

Hydrogen Fuel Experience

Hydrogen H_2

H_2 HYDROGEN POWER
CLEAN ENERGY OF THE FUTURE



Firm Profile

Affiliated Engineers, Inc. (AEI) is a leading 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 a reputation, built over the past 40+ years, as an industry-leading engineering firm that delivers leadership and innovative solutions for complex projects improving the world.

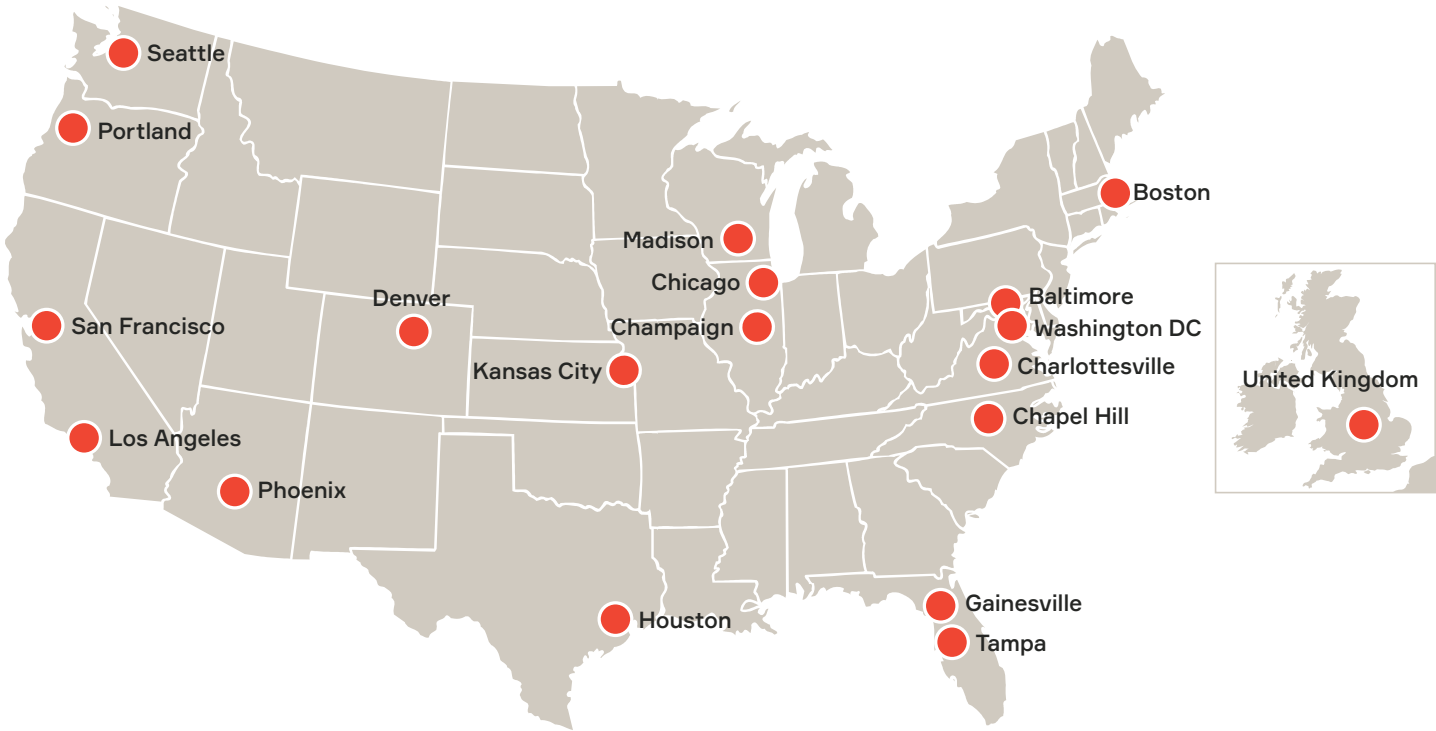


800+
employees

19
offices

1978
year Affiliated Engineers
was founded

Office Locations



Services

- Consulting & Leadership
- Planning
- Commissioning
- Mechanical
- Electrical
- Piping/Plumbing
- Fire Protection
- Building Performance Practice
- Instrumentation & Controls
- Process Engineering
- Technology Consulting & Design
- Security Consulting & Design
- Pivotal Lighting Design
- Cost Estimating
- Intelligent Buildings
- Geothermal Heating & Cooling

