HORIBA Institute for Mobility and Connectivity²

HIMaC²

University of California, Irvine

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Vehicle Evolution Laboratory (VEL)

Grid Evolution Laboratory (GEL)

Connected and Autonomous Mobility Laboratory (CAML)

Analytic Laboratory (AL)

HORIBA Institute for Mobility

The "HORIBA Institute for Mobility and Connectivity^2 (HIMaC^2)" is a joint initiative of HORIBA and the Advanced Power and Energy Program (APEP) at the University of California-Irvine (UCI) that is scheduled to open in August 2020. "Mobility" encompasses the future of transportation with the evolution of zero-emission vehicles operating on plug-in electricity, hydrogen, and a combination of plug-in electricity and hydrogen. "Connectivity" encompasses two distinct but related research thrusts:

- The emerging paradigm of "connecting" mobility with the electric grid (e.g., G2V, V2G), and "connecting" hydrogen with the electric grid for (1) long-duration of energy storage, and (2) providing fuel for both mobility and power generation.

- The communication "connection" between vehicles (V2V), and vehicles and the infrastructure (V2I).

HIMaC^2 will provide an advanced research and educational platform to address the critical grand challenges at the nexus of energy and the environment. One grand challenge is the development of vehicles, fuel supply chains, and mobility systems with zero-emission of greenhouse gases, short-lived climate pollutants, and criteria pollutants. A second grand challenge is the connectivity of zero-emission vehicles and mobility systems with an electric grid endowed with a high-penetration of renewable wind, solar, and energy storage resources. A third grand challenge is the development of next generation of vehicles that can sense and perceive their surroundings, engage with other vehicles, and communicate with the built-infrastructure.

The initiative will establish the Vehicle Evolution Laboratory (VEL) to address the development and deployment of next-generation zero-emission vehicles, and integrate the VEL with:

- An existing Grid Evolution Laboratory (GEL), developed to explore the next-generation smart, 100% renewable electric grid,

- A new Connected and Autonomous Mobility Laboratory (CAML) for state-of-the-art research in V2V and V2I connectivity as well as sensors and perception, and

- A new Analytic Laboratory (AL) with the latest instrumentation in support of electrochemical materials research.

and Connectivity^2 (HIMaC^2)

Using the VEL, HIMaC^2 will address the performance of components (e.g., batteries, fuel cell stacks and engines, electric motors, electric drivetrains), as well as the performance of zero-emission vehicles.

Through the GEL, HIMaC^2 will (1) address the design and control of the future grid to provide the energy (electricity and hydrogen) to power zero-emission vehicles with carbon-free fuels (G2V), and (2) recover the energy from vehicles as needed to stabilize the diurnal variation and intermittencies associated with solar and wind (V2G). Through the CAML, HIMaC^2 will inform the evolution of vehicle connectivity (V2V, V2I) as well as sensors and perception. Through the AL, HIMaC^2 will address the science and engineering supporting the development of electrochemical technology.

HORIBA and APEP collaborated on the design of HIMaC^2, and look forward to commissioning, dedicating, and utilizing HIMaC^2 in conjunction with vehicle manufacturers, technology suppliers to the vehicle industry, regulatory agencies, and other stakeholders in fulfilling the mission of HIMaC^2.

HIMaC^2 Laboratories

HIMaC^2 comprises the four following laboratories:

1. Vehicle Evolution Laboratory (VEL)
2. Grid Evolution Laboratory (GEL)
3. Connected and Autonomous Mobility Laboratory (CAML)
4. Analytic Laboratory (AL)

HIMaC^2 addresses the future of mobility, the future of the electric grid, and future of vehicle sensors and communication, with two evolving levels of connectivity between the three:

- Connectivity 1: Vehicle-to-Grid (V2G), and Grid-to-Vehicle (G2V)
- Connectivity 2: Vehicle-to-Vehicle (V2V), and Vehicle-to-Infrastructure (V2I)

