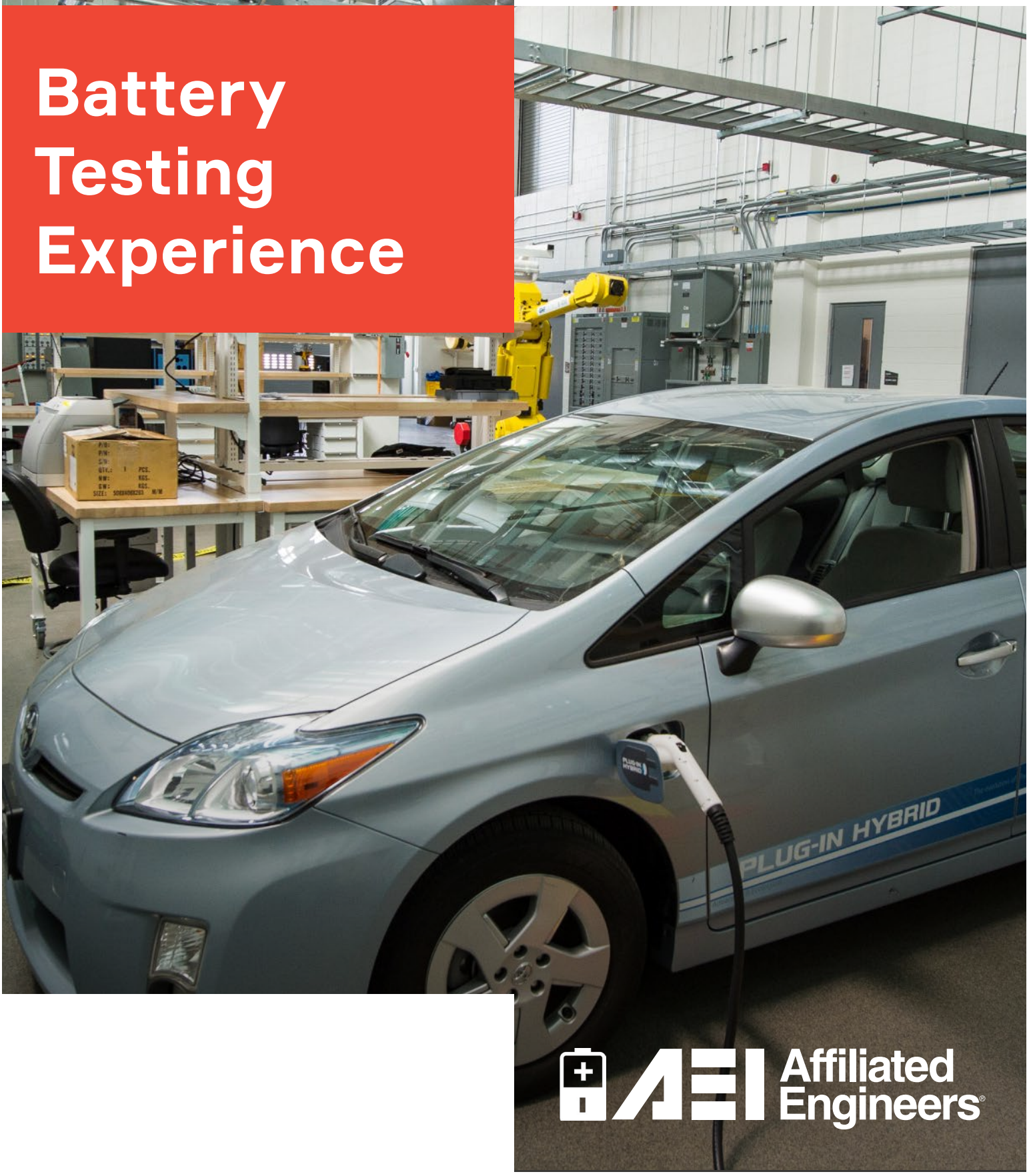
Battery Testing Experience



Affiliated Engineers®

Firm Profile

Affiliated Engineers, Inc. (AEI) is a leading US-based multidisciplinary consulting engineering firm that plans, designs, and delivers high performance engineered systems for technically complex building and utility infrastructure projects. AEI specializes in industrial, research, energy production and distribution, mission critical, healthcare, higher education, and sustainability markets. Building Design and Construction magazine ranks AEI the number one science and technology engineering firm.

AEI is made up of more than 800 individuals, working collaboratively across 19 office locations. They rely on one another's experience and expertise, sharing knowledge across markets, disciplines, and offices, so individual project innovations advance practices system-wide. AEI has built a reputation over the past 40+ years being an industry leading engineering firm that delivers leadership and innovative solutions for complex projects improving the world.

800+
employees

19
offices

Top 3
Science+Technology Laboratories Engineering Firm

14
Lab of the Year awards

RESEARCH LABORATORY AND BATTERY TEST FACILITIES EXPERIENCE

AEI's experience in Industrial Test Facilities ranges from 35,000 hp engines for Navy ships to fractional hp weed whackers, with a single commonality: ever shrinking measurement sensitivities. These testing facilities require reliable and repeatable data that involves meticulous planning from the ground up. Repeating a test is expensive in terms of energy and staff time and can delay a market launch. AEI routinely meets these measurement sensitivity challenges by first understanding the connectivity of systems and second by making design choices that result in ease of maintaining stable setpoints.

AEI has provided engineering and design services for a wide range of projects that include hybrid/battery electric vehicles, grid simulation/resiliency, and/or engine and vehicle emissions. The award winning Energy Systems Integration Facility, which is featured later in this brochure, houses more than 15 experimental laboratories and several outdoor test beds, including an interactive hardware-in-the-loop system that lets researchers and manufacturers demonstrate their products at full power and real grid load levels — up to one megawatt in scale.