Markets

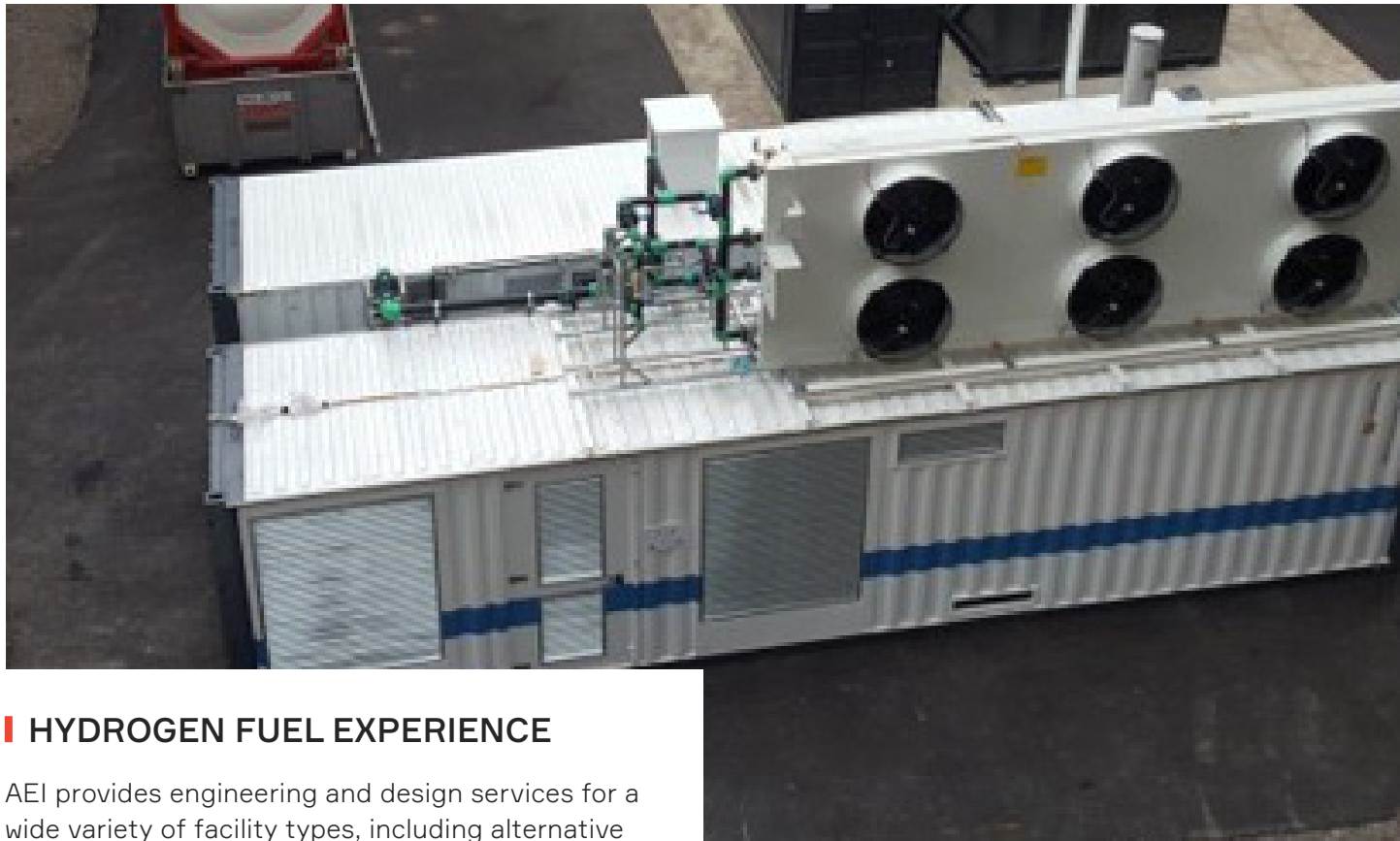
- Science & Technology
- Healthcare
- Energy & Utilities
- Commissioning
- Mission Critical
- Industrial Test
- Process Industries
- Higher Education
- Aerospace
- Aviation
- Federal Government
- Sports & Athletic Centers
- Cultural & Public
- Commercial/Office

#1 | Science+Technology
Laboratories Engineering Firm, 2019 & 2020
Building Design+Construction