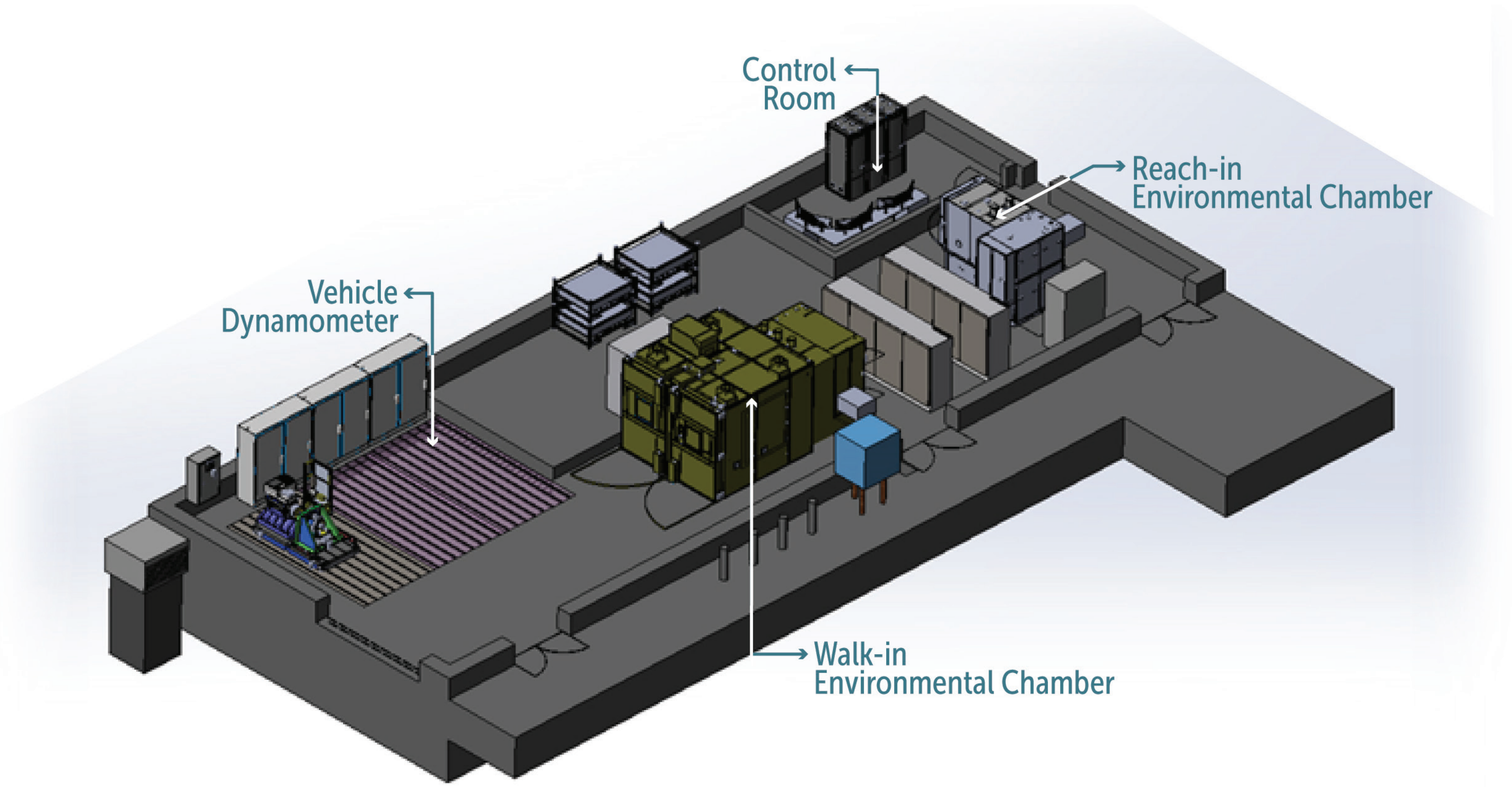
Connectivity "1" encompasses a physical connection between the VEL and the GEL for communications, and the conveyance of electricity and hydrogen. Connectivity "2" encompasses the CAML with communication links to both the VEL and the GEL. For example, the VEL and CAML interact through vehicle-in-the-loop and hardware-in-the-loop scenarios and thereby physically test powertrain components separately or within a complete vehicle.