AEI's experience in the esoteric aspects of battery testing allows for both an integrated design solution and a lean team. By way of its more than 5,000 automotive test cells AEI has been engineer of record for several industry firsts. In 2001 AEI integrated serial number 1 of battery emulator industry leader, Aerovironment, into Allison Transmission's Eagle Creek Test Center. In 2009, at the NREL ESIF project in Golden, Co, AEI co-authored the first DC Arc Flash study along with Dr. Ammermann University of Colorado, School of Mines. In addition to its automotive resume, AEI has also designed several directly relevant physical sciences laboratories. Pursuant to programmatic needs, AEI has been "climbing the DC voltage ladder" recently designing systems of 1000V, 1500V, and 3000-4000V for NREL, U of Arkansas, Raytheon Technologies, and Collins Aerospace.

Raytheon Technologies
High Power System Integration Lab

Windsor Locks, CT

Raytheon Technologies (formerly United Technologies Research Center (UTRC)) makes, models, powers, connects, and secures the next generation of Raytheon products in order to transform entire industries. UTRC operates as the innovation hub for technical interchange, as well as Raytheon's gateway to academic and government research.

Affiliated Engineers provided engineering design and construction support for a new High Power System Integration Lab. The team integrated Magna Power Supplies, Egston Emulators, and Systems Under Test, including:

- (4) 250 KW Power Supplies
- (4) 200 KW Egston Load Emulators
- (1) 1 MW Generator-Converter Under Test
- (1) 1 MW Motor Controller Under Test

The electrical team worked with UTRC and vendors to determine MEP facility connections and System Under Test connections. We researched and selected components for DC application, and we developed system diagrams, layouts, and specifications.

New HVAC was provided to deliver 68ºF, 35-45% RH laboratory environment. A new process chiller and dedicated control system is used to cool the System Under Test and Egston Emulators.

A safety PLC was provided as an added layer of protection for both people and equipment. The system interfaces with the test equipment, data acquisition system, ventilation system, access control, fire alarm system, and chilled water system.

AEI worked with UTRC Risk Assessment to develop a safety matrix that included breaker trips, breaker statuses, equipment faults, fire alarm, failure of stop sequence, contactor failures, stack removal of power, automatic grounding, hard stopping system, soft stopping system, and stack light indication. AEI's PLC design included detailed wiring schematics, panel layout with bill of materials, installation specifications, cable pull list, and selecting instrumentation.

Architectural and structural scope included reviewing sound level data of lab equipment and designing sound treatment for the Control Room. Design of a custom elevated access floor system to support the Power Supplies and Emulators with cable routing below. Analysis of existing building structure for support of new HVAC equipment.

Image courtesy of EGSTON Power

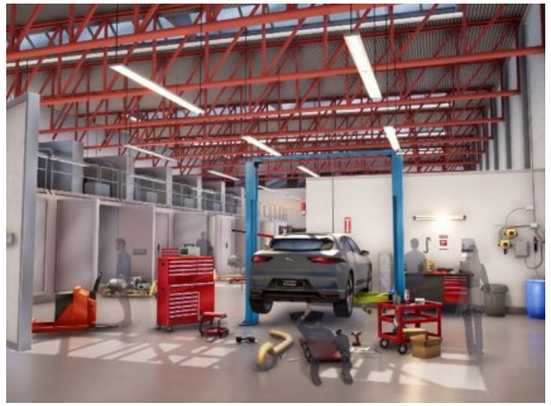
Intertek
Electric Vehicle Lab

Milton Keynes, Buckinghamshire, UK

Intertek is a multinational product testing, inspection, assurance, and certification company with over 1,000 locations, including large-scaled offices and testing facilities on multiple continents. To support growing test requirements, Intertek is building the European Centre of Excellence for electric vehicle and component testing in the UK. Phase 1 of the expansion features two 2-wheel-drive or one 4-wheel-drive full vehicle / chassis component hub dyno cell, a 27,000 rpm e-motor test cell, two 20,000 rpm e-motor test cells, three EV component test cells, and space for five more test cells in subsequent phases.

AEI was responsible for master planning, a Concept and Budget Report, and completion of an impact review of test equipment bids. Additionally, as principal designer, AEI provided designs for the following facility components and alterations:

- New 3MVA export-capable grid connection
- Planning & building Control
- Structural modifications
- Minimizing disruption to existing business on site
- Relocation of existing business functions to create space
- Power to new test equipment
- Lighting & low voltage power
- HVAC
- Fire alarm, suppression & interfaces to test cell safety systems
- 3 EV component test labs with test equipment consolidated from another site.



EV technology moves fast and the ability to pre-configure a new test cell off-site and swap it out with a minimum of disruption to the facility or current testing obligations was a huge driver. As such, Intertek selected a containerized solution for the majority of the test cells for flexibility. AEI worked with Intertek to evaluate the test cell proposals and establish the impact of each suppliers' proposal on the facility to ensure a fair comparison between the bids. Across the five containerized test cells Intertek have six 800A battery emulators and a battery cycler cell.

AEI have been the liaison between Intertek and the construction contractor to ensure the contractor fully appreciates the needs of the client and is providing quality workmanship and materials at the right price.

Confidential Client Transportation Electrification Laboratory

Midwest, US

Specializing in technical inspection services worldwide, including testing, auditing, certification, and consulting, this leading solutions provider was looking to expand its battery, electric vehicle, and component testing operations.

