procedures (Go/No-go)

Year 2 Milestones

- Fleet data collection review
- Capture conductive profile sets
- Complete EVSE characterization
- Capture non-conductive profiles sets

Year 3 Milestones

- Capture conductive profiles sets
- Finalize fleet data collection
- Complete R&D profile EVSE characterization
- Analysis, results, and reporting

Challenges and Next Steps

Challenges

Collaborative follow-through and schedule limitations

- It is important that laboratories and collaborative partners work through **asset availability and scheduling issues** to efficiently and comprehensively characterize the assets.

Ensure representative data quality from multiple sources

- Procedures will be executed at 4 different laboratories and in various field data gathering scenarios.
- Available equipment and data acquisition systems will vary by location.

Next Steps

Initiating new collaborative relationships as qualifying assets come to market

- Project timeline will align with numerous qualifying next-generation EV and EVSE announcements.
- Project team will need to **communicate project value** to capture new collaborative partnerships.

Extend the project work further – aim to add to EVs@Scale Consortium portfolio

- We are near the tipping point for e-Mobility – **high-power charging vehicles will quickly become standard**.
- Continuing characterization efforts and charge demand analysis will provide a basis for efficient capital investments that ensure **infrastructure reliability** and **keep future energy costs low**.

Thank You

- Discussion Questions

- Contact Info:

ddobrzynski@anl.gov

1-630-252-6440

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Resilient High Power Charging Facility

Michael Starke, PhD
Oak Ridge National Laboratory

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U.S. Department of Energy

Goal: Improve EV charging resilience

- ***Challenges:***
- Electric Vehicle Charging Infrastructure is needed to support reduced range anxiety.
- Failing Chargers or non-functional charging infrastructure has become a highly reported topic reducing the impact of deployed systems

More than 25% of public DC charging stations in California's Bay Area were unusable, according to researchers.

David Rempel. Carleen Cullen, Mary Matteson Bryan, Gustavo Vianna Cezar, Reliability of Open Public Electric Vehicle Direct Current Fast Chargers, Systems and Control (Submitted March 2022)

Scalability Is a Leading Challenge Facing the EV Charging Ecosystem Today

https://driivz.com/blog/ev-charging-industry-challenges/

EV Charger Reliability Is Critical

https://www.forbes.com/sites/forbestechcouncil/2022/02/14/ev-charger-reliability-is-critical/?sh=74f5defb2d40

Electric-car charging stations are becoming more common, but there's still one huge problem: Tons of them don't work

https://www.businessinsider.com/electric-car-charging-reliability-broken-stations-ev-2022-5

It's time to address a big issue with EV charging: reliability

https://www.greenbiz.com/article/its-time-address-big-issue-ev-charging-reliability

Resilient High Power Charging Facility: The Approach

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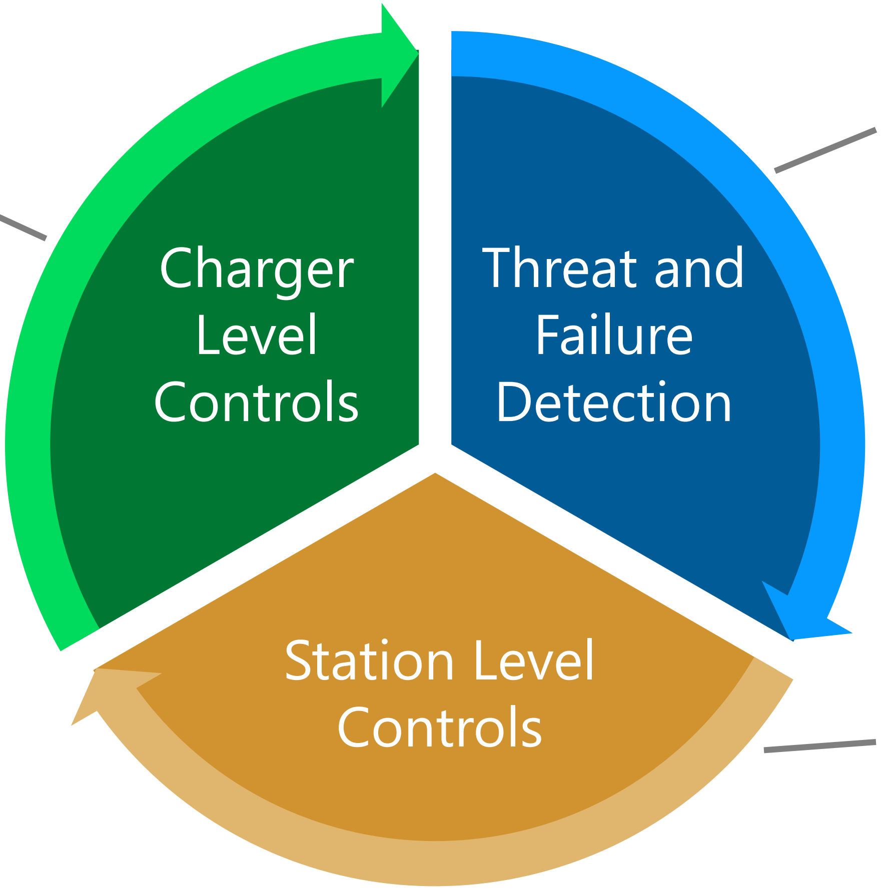
Overall Approach:

Develop control and anomaly detection techniques to improve the resiliency of the electric grid and charging stations.

Charger Level Controls

- Electric vehicle charger topologies and controls
- Electrical vehicle charger fault identification
- Electrical vehicle charger resilient operations



Threat and Failure Detection

- Cyber security threats and attacks
- Physical equipment threats and attacks
- Communication failures

Station Level Controls

- Electrical charging network
- Supporting Energy Storage / Renewables
- Islanding Options

Validation of technology development performed in both controller hardware in the loop and hardware platforms.