TOP 10 | MEP Giants, 2021
Consulting - Specifying Engineer

14 | Lab of the Year awards
R&D Magazine

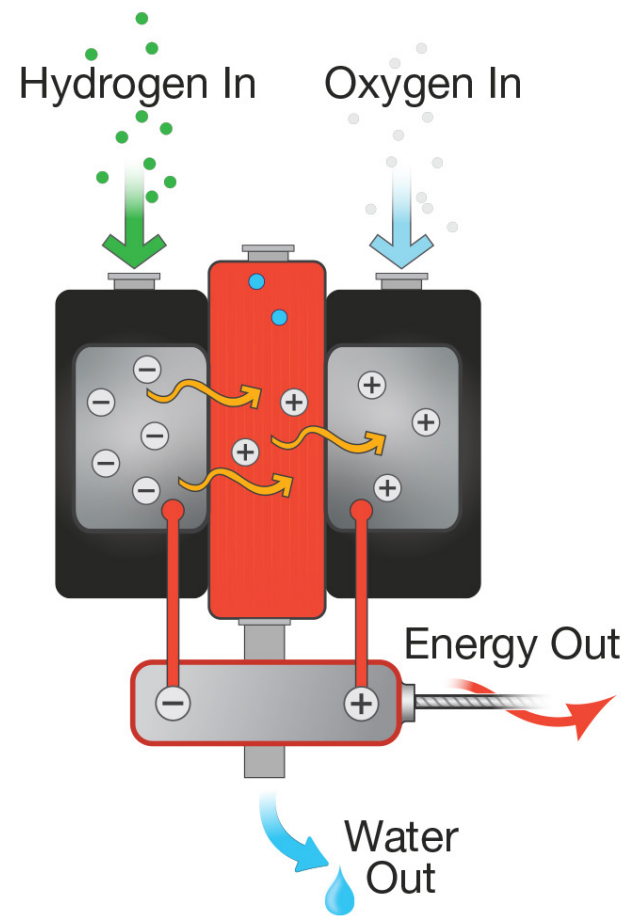
Multi-discipline consulting firm providing innovative solutions for technically-complex projects worldwide.



HYDROGEN FUEL EXPERIENCE

AEI provides engineering and design services for a wide variety of facility types, including alternative fuels, altitude test labs, containerized test cells, hydrogen test facilities, thermal chambers, climactic wind tunnels, and more. Specific to hydrogen management and safety, AEI's extensive experience and expertise encompasses fuel cells, internal combustion engines with hydrogen, and utility-grade combustion turbines burning hydrogen — from liquid hydrogen to 15,000 psi gaseous.

AEI performs in-depth feasibility studies to determine budget costs as well as identify and mitigate the potential risks associated with converting existing Internal Combustion Engine (ICE) test cells into hydrogen fuel cell testing facilities — a conversion that requires a deep understanding of relevant market conditions, mechanical and electrical components, logistics, battery management, and safety control. When converting existing test facilities into dual-purpose, AEI provides sound guidance and quality assurance, from interpreting applicable local legislation codes and best practices for implementation to maximizing design versatility for optimal site and infrastructure utilization. AEI helps our clients select and deploy the proper equipment, minimize scope gaps, and ensure total project success.



Test Facility Types

- Aerospace
- Alternative Fuels
- Altitude Test Labs
- Anechoic/Pass-by
- Aviation
- Containerized Test Cells
- EMI/EMC Test Chambers
- End-of-Line Production Test Cells
- Hybrid/Battery Drivetrain Labs
- Hydrogen Test Facilities
- NVH/Servo-hydraulic Test Labs
- Test Tracks
- Thermal Chambers
- Engine & Chassis Test Cells
- Emissions Test Facilities
- SCO3 Test Cells
- Climactic Wind Tunnels

US DEPARTMENT OF ENERGY

Energy Systems Integration Facility

Golden, Colorado

- Hydrogen storage and distribution system: piping, regulation, tank specification and controls for hydrogen generation, compression, storage (15,000 psig), and distribution to fueling station, test laboratory (3,000 psig) and facility house hydrogen (200 psig)
- Designed safety systems at hydrogen tank pad
- Executed PHA integrating hydrogen research with research electrical systems—AC and DC
- Performed CFD analysis at electrolyzers to model various leakage scenarios
- Designed “in flute” ventilation system to scavenge pockets at inverted Tee structural ribs to minimize likelihood of a lower explosive limit (LEL) concentration of hydrogen gas in the beam pocket
- Participated in commissioning, DOE Tiger reviews, training and approximately 20 future infill projects since beneficial occupancy in 2014