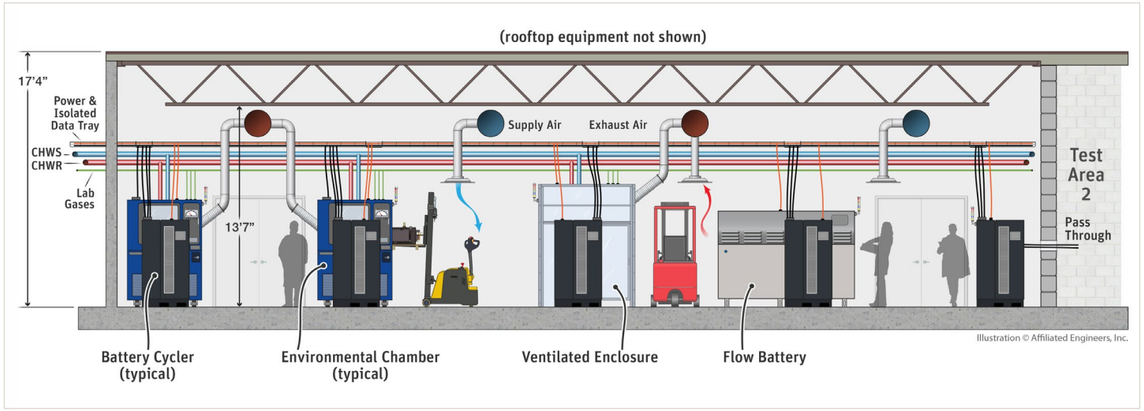
AEI was selected to provide mechanical, electrical, fire protection, process, and controls engineering services for the design of a new transportation electrification laboratory. Expanding operational capacity to meet increased automotive testing demand, the new lab — encompassing 7,400 square meters — incorporates a significant effluent remediation to optimize hazardous testing performance while ensuring the highest level of environmental and occupational safety.

A defining facility feature, dedicated bunkers were incorporated to provide adequate, environmentally-conscious space addressing the full spectrum of battery-related research and development — including performance, endurance, and safety. Focusing on battery performance and behavioral response, the electrification lab supports a comprehensive suite of abuse testing platforms, from thermal cycling, flammability, and voltage spikes to mechanical shock and vibration, corrosion, and dynamic impact. AEI's design emphasizes resiliency, ensuring the facility can withstand the often transient, extreme nature associated with battery testing.

In addition to the implementation of blast-resistant walls and ceilings in the battery abuse area, AEI conducted comprehensive hazard evaluation testing across all applicable spaces for chemical MAQs, battery off-gassing, blast hazards, and extreme room temperatures up to 1000° Fahrenheit.

To obtain regulatory data, AEI's process engineers calculated the burning battery's heat flux and off-gassing rate, using these values to specify a caustic scrubber. In conjunction with a scrubber manufacturer, the engineers were then able to calculate the cleaned effluent's emissions and issue all applicable data to the appropriate municipal entities, as well as the U.S. Environmental Protection Agency, for air permitting.

AEI also provided engineering design services for a central utilities plant encompassing process cooling water, compressed air, deionized water, and electrical distribution. The mechanical team strategically repurposed cooling towers and compressed air receivers from existing campus facilities, while the electrical team addressed client testing needs through collaboration with equipment suppliers, ultimately reducing overall electrical service from 20 MW to 4 MW.



Confidential Automotive Client Battery Cell Design and Manufacturing Lab

Midwest, US

A major automotive manufacturer is constructing a new 300,000 SF laboratory for battery cell innovation, prototype testing, and pilot manufacturing. AEI provided a conceptual study for the facility and is currently working on Construction Documents. The facility requires multiple clean rooms and zero-percent relative humidity areas. Due to the hazards of battery chemistry, many of the mechanical and electrical systems are redundant. AEI also assisted with site selection and cost estimating.

AEI is serving as the equipment integrator, assisting the client with selecting testing/manufacturing equipment and coordinating with the Design Team for facility and utility needs. And we are using our decades of automotive and testing experience to identify hazards and provide input to the Code Analysis.

The project is being procured as Design-Build with a compressed schedule. As such, AEI is providing multiple early-works design packages, including long-lead equipment, underground utilities, and a standalone central utility plant.

Confidential Automotive Client Outbound Charging

Midwest, US

A major automotive start-up continues to experience exponential growth, which has led to a desire to expand their Midwest plant. AEI was retained to provide MEP/I&C, Lighting, and Technology design services to allow for new open-air structures to house vehicle chargers and associated equipment. This 60,000 square foot charging facility is being phased with Phase I and Phase II being designed concurrently with separate drawing packages per phase.

In Phase I AEI designed a 16,000 square foot electric substation building and associated distribution, 20 charging stations, and the Electrical Stationary Storage (ESS) unit. AEI designed the facility using DC Fast Charging to optimize the charging abilities of outbound vehicles from 30% to 80%. Phase II consists of a 44,000 square foot charging facility with an additional 50 chargers.

Additionally, two new electrical substations will be built in a nearby 2,000 square foot building. The substations are required to power the outbound charging stations. And the project also includes solar panels on the roof structure and a 1MV ESS unit. AEI is coordinating a solar sizing analysis and a full solar array in the base scope.

Collins Aerospace Electric Propulsion Lab

Rockford, IL

Collins Aerospace is a global leader in aerospace solutions. To allow for substantial growth, Collins Aerospace is expanding their technological capabilities by introducing the most advanced electric propulsion lab, "The Grid". The Grid will be used to design and test motors, generators, motor controllers, aircraft cabling systems, and battery systems to revolutionized air travel. Generating hybrid-electric and fully electric aircrafts will help in preserving our planet and reducing our carbon footprint.