Resilient High Power Charging Facility: The Team

Charger Level Controls

Oakridge National Lab (ORNL):

Madhu Chinthavali, Michael Starke, Namwon Kim

Station Level Controls

Pacific Northwest National Laboratory (PNNL):

Rick Pratt, Thomas Carroll, Lori Ross O'Neil, Frank Tuffner

Threat and Failure Detection

Idaho National Laboratory (INL) :

Tim Pennington, Craig Rieger, Kenneth Rhode, Richard “Barney” Carlson

Virginia Commonwealth University (VCU)

Resilient High Power Charging Facility: Approach Details

Use Case: ***Defines a mechanism that could lead to potential failure of the charging station. This could be a piece of equipment, communication network, or line outage as examples.***

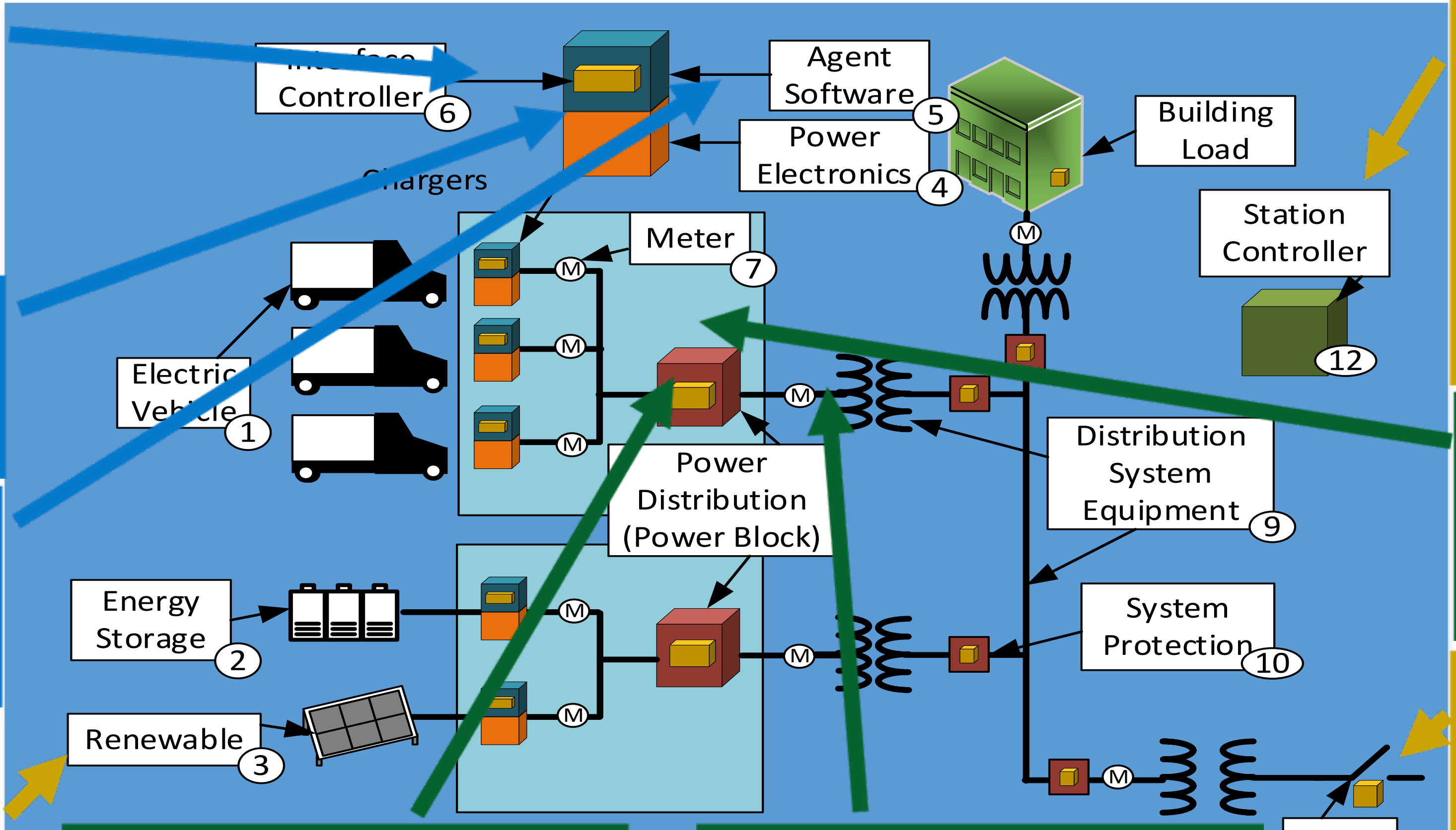
Use Case 7: External Event: EV/EVSE Communications Fault
Recover and restart charging

Use Case 8: External Event: EV/EVSE Communications to EV Agent Failure
Agent failure / disruption

Use Case 9: Internal Event: EVSE or EV controls communications failure / disruption

Use Case 6: Internal Event: Resilient response to Storage / Renewable Controller performance

Control output provides guidance to Interface Controller resulting from RE device control issues



Use Case 5: Internal Event: Resilient response to EVSE, EV, Controller performance

Controls provide guidance to Interface Controller resulting from EV/EVSE device control issues

Use Case 1: External Event: Grid Fault

Islanding outcome, resilient charger operation

Use Case 4: External Event: Resilient response to Grid Stress (DR / Brownout)