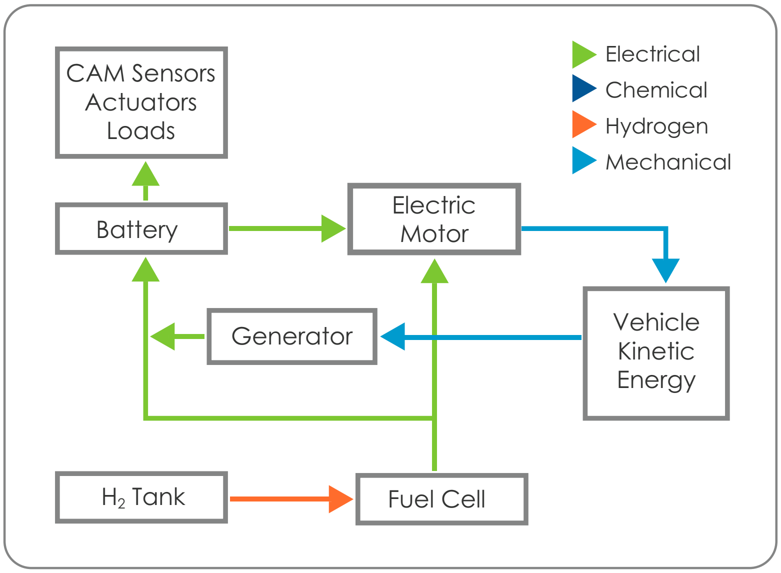
These controlled laboratories are complemented by a robust array of simulation models and computational resources, as well as state-of-the-art controls and sensors.

Vehicle Evolution Laboratory (VEL)

The Vehicle Evolution Laboratory (VEL) looks to powering the future of zero-emission on-road mobility. Testing equipment includes a dynamometer, a walk-in environmental test chamber, and a reach-in test chamber. These three components provide a wide range of testing capability on vehicle powertrains.

The dynamometer serves to characterize powertrains of the zero-emission vehicles with a focus on electric motors powered by electricity from battery and/or fuel cell stack. The research focuses on (1) the design of electric powertrains to effectively and efficiently meet drive cycle demand, (2) the performance of battery and fuel cell engines, (3) the interaction between fuel cell stacks and hybrid batteries, and (4) the enhanced torque associated with electric motors.





The two test chambers are outfitted to exercise the electrochemical power supplies and energy storage of zero-emission electric vehicles whether powered by a battery or fuel cell engine. The test chambers provide a broad capability to test electrochemical devices (batteries and fuel cell stacks and engines) over a range of duty cycles and environmental scenarios. Areas of interest include improved efficiency, decreased aging effects, and decreased cost both in material and manufacturing.

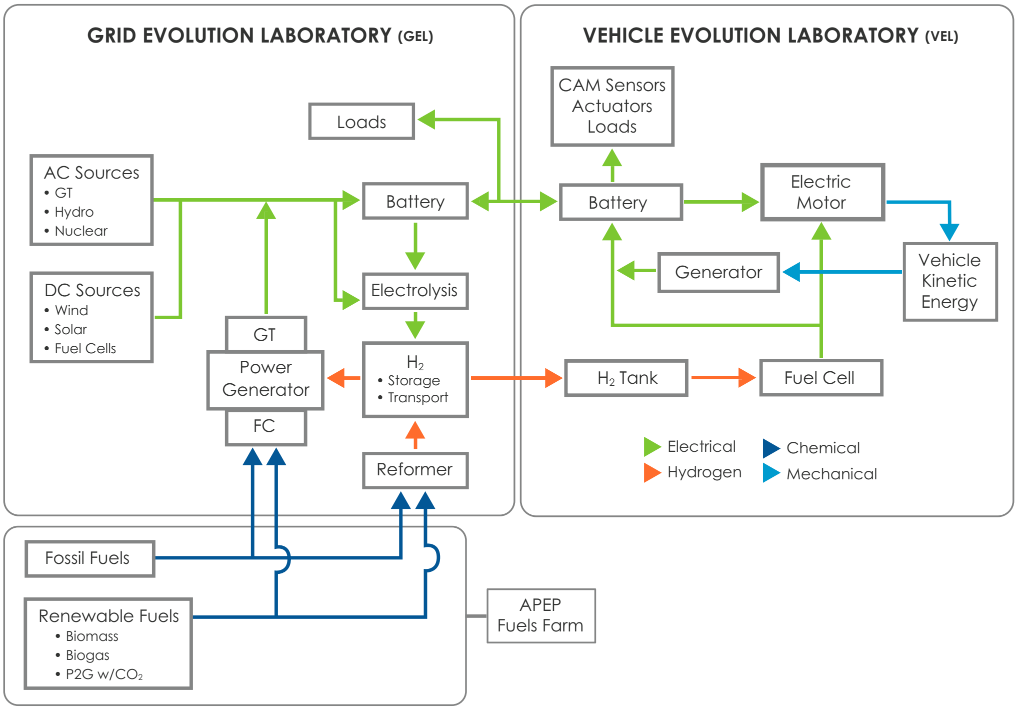
Grid Evolution Laboratory (GEL)

The Grid Evolution Laboratory (GEL) was established by APEP for:

- Supporting education and research;
- Engaging the market;
- Exploring the future smart grid including next-generation smart grid technology, microgrids (and nanogrids), the interaction between the microgrid and the utility grid, high penetration of renewable generation, and distributed energy resources (DER); and
- Assessing the evolving marriage of the electric and hydrogen grids with the transportation sector.