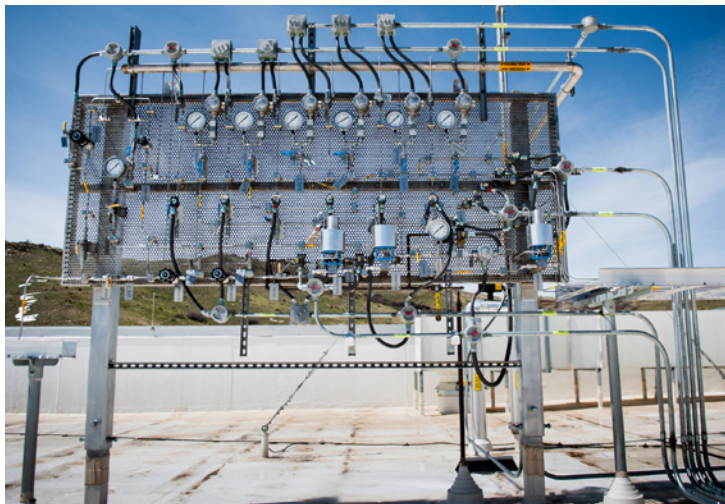


CUMMINS, INC

Sacramento Fuel Cell Laboratory

Sacramento, California

- Designed fuel cell test room, including hydrogen measurement, fuel conditioning system, and E-storage designed battery enclosure
- Also included ventilation, cooling water, and thermal runaway fire suppression system, and hydrogen gas storage, 2400 psi, cell ventilation system to ensure room stays below lower explosive limit
- Fire protection system included containment safety systems, including gas detection, flame detection, and scavenge exhaust



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LH2 Separator Installation, Launch Pad 39B

Kennedy Space Center, Florida

- Demo existing LH2/GH2 cross-country piping
- 60,000 gal. LH2 (-423°F) liquid separator
- Deluge fire protection at LH2 tank
- Integration with campus fire alarm
- Explosion-proof and marine wiring
- Integration with existing flare stack
- Heat exchanger for Helium (-452°F) refrigeration system inside the LH2 storage sphere
- Connect to campus compressed air for actuation



CATERPILLAR INC.

Mossville Bulk Hydrogen System

Mossville, Illinois

- Selected and specified liquid hydrogen storage tank
- Selected and specified hydrogen vaporizers
- Designed recapture system for liquid hydrogen tank vent hydrogen recapture system
- Designed safety systems at hydrogen tank pad
- Designed hydrogen distribution piping system
- Performed code analysis related to tank siting, setback, venting, and delivery truck access



CONFIDENTIAL CLIENT

Hydrogen Chassis Test Cell Study

United States

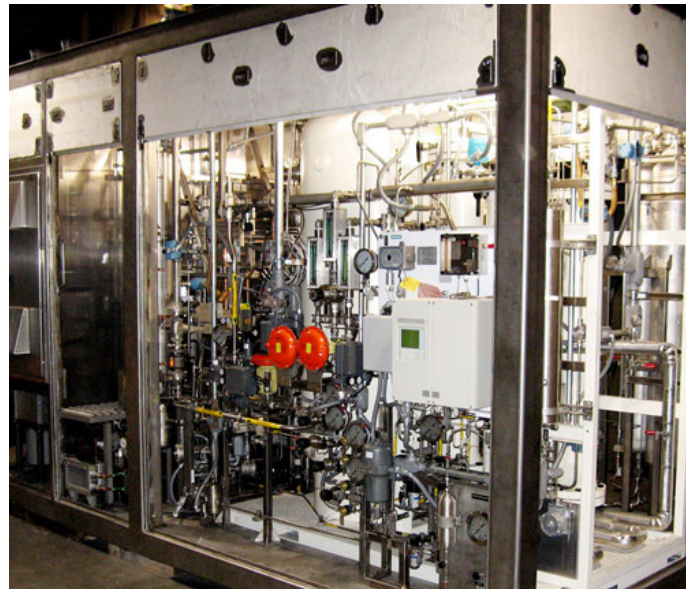
- Existing climatic (-30°C) chassis test cell (Class 8 truck) and wind tunnel
- Desire to have 350 bar (5,000 psi) GH2 brought into the test cell in the truck's fuel tank
- Analyzed safety systems required for safe operation
- Worked with Global Risk insurance to validate design