Load Profiles and Control applied at Power Distribution Blocks

Use Case 2: Internal Event: Power Block Component Fault

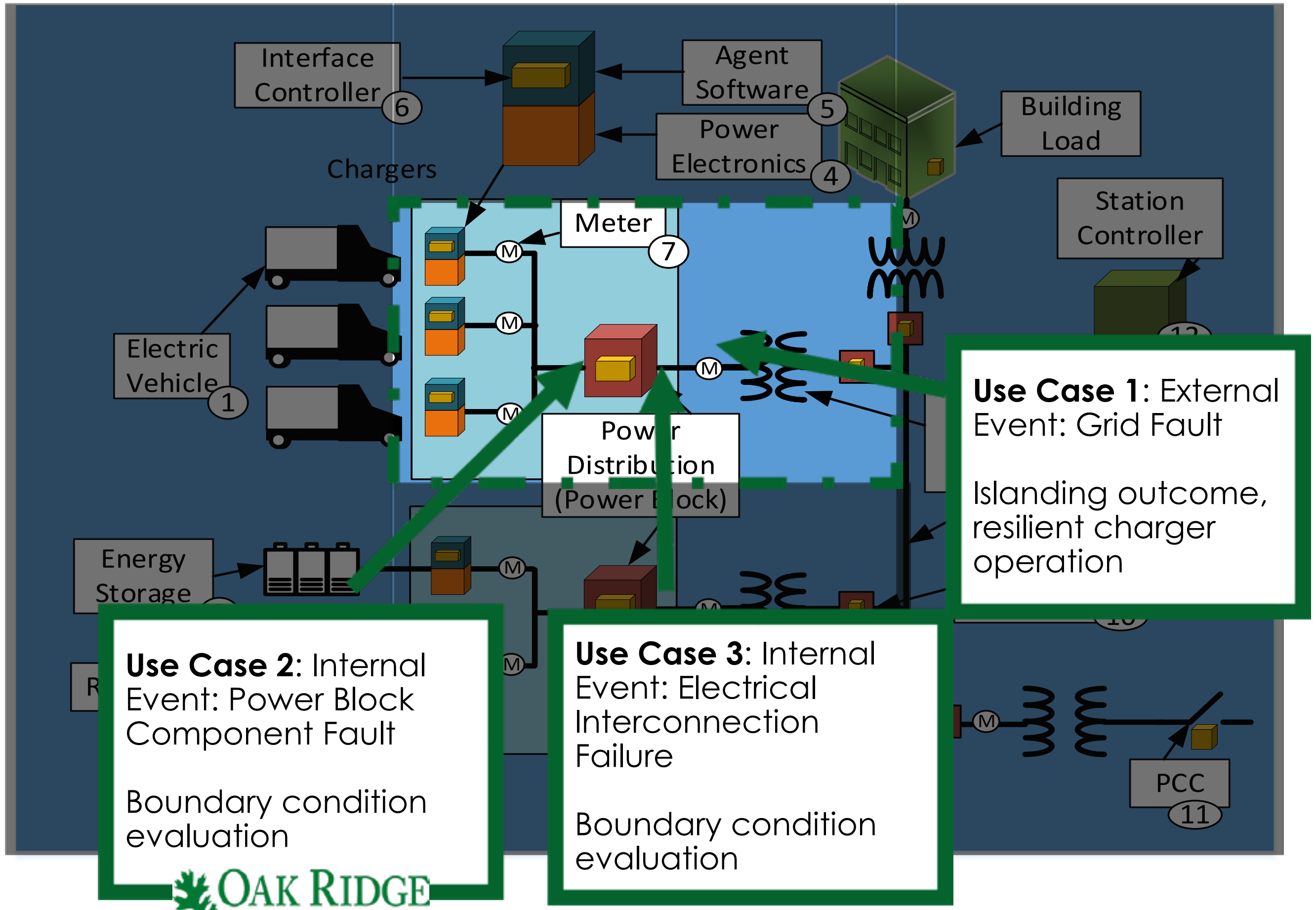
Boundary condition evaluation

Use Case 3: Internal Event: Electrical Interconnection Failure

Boundary condition evaluation

Resilient High Power Charging Facility: Technical Accomplishments (1/3)

- Simulation of Power Electronic Systems for Evaluating EV Chargers developed.
- Successfully developed new controls and architectures to support resilient operation
- Successfully characterized system behavior under fault (baseline) and new control conditions
- Use case evaluations of chargers under grid transient events.
  - **Use Case 1:** External Event: Grid Fault
  - **Use Case 2**: Internal Event: Power Block Component Fault
  - **Use Case 3:** Internal Event: Electrical Interconnection Failure



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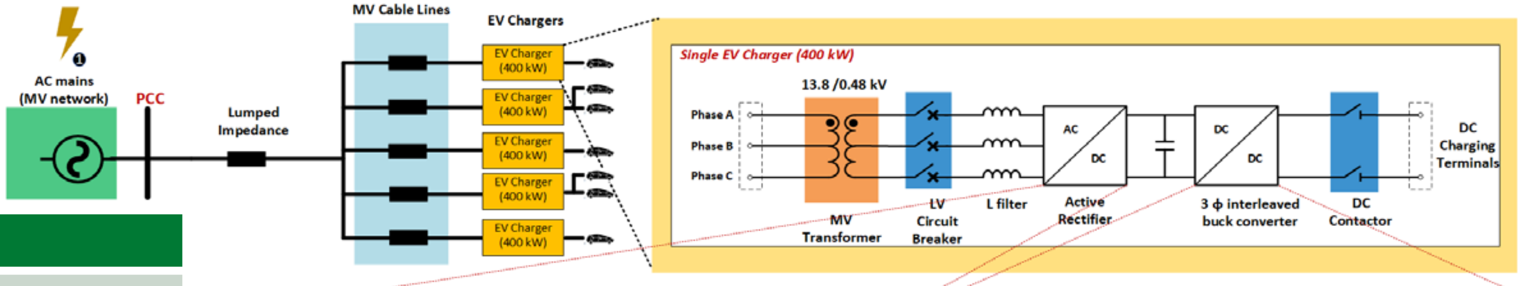
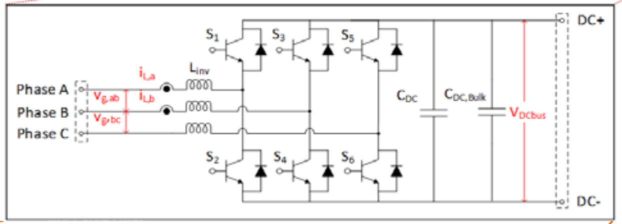
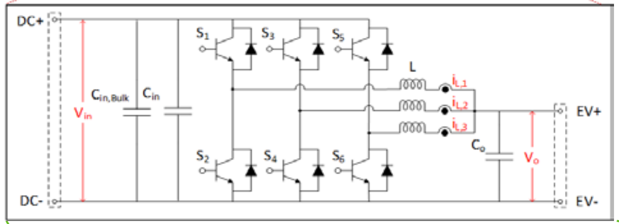
Controller hardware in the loop modeling and control development