The GEL has three platform levels:

1. Simulation Platform. Simulation software and robust computational resources are employed to develop models of distribution circuits, microgrids, grid components, and control methodology.
2. Controlled Physical Experimental Platform. Grid components and controllers are tested with Hardware-in-the-Loop (HIL) within a controlled physical laboratory outfitted with power generators (e.g., fuel cells, microturbine generators), and other DER (e.g., batteries, electrolyzers, inverters, load banks).
3. Field Experimental Platform. Once qualified at Level 2, DER are deployed on the UCI Microgrid for testing under practical conditions. Examples of the plug-and-play features of this level include the evaluation of a 2MW battery, 30kW to 200kW microturbine generators, and a 115kW dual- axis-tracking, concentrated photovoltaic (CPV) panel system, as well as operation and control of the Anteater Parking Structure nanogrid.



Equipment in the GEL includes an OPAL-RT real-time simulator (used both for simulation only as well as HIL requiring real-time simulations), MCC, DC and AC buses, Chorma load banks, a PV simulator, and an array of Schweitzer Engineering Laboratories instrumentation.

The GEL and the Vehicle Evolution Laboratory (VEL) are connected electrically and with the conveyance of hydrogen, and communicate via fiber optics to characterize interactions of the grid or microgrid and grid components with the transportation sector. For example, the power generation equipment of the GEL can charge a battery electric vehicle being tested in the VEL. This allows for detailed study of novel power management techniques such as vehicle-to-grid (V2G) during which the electric vehicle discharges power back into the electric grid. Another example is the control of charging vehicles (G2V) with smart algorithms in order to protect electrical equipment such as transformers.

Connected and Autonomous Mobility Laboratory (CAML)