MILLIPORESIGMA

Hydrogen Flow Control Station

Madison, Wisconsin

- Provided turnkey delivery of FDA 21CFR Part 11 compliant hydrogen control station
- Designed systems for controlling and metering flow, pressure, and temperature of high purity hydrogen gas
- Hydrogen systems utilized to a process vessel configured for the manufacturing of active pharmaceutical ingredients



MODINE MANUFACTURING COMPANY

Purified Hydrogen & Generator Design

Racine, Wisconsin

- Planning, fabrication, and implementation of purified hydrogen generator
- Class 1/Division 1 design
- Passed CSA audit for complete safety compliance with all codes and regulations

NATIONAL RENEWABLE ENERGY LABORATORY

Field Test Laboratory Building Microbial Energetics Lab

Golden, Colorado

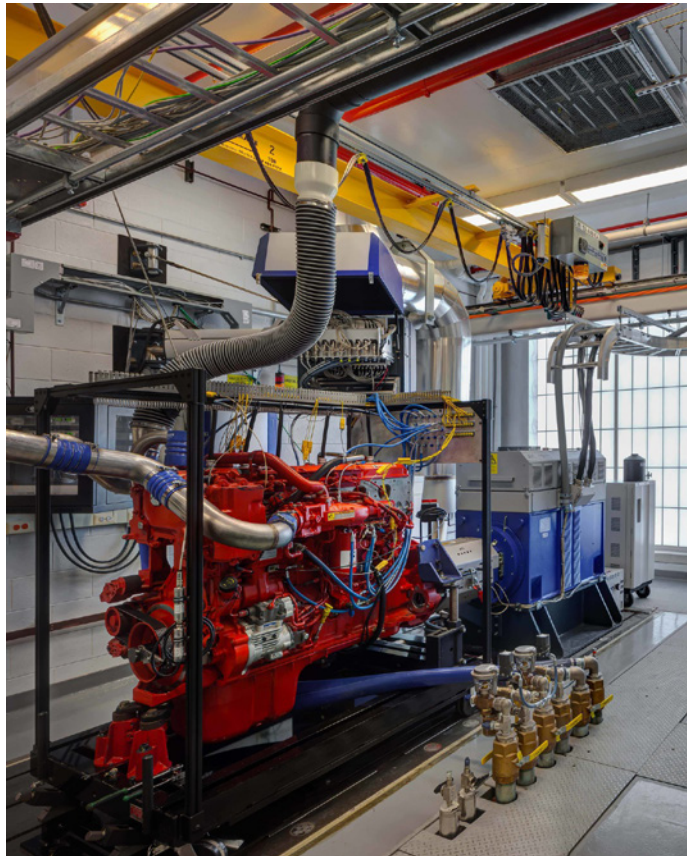
- Piped laboratory gases from tanks & centralized gas cylinder room (O2, CO, H2, Argon, inert gas)
- Renovation includes: centrifuge, autoclave, glass wash, undercabinet refrigerator/freezer, chemical cabinets, wet bench prep, anaerobic glove chambers, several 6-foot and 5-foot chemical fume hoods, and a dedicated laser table



CONFIDENTIAL CLIENT
High Pressure Hydrogen Test Cell (ICE)

Novi, Michigan

- 3,500 gallon LH2 storage tank and vaporizer
- Compression, storage, and distribution of GH2 at 15,000 psi
- Performed safety study to locate LH2 and GH2 storage based on building codes, NFPA, FM Global data sheets, and the client's insurance provider's requirements
- Designed pressure regulation, valving, flow measurement, venting, and nitrogen purging of exterior systems and five interior engine test cells
- Power, grounding, controls, and lighting at exterior storage area
- Retrofit existing air handlers to ensure safe operation and guarantee a non-flammable test cell environment