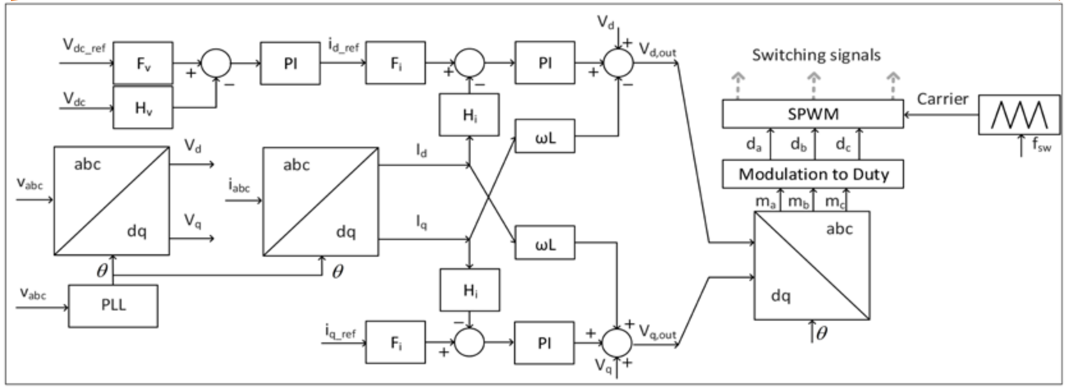




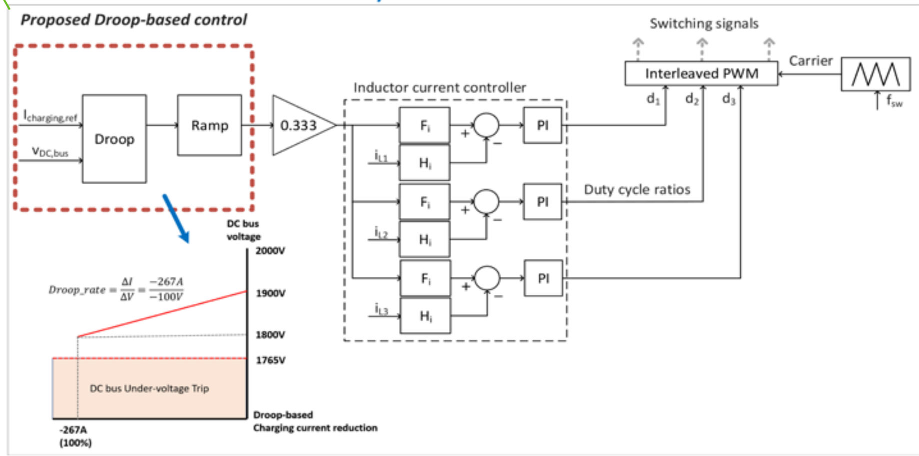
Charger Level Controls

- Electric vehicle charger topologies and controls
- Electrical vehicle charger fault identification
- Electrical vehicle charger resilient operations