The Grid is a 25,000 square foot, 8MW lab containing sixteen 100 kW battery simulators and six electric regenerative dynamometer test stands. Each test stand contains two 1,500 hp dynamometers. The lab includes a DC Grid System allowing for DC electrical power to interconnect between lab equipment and equipment under test. The lab control area is 9,500 square feet and contains two control rooms, an assembly room, display area, pump room, and future power hardware-in-the-loop (HIL) room. Additionally, a 24,000 square foot equipment yard will contain substations, switchgear, battery enclosure, future turbo engine, and future fuel tank.

AEI's project scope included:

- Defining capacity and concepts of MEP utility systems that support test stand operation
- Coordinating new electrical service with utility
- Preparation of construction drawings and specifications
- Designing an emergency stop panel and system
- Design of utilities for a battery testing container
- Preparing test stand integration and commissioning documentation

Oak Ridge National Laboratory Translational Research Capability

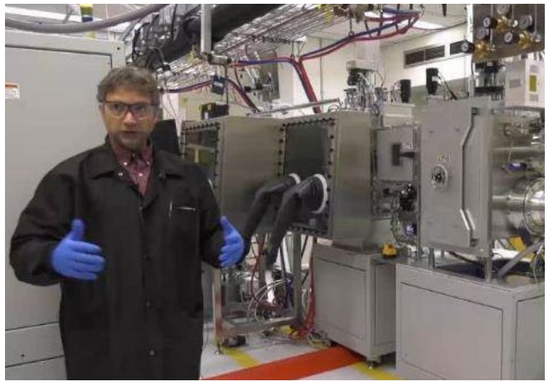
Oak Ridge, TN

The Oak Ridge National Laboratory (ORNL) is the US Department of Energy's largest science and energy laboratory. As an international leader in a range of scientific areas, ORNL has six major mission roles: neutron science, energy, high-performance computing, systems biology, materials science at the nanoscale, and national security.

The Translational Research Capability (TRC) will be a purpose-built building dedicated for world-leading research in batteries, computing and materials science, with the sole intent in serving to advance the science and engineering department.

This two-story, 97,793 square foot research facility will be located within a central campus. This building will accommodate an array of spaces including lithium ion battery labs, sensitive equipment labs, high bay labs and heavy equipment labs. Within these laboratory spaces include: a suite of battery testing labs including thermal battery cycling, lithium ion deposition, spectroscopy, ceramic processing and a lithium dry room; corrosion laboratories including liquid metals/molten salts; materials testing labs, including servo-hydraulic cyclers, electro-mechanical and dead weight testing; lastly, a sensitive equipment laboratory with critical vibration and EMI requirements for laser optics and STM (scanning tunneling microscope) and dilution refrigerators. The new laboratories will provide noise isolation, electromagnetic shielding, and low vibration environments required for multidisciplinary research in quantum information science.

AEI is designing and implementing a sensitive laser (optics) lab HVAC system featuring HEPA filtration and .5C temperature tolerance.



The Inert Environment Laboratory features an extremely dry Dry Room (-64F dewpoint) and adjacent vestibule will be served by one custom air handling unit with a factory fabricated custom desiccant unit to pre-condition make-up air from the laboratory air system.

3D modeling and visualization with BIM allows AEI to enhance project coordination resulting in minimal change orders due to field rework and overall coordinated productivity. Non-traditional AEI services include process integration of test and PLC safety interlocks. The facility is being designed per FEMP (Federal Energy Management Program) Guidelines, to exceed ASHRAE 2013 energy efficiency standards by at least 30%.

Spaces at ORNL include:

- Sample Prep/Ceramic Processing Lab
- Organics/Polymers Lab
- Thin Film Deposition Lab (in glove boxes)
- Spectroscopy
- Battery Cycling/Electro-Chemical Cycling (in environmental chambers)
- Dry room suite including:
  - Mechanical testing of lithium & ceramics,
  - Electrode manufacturing
  - Consolidation and hot pressing
  - Slurry processing (Turbula mixing machines)
  - Calendering
  - Stores: foils, salts, binders, solvents

Tesla, Inc. Multiple Projects

Fremont, CA

Tesla's mission is to accelerate the world's transition to sustainable energy. This innovative company was founded in 2003 by a group of engineers in Silicon Valley who wanted to prove that electric cars could be better than gasoline-powered cars.

AEI provided MEP design services for the new Model 3 General Assembly Line at Tesla's Fremont campus. The General Assembly areas include:

- Distribution to Trim & Final Assembly Conveyor, Phase I (future)
- Distribution to Trim & Final Assembly Conveyor, Phase II (future)
- Paint Conveyor Tunnel
- Trim Line, Phase I
- Trim Line, Phase II (future)
- Building Expansion, Phase I
- Building Expansion, Phase II (future)
- Trim to final Assembly Conveyor
- Final Assembly Line Phase I
- Final Assembly Line Phase II (future)
- General Assembly Electrical Substation

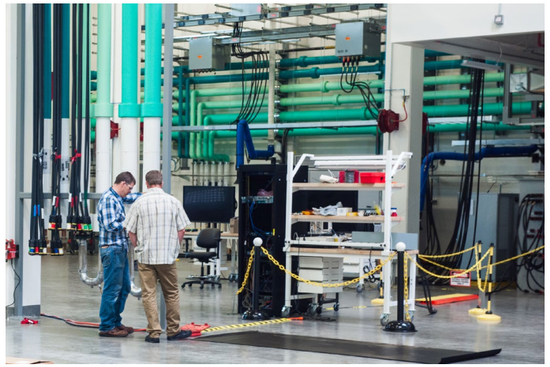
The project scope for the aforementioned areas includes 30,000 sf of new building expansion and approximately 500,000 sf of renovated and repurposed factory area. The scope includes: demolishing existing structures, decommissioning the equipment; new foundations and pits for equipment; new structural steel supports, including columns and trusses and lateral supports, modification of existing structural steel supports, including columns and trusses and lateral supports; new building envelope for building expansion; modification of existing building envelope, including wall panels, roof and openings; new building utilities, mechanical, electrical, and plumbing, fire suppression and fire alarm; modification of existing utilities; new equipment utilities, including compressed dry air (CDA), and medium voltage electrical substation and distribution system.