**CALIFORNIA DEPARTMENT OF
GENERAL SERVICES**

Air Resources Board Southern
California Consolidation

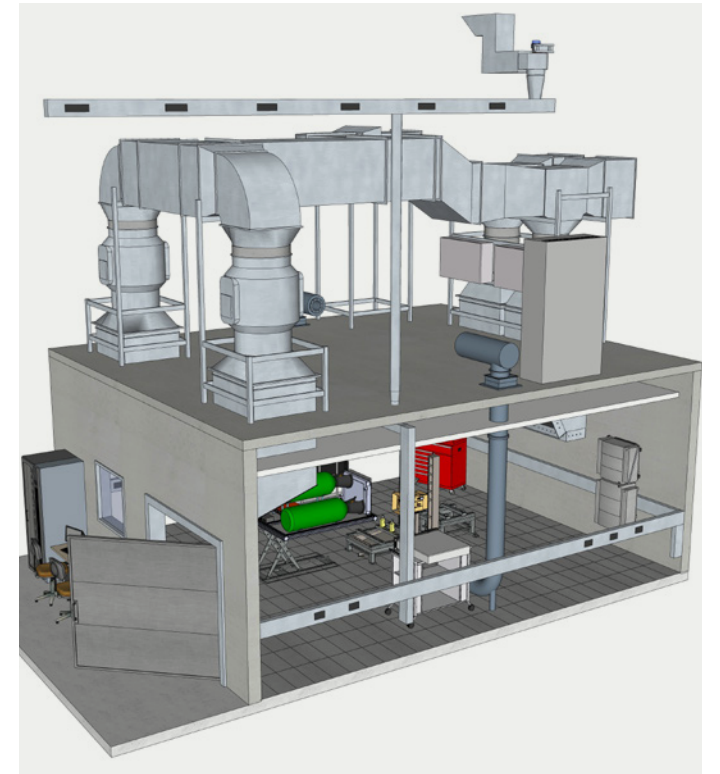
Riverside, California

- 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
- 99.9999% ("six nine") purity hydrogen distribution in Chemistry Lab
- Facility is prepared for future addition of steam methane reformer (SMR) hydrogen fuel cell and internal combustion of hydrogen
- Zero net energy (ZNE) facility. Building energy consumption is offset by 3.8 MW of photovoltaic (PV) panels on site.
- 1.5 MWh battery energy storage system (BESS) is used to optimize grid power consumption

CHANGAN UK R&D CENTRE LIMITED
Hydrogen Fuel Cell CBR

Birmingham, United Kingdom

- Client requirements developed to technical specifications
- Collation and reporting of requirements
- Hydrogen molecule supplier evaluation
- Hydrogen storage & delivery
- Hydrogen distribution
- In-cell hydrogen distribution
- Modifications to existing ventilation, purge, controls, E-stop, electrical, dyno re-purposing, fire detection/suppression, and building construction to remove potential pockets of escaped hydrogen
- Deflagration overpressure mitigation



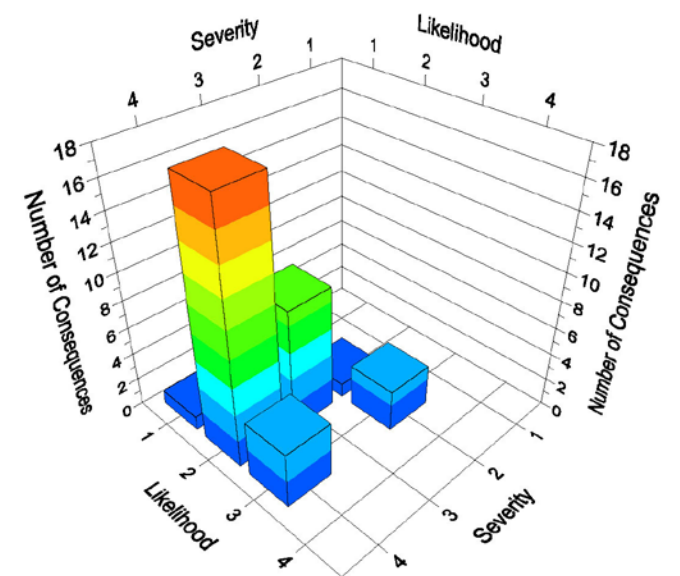
Strategic Planning + Innovative Design + Proven Performance