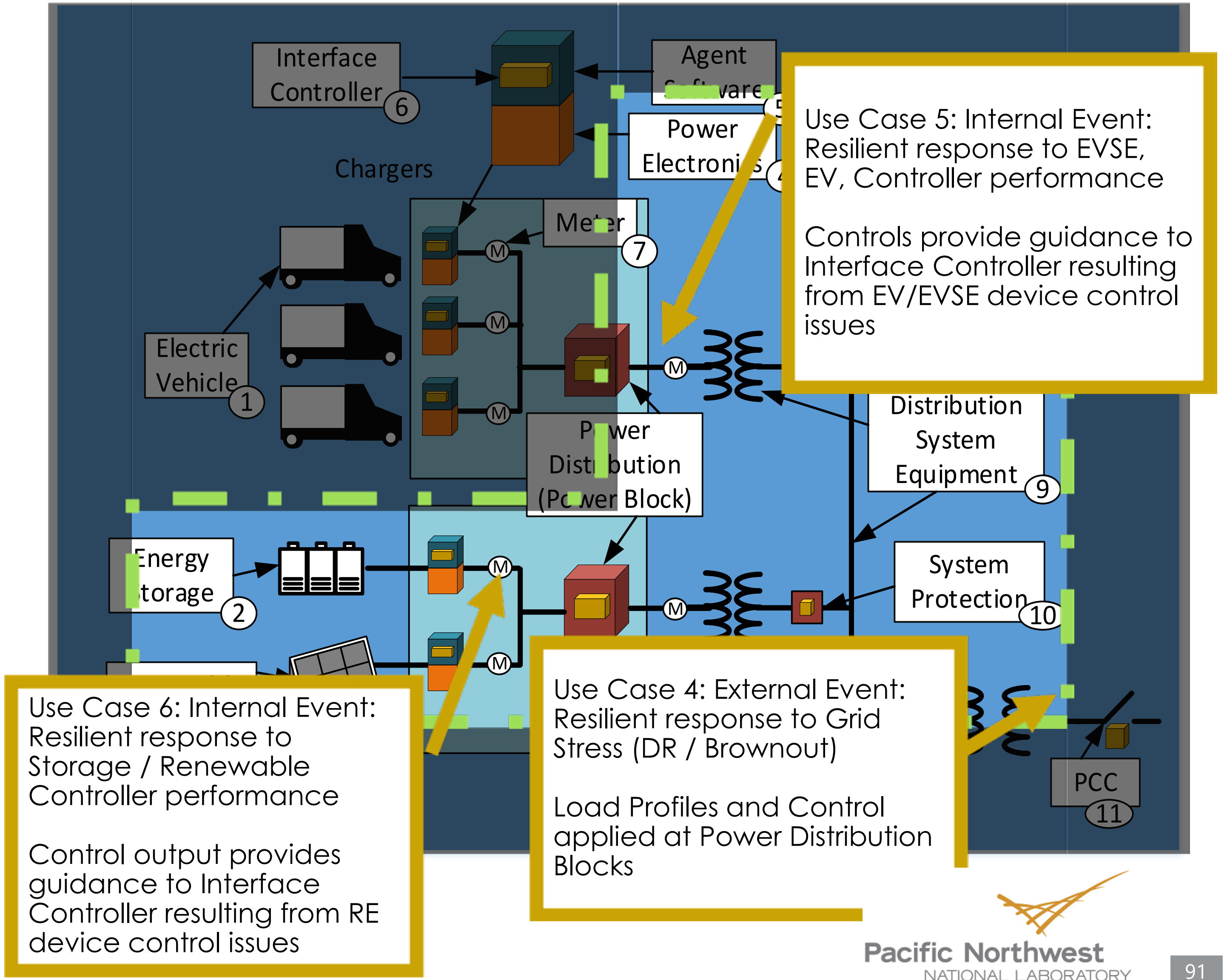
PWM Rectifier Control



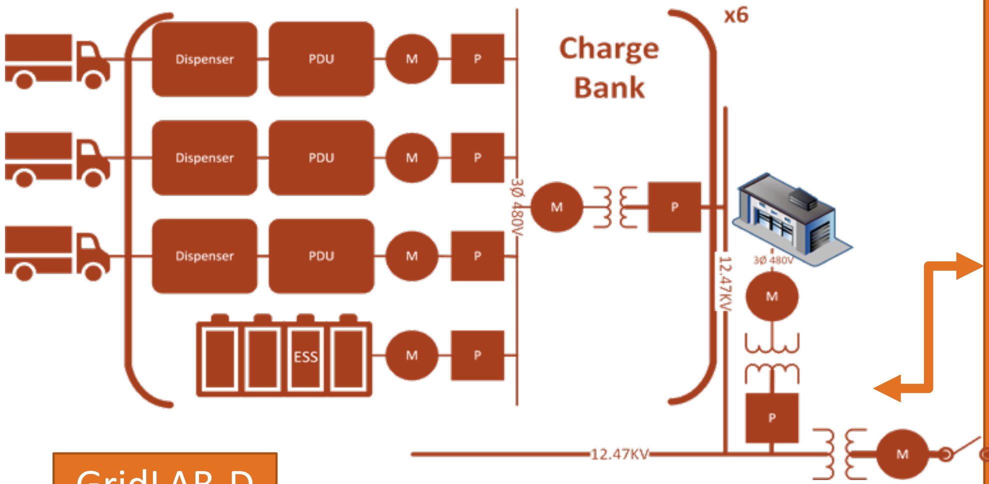
DC/DC interleaved Buck Control



- Successful development of models in Gridlab-D to support EV control development and evaluation.
- Use case evaluations of equipment failures and system wide control responses based.
- Use cases evaluated considering equipment failure and grid stresses (use cases #4, 5 and 6)
    - **Use Case 4:** Grid Stress anomaly
    - **Use Case 5:** EVSE anomaly
    - **Use Case 6:** Internal Event: Storage / Renewable Controller anomaly



Simulation development and validation of station level controls



GridLAB-D Model

HELICS

Open-source, co-simulation system aligns temporal data from multiple sources.

DirectX // Caldera Charge Profiles

Discrete event simulator for vehicle arrivals.
Temporal EV Energy Required, battery size, and SOC, EV Energy Delivered

Grid Conditions
Temporal PCC voltage input
Temporal PCC Power and sub-transmission

Controller
VOLTTRON-managed power control

Building & Renewables Asset Integration
Building, Stationary Storage and Solar Generation Integration

Modeling Description:

- Studying a 24-hour short-haul freight service, operating a medium-duty EV fleet
- Depot performs a short-dwell, return-to-base mission, operating in two shifts
- Every vehicle serves both shifts
- 18 MW charging capacity; subdivided into six modular banks; each bank has a local ESS and three PDUs+dispensers
- Warehouse is a static load
- ESS regulates the PCC and microgrid voltages
- Demonstrates an AC-coupled architecture, where the ESS and PDU share a common AC connection

Station Level Controls
Electrical charging network
Supporting Energy Storage / Renewables
Islanding Options

Resilient High Power Charging Facility: Technical Accomplishments (3/3)

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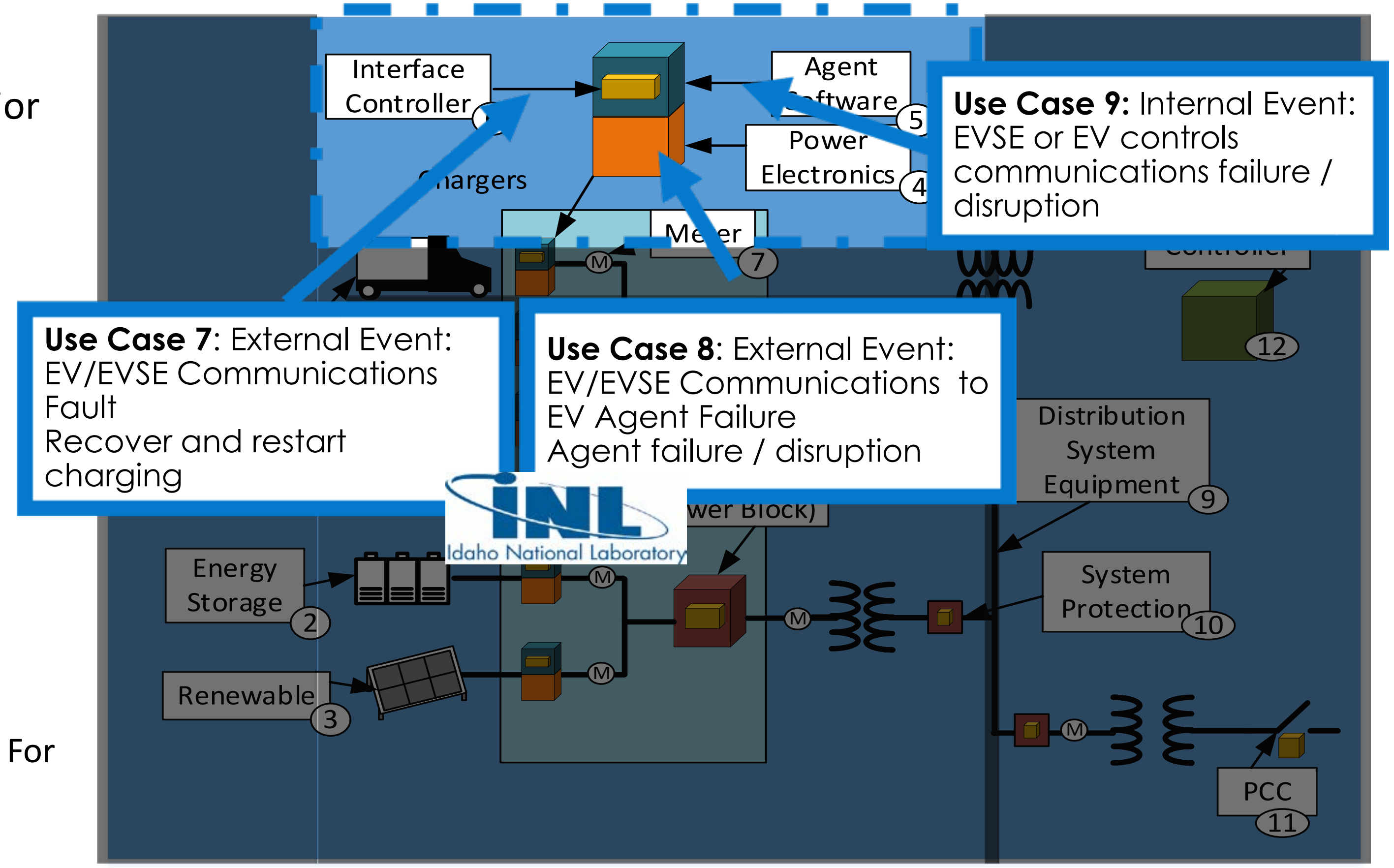
- Successfully developed and tested anomaly detection systems (ADS) to detect anomalies during EV charging
- Real time data collection system to detect anomalous behavior and train ML algorithms for ADS
- Successfully characterized system behavior under normal (baseline) and anomalous operating conditions
- Six charging tests evaluated different anomalous scenarios under use cases #7, 8 and 9
  - **Use Case 7:** EV to EVSE Communication Fault. For e.g., unintentional or malicious CAN message flooding resulting in charge session termination
  - **Use Case 8:** EVSE or EV to External Agent Communication Fault. For e.g., OCPP fault that interrupts the charge session
  - **Use Case 9:** EVSE Internal Controls or Communication Fault
    - Scenario 9-1: EVSE air intake blocked completely
    - Scenario 9-2: CCS liquid cooled cable chiller