US Department of Energy
Energy Systems Integration Facility

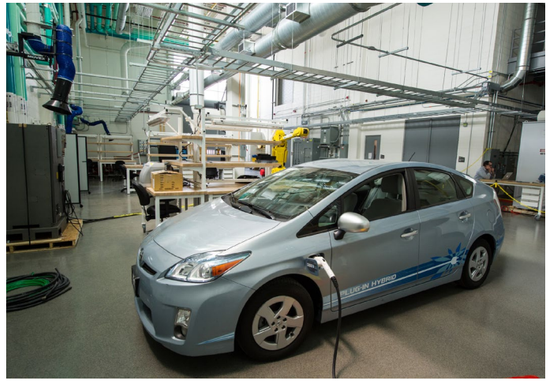
Golden, CO

The U.S. Department of Energy's new Energy Systems Integration Facility (ESIF), located at the National Renewable Energy Laboratory in Colorado, is the Golden Field Office of Energy Efficiency and Renewable Energy's signature building for energy technology integration research and engineering. Winner of R&D Magazine's 2014 Laboratory of the Year Award, ESIF is a high visibility project of national scope.

The 182,500 square foot building provides laboratory and research space for 200 scientists and staff working on promising clean energy technologies and testing their interaction with each other and the grid. ESIF houses more than 15 experimental laboratories and several outdoor test beds, including an interactive hardware-in-the-loop system that lets researchers and manufacturers demonstrate their products at full power and real grid load levels — up to one megawatt in scale.



The laboratory infrastructure and safety systems provide for the capability of battery testing and integration related to microgrid development, grid energy storage, and electric vehicle integration. Battery systems and their associated power electronics can be configured in a modular format as experiments require. Battery cooling and protection is supported by facility process cooling water and appropriate battery containment enclosures. With the use of battery charge/discharge converters/ cyclers, the batteries under test are able to be put through their paces to validate system capability and batter management systems. For prototype battery systems, the Electrical Characterization Laboratory within ESIF provides a reinforced test room where potential battery failure events can be properly contained while maintaining safety of the facility and



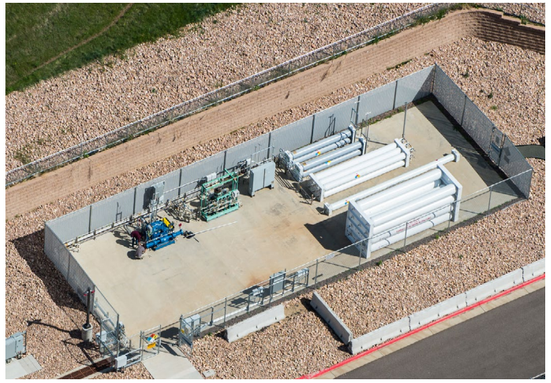
personnel working therein. Additional safety systems of gas detection and fire protection are included within these spaces for detection and removal of potential battery off gassing and battery fires.

Specific areas of research include:

- Smart grids, microgrids, power electronics.
- Solar: interconnection, inverter testing, parabolic solar concentrators, building integration, and system optimization.
- Wind: models, generation, and grid interaction, electrical grid analysis.
- Energy storage: electrical, mechanical, and thermal.
- Vehicles: grid connected plug-in and vehicle-to-grid electrical integration, battery thermal management, and power electronics.
- Buildings: sensors and controls, systems integration, modeling, and Zero Energy Building simulation.
- Hydrogen: electrical interfaces, electrolyzers, storage, quality standards, fueling systems, fuel cell integration.
- Biofuels: generator sets and engines.
- Microturbines.

As a member of a design-build team, AEI provided MEP/FP/I&C/IT, utility infrastructure, and sustainability design services, including the design of a 88,100 square foot high bay lab. The high bay lab is heated using waste heat from the building's 10,000 square foot data center. AEI's work included:

- Research Electrical Distribution Bus (REDB): A first-of-its-kind, the REBD is a power integration circuit made up of four AC and four DC ring buses that interconnects testing components across the building's 15 laboratories. Researchers can test new energy technologies on real and simulated power systems.
- Supervisory Control and Data Acquisition (SCADA) System: Integrated throughout the facility, the SCADA monitors and controls the REDB operations and gathers real-time, high-resolution data for collaboration and visualization. The SCADA also monitors SIL-2 (Safety Integrity Level) rated laboratory PLCs providing emergency stop functionality, gas detection, alarming (horns and lights), and other required safety measures. These systems are all interconnected with the fire alarm, building automation system, and local lab equipment to provide a seamless facility response across systems to various conditions.
- Hydrogen storage and distribution system: Piping, regulation, tank specification and controls for hydrogen generation (electrolyzers), compression, storage (15,000 psig), and distribution to fueling station, test laboratory (3,000 psig) and facility house hydrogen (200 psig).



A state-of-the-art high performance, 10MW computing data center supports improved and expanded capabilities in modeling and simulation of renewable energy and energy efficient technologies. In addition to the research spaces, the facility includes offices and shared common space for a minimum of 200 staff. Conference rooms, visualization centers, interaction areas, and guest offices facilitate collaboration among private, academic, and public sector partners.