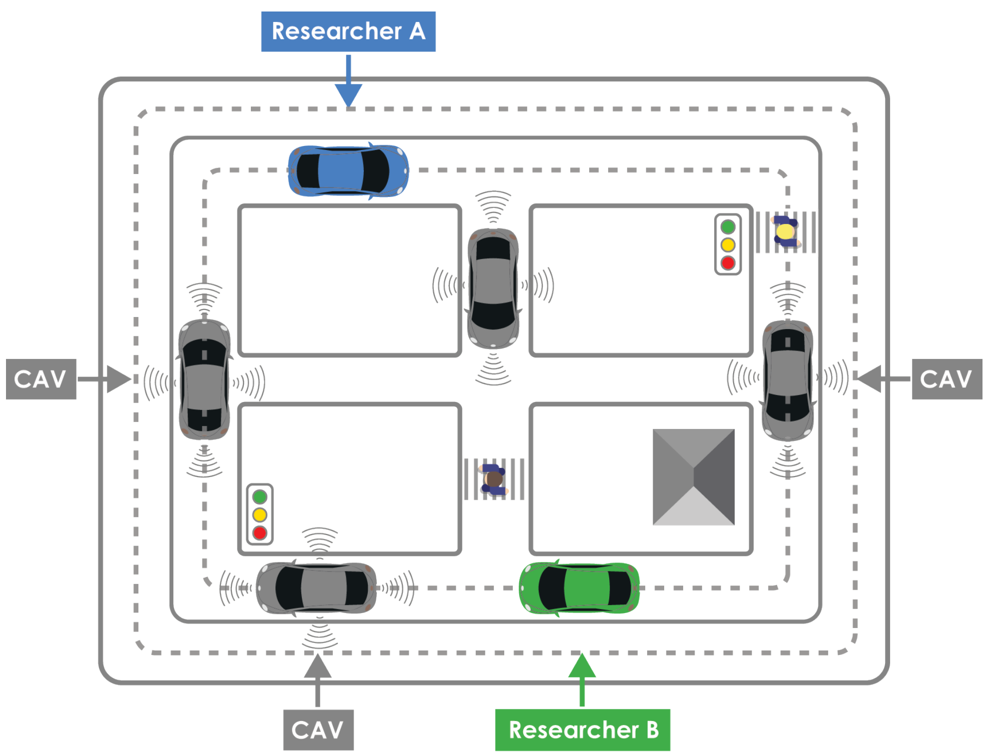
Driving Simulators

- Visible and interactive.
- More than one, such that human-to-human driving behavior, and "CAM Reactions" can be measured against one another in real time.
- Simulation data/results relayed into server rack and utilized for analyses or as input to computing resources supporting real-time simulation.
- Ability to feed inputs to the VEL powertrain dynamometer and environmental chambers.

Connectivity technology includes both vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) connectivity. These are both methods of transferring information from one physical location to another and between vehicles to improve safety, fuel efficiency, and travel time.

Sensor technology is a wide field, including lidar, radar, cameras, ultrasound, and more. The CAML is set to test each of these as well as new technologies that are introduced. One method of doing so is with a scale connected and automated vehicle (CAV) testbed. This testbed utilizes vehicle and traffic simulation software to test and analyze connectivity, both V2I and V2V, as well as sensor technologies for autonomy.

Furthermore, the robotic and simulated vehicles can be used interchangeably. Sensor data can be obtained either from simulated sensors, real sensors or the mixture of both. The road networks, simulated vehicles, and some infrastructure can be projected on to the test area with the remaining features physically constructed. This platform combines the benefits of simulation such as scalability and the ease of deployment with the features of a physical testbed. Platform data interfaces will enable researchers to work with real and simulated data streams simultaneously.



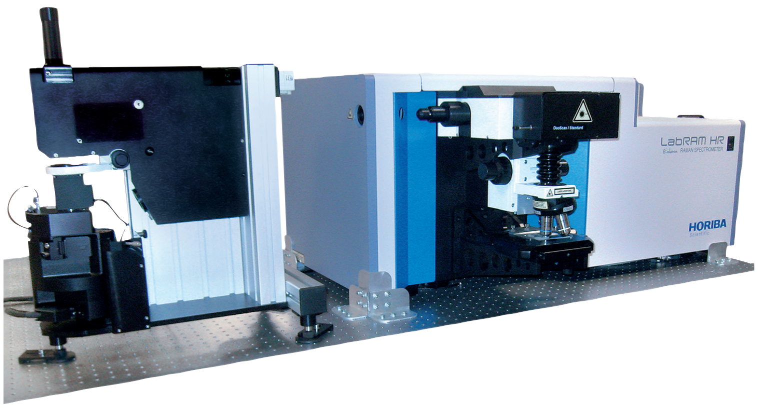
Analytic Laboratory (AL)

The HIMaC² Analytic Laboratory (AL) is outfitted with four primary pieces of equipment which are customized for the high-precision electrochemical evaluations that are critical in the future utilization of electrochemical systems.

1) GD-Profiler 2 – Glow Discharge Optical Emission Spectroscopy (GDOES)

GD-OES provides depth profile and elemental composition from the first nanometers down to hundreds of microns into samples. The technique is fast (10 minutes per sample), can characterize all elements from hydrogen to uranium and has excellent depth resolution.

HIMaC² applications: Perform elemental depth profiles on materials involved in batteries and fuel cells.



2) LabRAM HR Evo Nano - AFM-Raman for Physical and Chemical Imaging

The LabRAM HR Evolution confocal Raman microscope, seamlessly integrated with the SmartSPM Scanning Probe Microscope, offers a versatile and reliable platform for fast simultaneous co-localized Raman-AFM & Tip-enhanced Raman Spectroscopy (TERS). TERS brings the best of both worlds: the chemical specificity of Raman spectroscopy with imaging at high spatial resolution.

HIMaC² applications: Study the effect of corrosion on carbon felts in PEM fuel cells and redox-flow batteries. Develop durable oxide and nitride supports for PEM fuel cell electrocatalysts.