Resilient High Power Charging Facility: Technical Accomplishments (3/3)

Exploit: Chiller disables & CCS cable temperatures spoofed during high-power charging

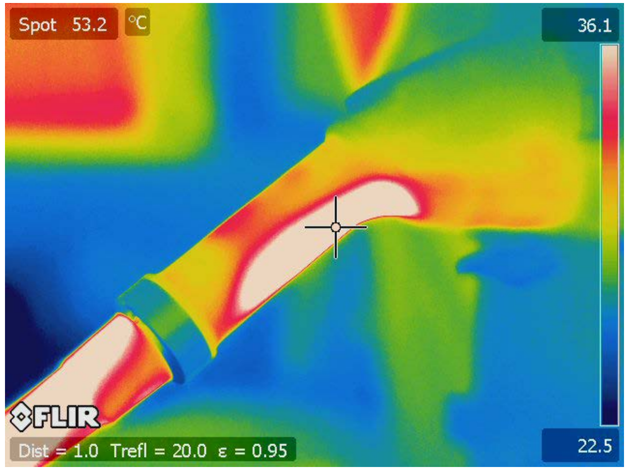


Fig. Thermal image of CCS connector during Scenario 9-2 showing a 52 C hotspot

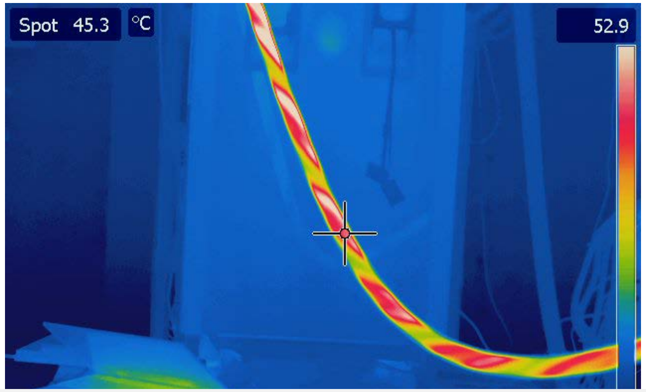


Fig. Thermal image of CCS cable during Scenario 9-2 showing a 45 C hotspot

SIS successfully detected anomalous behavior caused by the intrusion and exploit
Low chiller current error: 1 sec. detection time
Temperature limit: 1 to 9 sec. detection time

Exploit: Air Inlet Blocked on EVSE

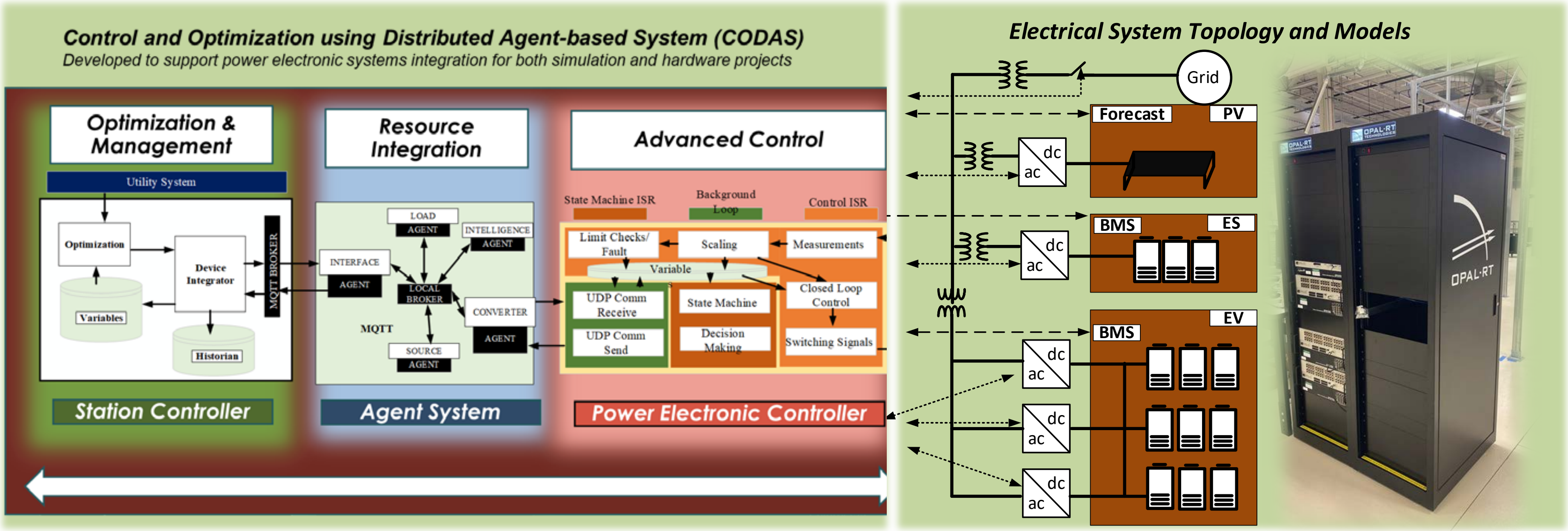
Threat and Failure Detection
Cyber security threats and attacks
Physical equipment threats and attacks
Communication failures

Charge session throttles after ~185 sec

Blocked air inlet: When undetected, this anomaly results in a faster rise in cable temperature and a throttling of charging power. This condition only resets after physical power cycling (reboot) of EVSE, resulting in denial of service and consumer inconvenience.