HAZARD ANALYSIS AND SAFETY ENGINEERING

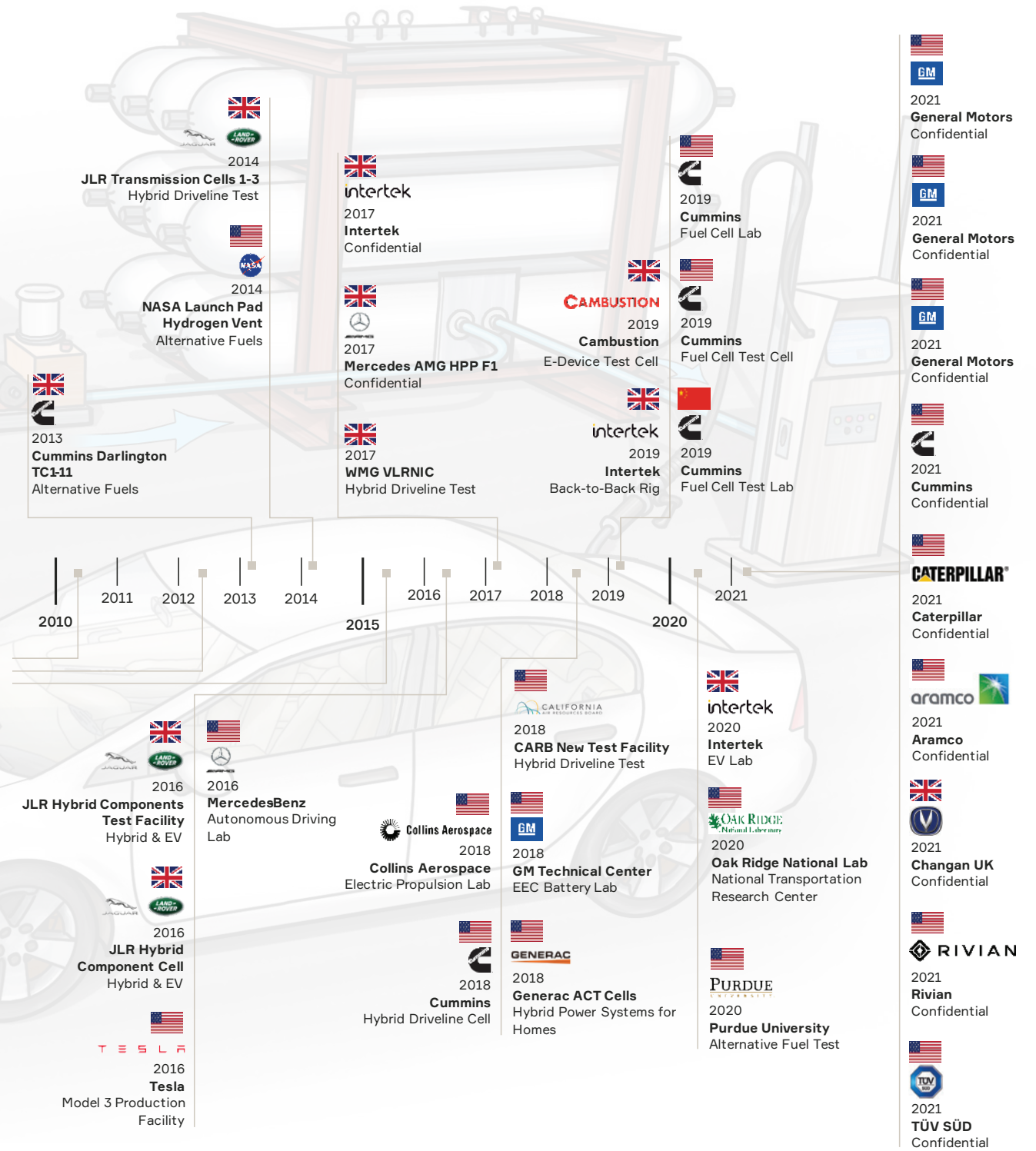
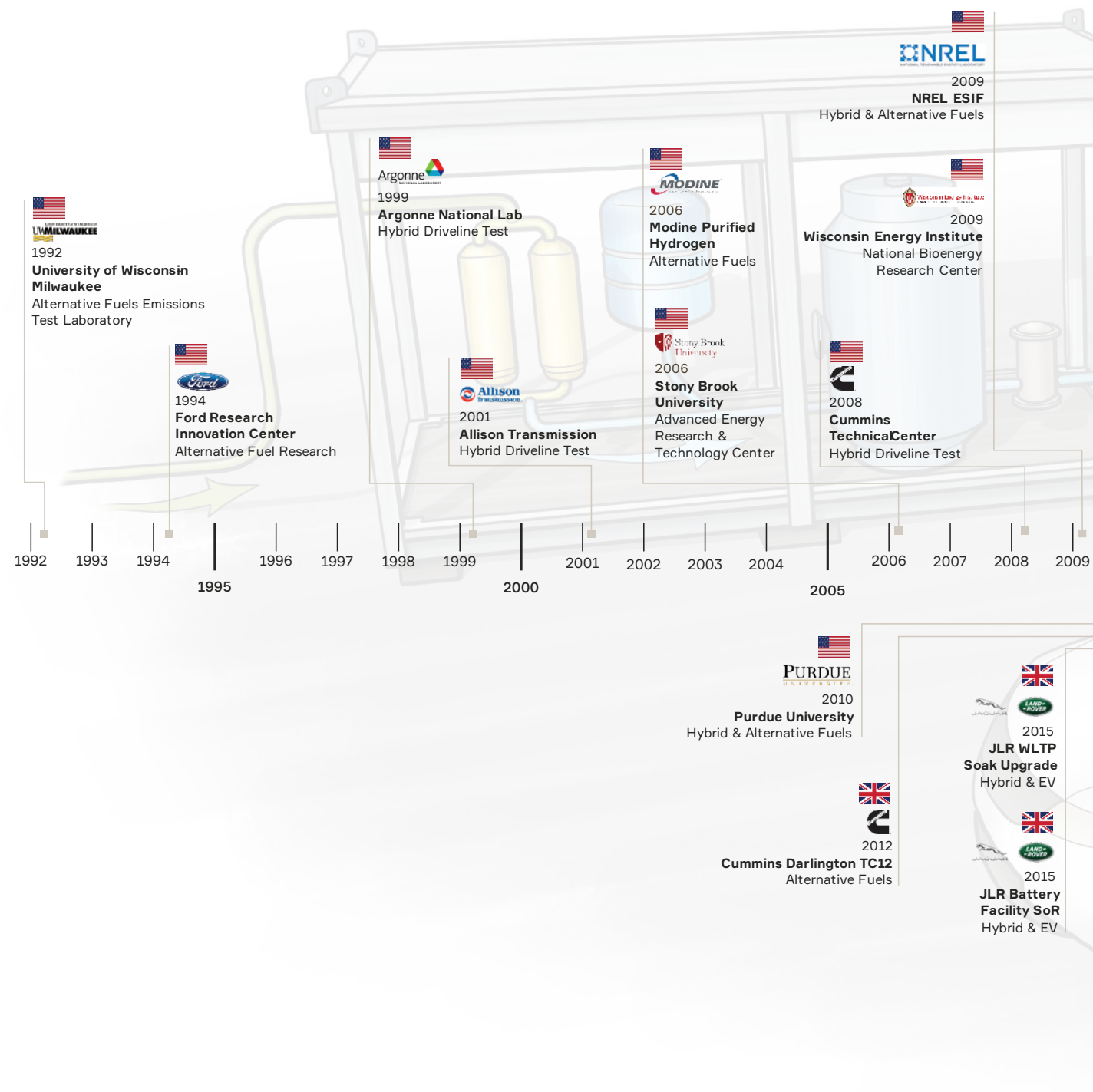
With respect to hazards, AEI has extensive experience with codes and standards (NFPA 2, 54, 55, 68, 69, etc.), guidelines, Factory Mutual data sheets, insurance carriers, and our clients' EH&S groups. Our capabilities are listed below:

- Process Hazards Analysis:
 - PHA, HAZOP, FMEA, LOPA, Dust
 - PHA-Pro Software
- Hazardous material handling and mitigation (gases, liquids, and 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, and dispensing
 - Hydrogen, methane, propane, acetylene, dimethyl-ether, ethyl alcohol, RP-1, HTP, gasoline, diesel, methanol, naphtha, etc.
- Relief header/valve design

Number of Consequences by Severity and Likelihood (Risk Matrix)



Electric Vehicle, Hybrid & Alternative Fuels Project Experience



Guiding clients in the era of electrification and on-site alternative power needs, AEI's electrical generation and distribution systems design balance increasing capacity requirements due to decarbonization goals with critical resiliency aspects of utility service failure risks.

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