The building achieved LEED Platinum certification and is 40% more energy efficient than the baseline ASHRAE/IESNA building performance rating.

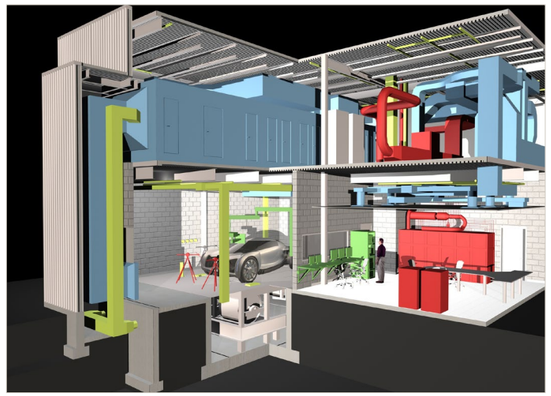
Argonne National Laboratory
4WD Hybrid Drivetrain Test Facility

Lemont, IL

The U.S. Department of Energy's Argonne National Laboratory helps make advanced vehicles a reality. Argonne's research includes alternative fuels, engines and emissions control, fuel cells, and hybrid vehicles. Argonne enlisted AEI's services in designing a new 6,500 sf four-wheel drive chassis dynamometer test cell facility - the only such facility in the U.S. - to further enhance its research capabilities. This facility conducts emission and energy efficiency tests on electric vehicles, hybrid electric vehicles, sport utility vehicles, and advanced technology vehicles.

AEI's services culminated in the preparation of construction documents for this new facility, which integrated the laboratory's process equipment components:

- Systems for high-speed combustion fuel testing using flame ionization detector FID, chemiluminescence detector (CLD), and non-dispersive infra-red (NDIR) techniques
- Constant volume system prime mover and controls
- Particulate bench
- Dilute emissions bench
- Front and rear dynamometer computers and 15-inch monitors
- File Transfer Protocol (FTP) computer for enhanced data integration capabilities
- Standardized 19-inch rack mounts for electronic modules
- Argonne National Laboratory's PC towers



AEI also provided infrastructure design services for the process equipment's space, telecommunication, and utility feeds; supplied bottled gas distribution documents; and assisted Argonne in determining the optimal process equipment layout.

Specialized MEP infrastructure in the facility included:

- Air handling equipment, including desiccant conditional dilution air to enable precise measurements for super ultra-low emissions vehicles
- Regenerative AC dynamometer drive cabinets, which were isolated to negate harmonic distortion for the facility's advanced testing equipment
- Ram air distribution to address undercarriage cooling requirements of advanced/hybrid vehicles

Under a second contract, Argonne retained AEI's services to provide construction administration support. In this role, AEI provided daily contact for document and field questions, reviewed shop drawings, made field visits, provided witness testing, and attended progress meetings.

General Motors
Estes Alternative Energy Center and Battery Lab

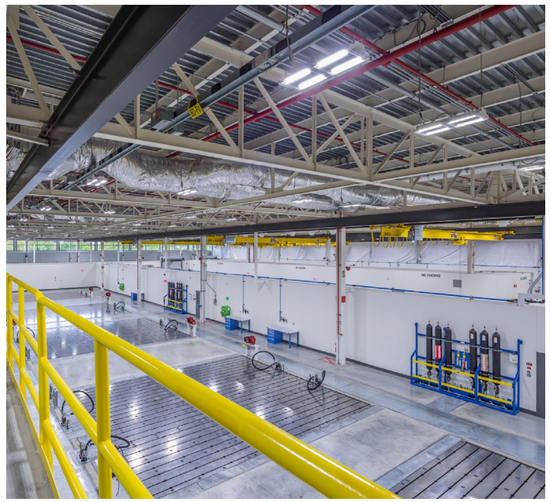
Warren, MI

AEI completed MEP/FP/T/I&C construction documents for an addition to the Estes Alternative Energy Center at General Motors' Global Technical Center. The client constructed a 138,000 square foot vehicle chassis test lab addition to an existing building, with associated site work and interface tie-ins to the existing building and surrounding site.

Utility upgrades for the Battery Lab were also required. AEI developed a substation procurement package, a medium voltage cable pull package, manhole additions, and "make-clear" drawings for substation installation inside of an existing mezzanine.

In addition to engineering design consulting services, AEI provided test programming services for this 2,200 GPM servo-hydraulic test facility. Services included delineation of a large central hydraulic pump room, distribution piping and trenches, power, compressed air, process data acquisition instrumentation, and emergency stop process controls. Trench design required careful coordination due to the size of the hydraulic system and associated devices: accumulators, bend radii, isolation valves, servo-valves, and drain back lines/sumps.

Beyond the process coordination, the facility design presented two additional challenges: 1) planning a large addition with extensive existing underground utilities, and 2) maintaining the exterior aesthetic of the historically significant, AIA award-winning campus design.



Additional design and programming considerations included:

- Because the lab is used for vibration testing with hydraulic actuation to failure, AEI specified safeties in the event of hydraulic rupture and atomization.
- Calculating the heat load to determine the size of the HVAC system necessary to cool hot engine exhaust systems and open-flame natural gas burners presented a unique challenge.
- A new cold well was designed to intercept and pump water from a remote cooling tower. The water must be pumped overhead rather than running through aging underground pipes in an area that will be near the vibration testing system. Additionally, AEI's design provides for year-round chilled water capability that does not currently exist.
- The test lab will require 10 MW of substation capacity to support hydraulics and other equipment. This represents nearly an eighth of the power used for the entire campus.
- Most of the electrical distribution within the lab will be underground, requiring coordination with hydraulic spacing and deep inertia masses.