- **Continue development of use cases**
- **Integration of efforts (coordination linkages of system identifications and responses between developed systems)**
- **Tool development and final validation of use cases.**

Electric Vehicle Station Analytics (EVSA) Tool



Station Architecture

EVs@Scale Bi-Annual Stakeholder Meeting Interaction w/Consortium

1 p.m. – 1:10 p.m. MT	**Deep-dive Sessions** *Andrew Meintz*
1:10 p.m. – 1:20 p.m. MT	**Direct Project Participation** *Andrew Meintz*
1:20 p.m. – 3 p.m. MT	**Roundtable Questions & Comments** *All attendees*

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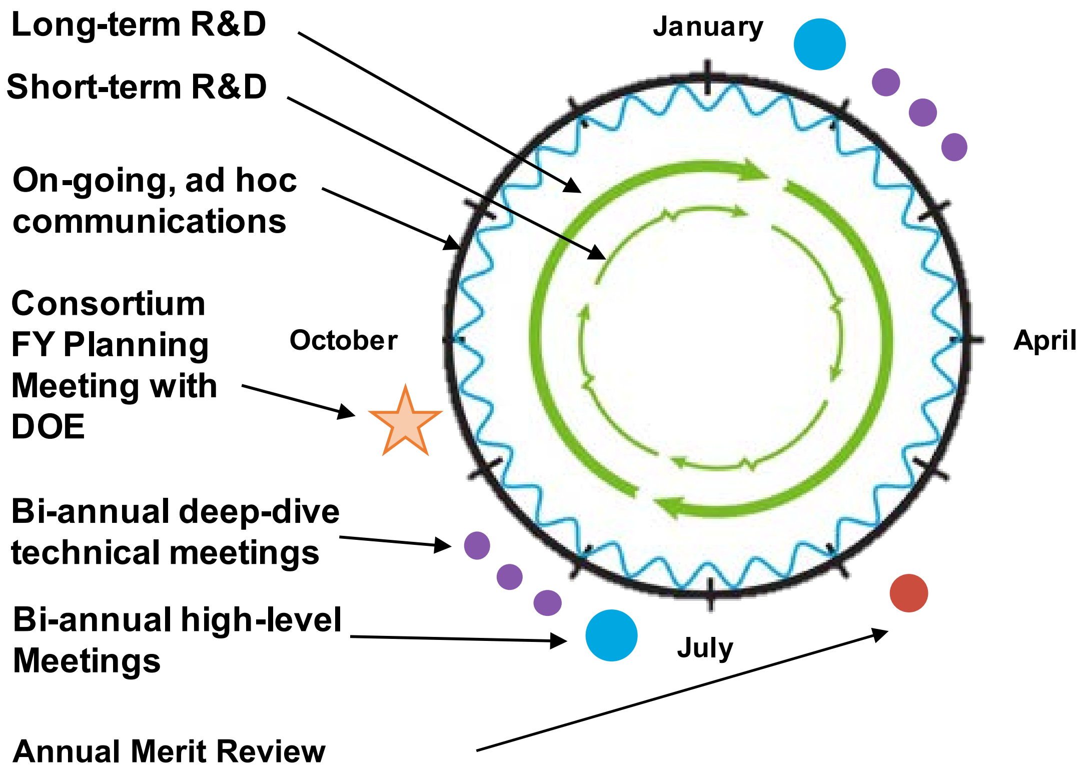
Deep-Dives and Direct Project Participation

Andrew Meintz

August 17, 2022

Collaboration and Coordination

- **Consortium Laboratories**
  - ANL, INL, NREL, ORNL, PNNL, SNL
- **External Steering Committee**
  - Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure
- **Direct interaction for each pillar projects**
  - Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure
  - Webinars / Project discussions
- **Bi-annual high-level meetings**
  - Rotation among labs with discussion on all pillars
- **Bi-annual deep-dive technical meetings**
  - VGI/SCM, HPC & WPT, and CPS with C&S incorporated into all meetings



Smart Charge Management and Vehicle Grid Integration

- Meeting Details
  - September 28th and 29th, as virtual half-day discussions
  - Contact: Jesse Bennet (jesse.bennett@nrel.gov)
- Topics
  - Analysis
    - Grid (Feeder-level analysis overview, broad analysis overview)
    - Vehicles/Charging (EV Adoption LMHDV – TEMPO, EVI-X charging load dataset analysis overview
  - Development/Demonstration
    - Charge Scheduling (Background, Applications)
    - Workplace Charge Reservation (Backround, EVrest: Development/Demonstration
    - Smart AC L2 EVSE (Background, OptiQ: Smart AC L2 EVSE Development/Demonstration)
  - Standards
    - Existing standards of value
    - Gaps in standards based on analysis and demonstration

High-Power Charging and Wireless Power Transfer

- Meeting Details
  - September 13th and 14th , as virtual half-day discussions
  - Contact: Veda Galigekere (galigekerevn@ornl.gov)
- Topics
  - Wireless Power Transfer
    - High power dynamic wireless charging: Prior work
    - 200 kW Dynamic wireless power transfer system demonstration at ACM
    - Next Steps for R&D to Transition DWPT to Real-World
  - High Power Charging
    - High Power Charging Station: Present and the Future
    - Energy Management and Power Control in an HPC Station
    - Identifying next steps and R&D needs
  - Codes & Standards Functional and Regulatory requirements

Cyber-Physical Security

- Meeting Details
  - Contact: Barney Carlson (richard.carlson@inl.gov)

Sept. 20 from 11AM – 1:30PM (eastern time zone): Cybersecurity Assessments
Microsoft Teams meeting Click here to join the meeting Meeting ID: 255 948 253 256 Passcode: qs77xa Download Teams | Join on the web **Or call in (audio only)** +1 208-901-7635,,297341807# Phone Conference ID: 297 341 807#

Sept. 21 from 11AM – 1:30PM (eastern time zone): Cyber Tools, Training, Mitigation Solutions, and Codes& Standards
Microsoft Teams meeting Click here to join the meeting Meeting ID: 251 020 059 947 Passcode: 4cjrDc Download Teams | Join on the web **Or call in (audio only)** +1 208-901-7635,,220980010# Phone Conference ID: 220 980 010#

- Topics
  - Assessment of systems, features, and architectures
  - Cybersecurity tools and mitigation solutions to improve security
  - Training of the next generation of cybersecurity work force
  - Codes & Standards discussion