3) XGT-9000 – Micro XRF Analytical Microscope

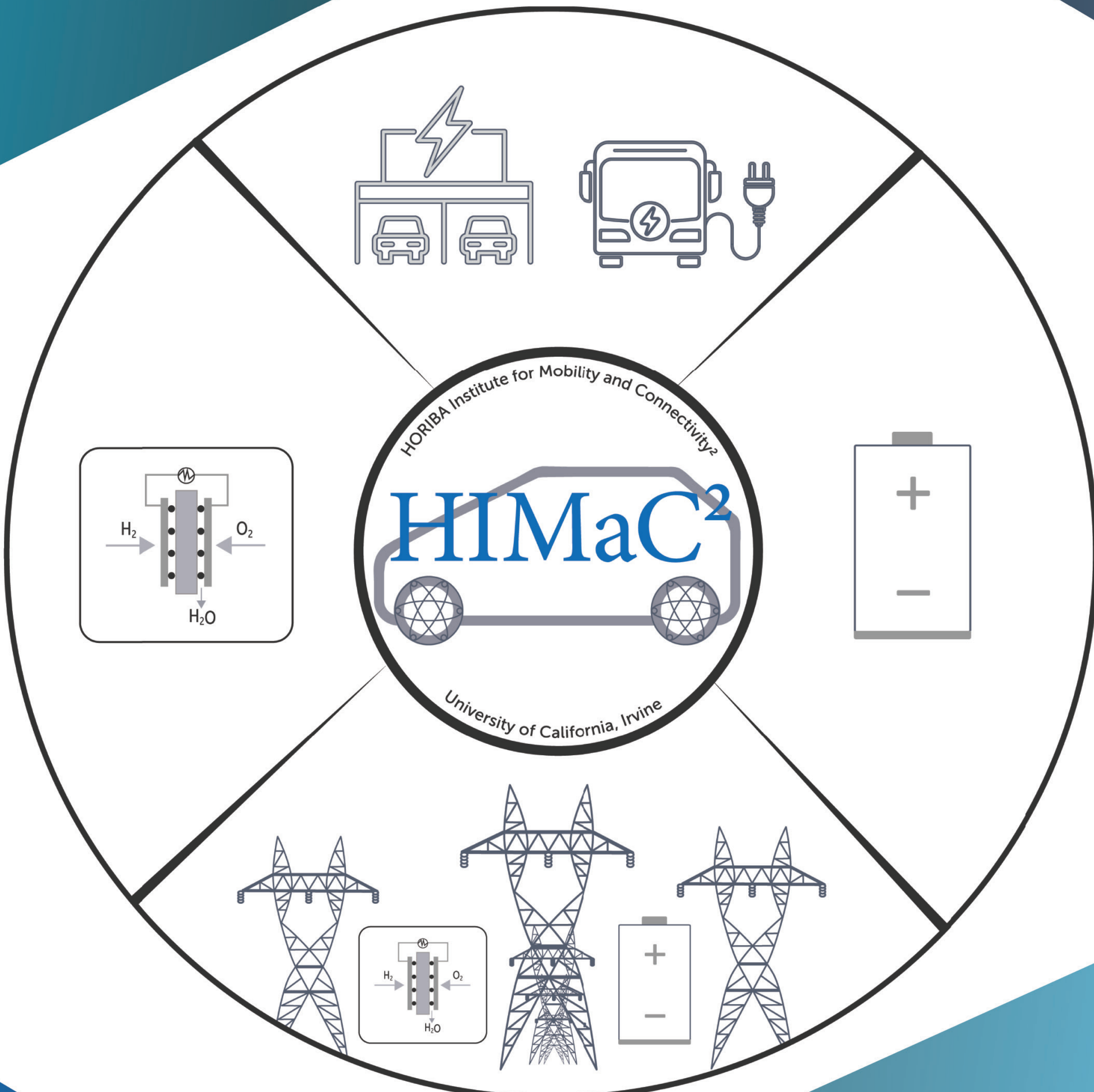
X-ray Analytical microscope combines fast mapping over large areas and non-destructive elemental analysis (EDXRF) with the capability to pinpoint individual particles or defects down to <10 μm in size.

HIMaC² applications: Quantify electrode content (Sm, Ce, Zr and Y for Solid Oxide Fuel Cells; Platinum for Proton Exchange Membrane Fuel Cells).

4) SZ-100 – Particle Size Analyzer

Dynamic light scattering (DLS) measures particle size (0.3 nm – 8 um) distribution and zeta potential of a colloidal suspension. The instrument utilizes a small volume of suspension and uses automatic titration for pH change, measuring the zeta potential change as it does so.

HIMaC² applications: Analyze stability of Pt/C and ionomer ink suspensions for making PEM fuel cells.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