California Air Resources Board (CARB) Southern California Consolidation Project

Riverside, CA

Consolidating five existing locations, the new home of the California Air Resource Board (CARB) will be one of the largest and most advanced vehicle emissions testing and research facilities in the world – as well as the world's largest zero net energy (ZNE) laboratory. The nature of CARB's research mission, regulating as-yet unregulated emissions constituents, demands high-performance precision laboratory environments to produce repeatable data and meet ZNE.

Housing more than 400 employees near the University of California, Riverside campus, the design-build project will provide advanced chemistry laboratories, a range of dedicated vehicle test cells, workspace for accommodating new test methods for future generations of vehicles, space for developing enhanced onboard diagnostics and portable emissions measurement systems, and public areas. Awarded through design competition, the project team used AEI-developed performance modeling tools for rapid system concept testing, validating a suite of climate-responsive systems strategies improving on the project's required energy use intensity (EUI) by an additional 20%.

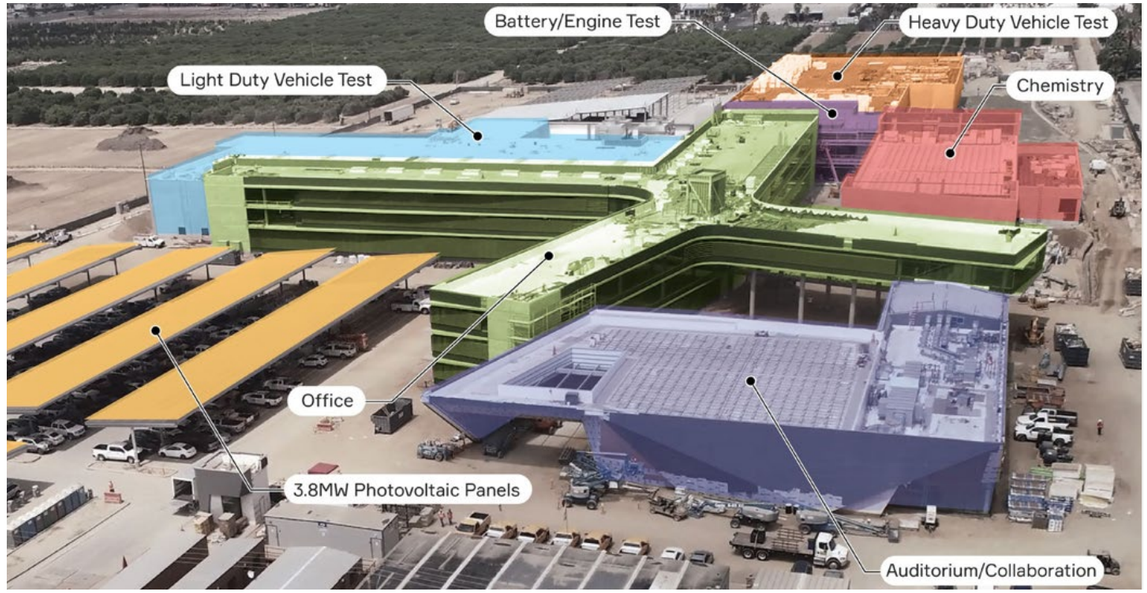
The building's energy use will be offset by 3.8 MW of photovoltaic (PV) panels on site. 1.5 MWh of battery storage will optimize utility costs under a net-metering agreement.

A comprehensive approach to water conservation, collection, and reuse will contribute to a nearly 50% reduction in required potable water use. The new facility and 19-acre CARB campus will be designed and built targeting the highest possible levels of measured sustainability, with the intention to achieve LEED Platinum certification and meet California's CALGreen Tier 2 threshold for overall sustainability and energy efficiency.

AEI is integrating battery systems on three levels:

1. This $368M, research and development center will be the largest ZNE laboratory in the world. A key ingredient to achieving ZNE is integration of over 3.8MW of PV panels with a 750kw/1.5mwh battery. In addition, the project incorporates over 100 vehicle charging stations.
2. At the testing level, batteries are the new frontier of emissions validation. State of Charge (SoC) monitoring and measurement as well as battery emulators and charging stations are part of the 16-vehicle chassis dynamometer test cells.
3. Similar capabilities exist at three engine test cells: two 600 kw Heavy Duty (one with a battery emulator and powerpack with integrated battery) and one Small Off-Road Engines (SORE) test cell (with three test beds ranging from weed eaters to 75kw).

The engine cell will incorporate battery containment testing. The European Council for Automotive R&D (EUCAR) has become the global benchmark for classifying the hazard level associated with Li-ion battery testing. EUCAR levels and associated concepts shown on the next page.



External Influences Such as:

- External heating
- Overcharging
- Deep discharge
- Excessive charging current
- External short-circuit

Internal Events Such as:

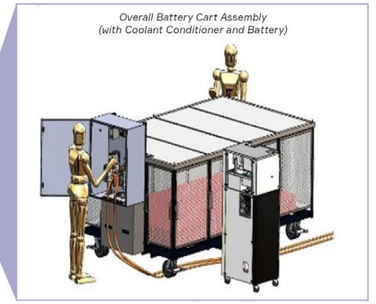
- Electrode-electrolyte reactions
- Electrochemical reactions