Direct Participant Interaction

Direct Project Participation

- Existing Efforts
  - Codes & Standards
    - Direct support of J3271 and IEC 63379 for Megawatt Charging System standards efforts for Thermal and Communications evaluation events
    - ANSI Electric Vehicles Standards Panel
  - Wireless Power Transfer
    - Partners providing vehicles and engineering support for demonstration activites
    - American Center for Mobility and Virginia Tech Transportation Institute
  - NextGen Profiles
    - Partners supporting collection of >200 KW charging with vehicle and EVSEs

Direct Project Participation

- Outreach Efforts
  - US DRIVE Grid Integration Tech Team
  - 21st Century Truck Partnership
  - Bi-annual meetings, Deep-Dives, and Annual Merit Review
  - Other direct outreach
- How to become more involved in future efforts
  - Support engagement efforts at US Drive and 21st Century Truck Partnership
  - Engage with technical pillar leads and leadership council at outreach events
  - Reach out to our team via our website and email

Direct Project Participation

https://www.energy.gov/eere/vehicles/electric-vehicles-scale-consortium

Electric Vehicles At Scale Consortium

Vehicle Technologies Office

Vehicle Technologies Office » Electric Vehicles At Scale Consortium

EVs@Scale
U.S. Department of Energy

Harmonizing EVs with the Grid

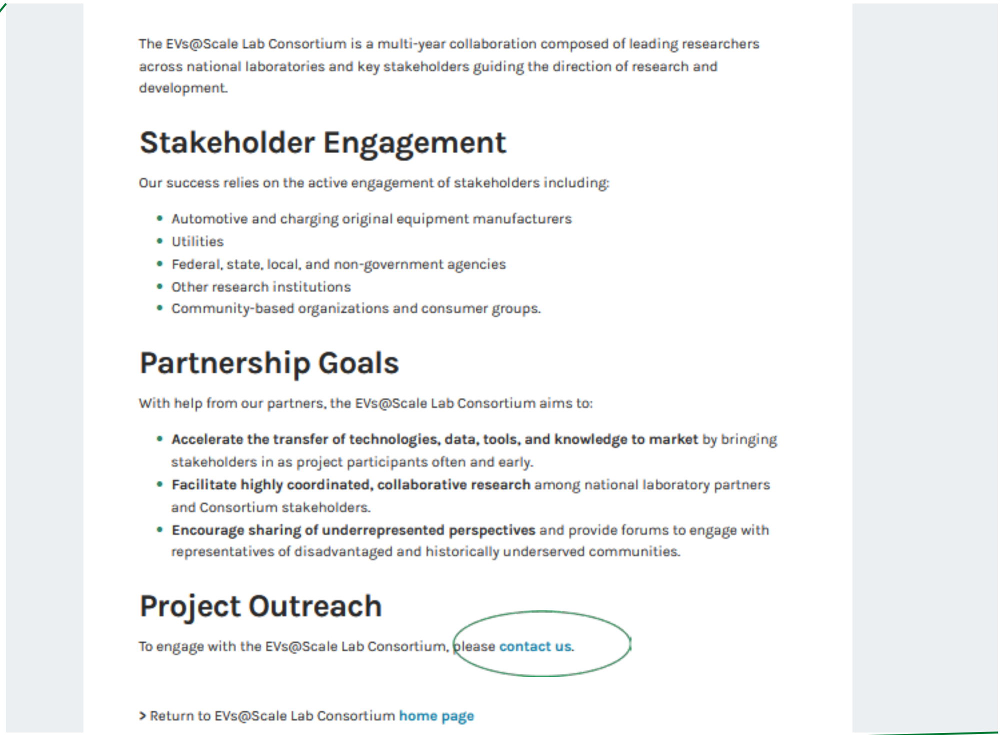
With tens of millions of light-, medium-, and heavy-duty electric vehicles (EVs) projected to hit American roads by 2030, establishing a secure and scalable infrastructure is necessary to support the transition to an electric fleet. The U.S. Department of Energy's Electric Vehicles at Scale Lab Consortium (EVs@Scale Lab Consortium) brings together national laboratories and key stakeholders to conduct infrastructure research and development to address challenges and barriers for high-power EV charging infrastructure that enable greater safety, grid operation reliability, and consumer confidence.

Learn More

RESEARCH

ENGAGEMENT

PUBLICATIONS



The EVs@Scale Lab Consortium is a multi-year collaboration composed of leading researchers across national laboratories and key stakeholders guiding the direction of research and development.

Stakeholder Engagement

Our success relies on the active engagement of stakeholders including:

- Automotive and charging original equipment manufacturers
- Utilities
- Federal, state, local, and non-government agencies
- Other research institutions
- Community-based organizations and consumer groups.

Partnership Goals

With help from our partners, the EVs@Scale Lab Consortium aims to:

- **Accelerate the transfer of technologies, data, tools, and knowledge to market** by bringing stakeholders in as project participants often and early.
- **Facilitate highly coordinated, collaborative research** among national laboratory partners and Consortium stakeholders.
- **Encourage sharing of underrepresented perspectives** and provide forums to engage with representatives of disadvantaged and historically underserved communities.

Project Outreach

To engage with the EVs@Scale Lab Consortium, please contact us.

> Return to EVs@Scale Lab Consortium home page

evsatscale@googlegroups.com

EVs@Scale Bi-Annual Stakeholder Meeting Interaction w/Consortium

EVs@Scale U.S. Department of Energy

1:20 p.m. – 1:50 p.m. MT	**Consortium Audience Feedback Session** *Lee Slezak*
1:50 p.m. – 2:35 p.m. MT	**Pillar Audience Feedback Session** *All Pillar Leads*
2:35 p.m. – 3:30 p.m. MT	**Open Mic Audience Feedback Session** *All Attendees*
3 p.m. – 3:30 p.m. MT	**Break & Networking Session** *All attendees*

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Consortium Audience Feedback Session

Pillar Audience Feedback Session

Open Mic Audience Feedback Session

In-Person Networking

- Please feel free to mingle

Virtual Networking

- Breakout rooms according to research pillars and a general room for misc. topics will open momentarily
- Please feel free to join a room and move between them based on your interests
- All sessions will close at 4 p.m. MT

Thank you for your participation. We look forward to hearing from you soon!

EVs@Scale

U.S. Department of Energy