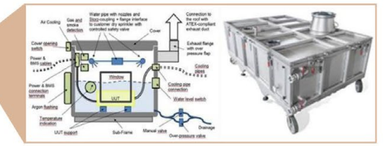
Impacts on the lithium battery

Hazard Level	Description	Classification Criteria & Effect
0	No effect	No effect. No loss of functionality.
1	Passive protection activated	No defect; no leakage; no venting, fire or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell reversibly damaged. Repair or protection device needed.
2	Defect/Damage	No leakage; no venting, fire or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell irreversibly damaged. Repair needed.
3	Leakage Δ mass < 50%	No venting, fire or flame; no rupture; no explosion. Weight loss < 50% of electrolyte weight (electrolyte = solvent + Salt).
4	Venting Δ mass ≥ 50%	No fire or flame; no rupture; no explosion. Weight loss ≥ 50% of electrolyte weight (electrolyte = solvent + Salt).
5	Fire or Flame	No rupture, no explosions (i.e. no flying parts).
6	Rupture	No Explosion, but flying parts of the active mass.
7	Explosion	Explosion (i.e. disintegration of the cell).

Source: EUCAR: European Council for Automotive R&D

Overall Battery Cart Assembly (with Coolant Conditioner and Battery)

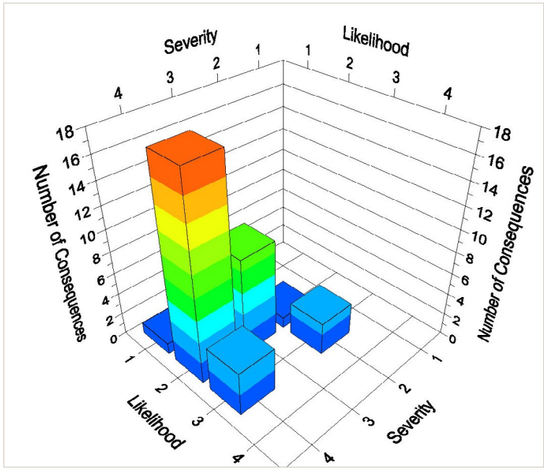




Hazard Analysis and Safety Engineering

With respect to hazards, AEI has extensive experience with codes and standards (NFPA 855, 68, 69, 70E, etc.), guidelines, Factory Mutual data sheets, insurance carriers, and our clients' EH&S groups. Our capabilities are listed below:

- Process Hazards Analysis:
  - PHA, HAZOP, FMEA, LOPA, Dust
  - PHA-Pro Software
- Hazardous Material Handling & Mitigation (Gases, Liquids & Dusts)
- Explosion Relief and Prevention



- Specification of Flairs, Thermal Oxidizers, and Scrubbers
- Safe Operating Procedures (SOP)
- E-Stop Matrices
- Code Studies
- Fuel and Oxidizer Storage, Distribution & Dispensing
  - Hydrogen, Methane, Propane, Acetylene, Dimethyl-Ether, Ethyl Alcohol, RP-1, HTP, Gasoline, Diesel, Methanol, Naphtha, etc.
- Relief Header/Valve Design

Electric Vehicle, Hybrid & Alternative Fuels Project Experience

1992
University of Wisconsin Milwaukee
Alternative Fuels Emissions Test Laboratory

1994
Ford Research Innovation Center
Alternative Fuel Research

1999
Argonne National Lab
Hybrid Driveline Test

2001
Allison Transmission
Hybrid Driveline Test

2006
Modine Purified Hydrogen
Alternative Fuels

2006
Stony Brook University
Advanced Energy Research & Technology Center

2008
Cummins TechnicaCenter
Hybrid Driveline Test

2009
NREL ESIF
Hybrid & Alternative Fuels

2009
Wisconsin Energy Institute
National Bioenergy Research Center

2010
Purdue University
Hybrid & Alternative Fuels

2012
Cummins Darlington TC12
Alternative Fuels

2015
JLR WLTP Soak Upgrade
Hybrid & EV

2015
JLR Battery Facility SoR
Hybrid & EV

1992 1993 1994 **1995** 1996 1997 1998 1999 **2000** 2001 2002 2003 2004 **2005** 2006 2007 2008 2009

2013
Cummins Darlington TC1-11
Alternative Fuels

2014
JLR Transmission Cells 1-3
Hybrid Driveline Test

2014
NASA Launch Pad Hydrogen Vent
Alternative Fuels

2016
JLR Hybrid Components Test Facility
Hybrid & EV

2016
JLR Hybrid Component Cell
Hybrid & EV

2016
Tesla
Model 3 Production Facility

2016
MercedesBenz
Autonomous Driving Lab

2017
Intertek
Confidential

2017
Mercedes AMG HPP F1
Confidential

2017
WMG VLRNIC
Hybrid Driveline Test

2018
CARB New Test Facility
Hybrid Driveline Test

2018
Collins Aerospace
Electric Propulsion Lab

2018
GM Technical Center
EEC Battery Lab

2018
Cummins
Hybrid Driveline Cell

2018
Generac ACT Cells
Hybrid Power Systems for Homes

2019
Cambustion
E-Device Test Cell

2019
Intertek
Back-to-Back Rig

2019
Cummins
Fuel Cell Lab

2019
Cummins
Fuel Cell Test Cell

2019
Cummins
Fuel Cell Test Lab

2020
Intertek
EV Lab

2020
Oak Ridge National Lab
National Transportation Research Center

2020
Purdue University
Alternative Fuel Test

2021
General Motors
Confidential

2021
General Motors
Confidential

2021
General Motors
Confidential

2021
Cummins
Confidential

2021
Caterpillar
Confidential

2021
Aramco
Confidential

2021
Changan UK
Confidential

2021
Rivian
Confidential

2021
TÜV SÜD
Confidential

2010 2011 2012 2013 2014 **2015** 2016 2017 2018 2019 **2020** 2021

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