FUEL CELL COLLABORATION BETWEEN GM & U.S. ARMY CCDC GVSC

March 19, 2019

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HYDROTEC
GENERAL MOTORS

HYDROGEN
FUEL CELL SOLUTIONS
ZERO EMISSIONS • MAXIMUM CAPABILITY

CCDC GVSC GM FUEL CELL COLLABORATION 2004-2019

2005 Chevrolet Silverado with Two Fuel Cell Systems & Drive Motors

For CCDC GVSC:

- Ability to evaluate/implement advanced FC technology
- Fuel cells provides quiet operation, exportable power, aggressive off-road mobility & water production

For GM:

- Opportunity to validate technology in unique environments
- Additional production volume – faster technology advancements

2018 to Present Battlefield Capable Hydrogen Production, distribution and dispensing system. Build of one Silverado ZH2 fuel cell electric vehicle.

2008-2012 Ten Fuel Cell Chevrolet Equinoxes at Fort Belvoir, West Point and Schofield Barracks

2012 to Present Three Fuel Cell Test and Development Stands at CCDC GVSC

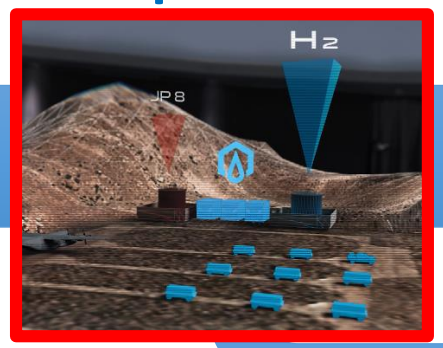
2016-2018 Chevrolet Colorado ZH2 Fuel Cell Electric Vehicle

2017 to Present SURUS Fuel Cell Powered Autonomous Vehicle

U.S. ARMY FUEL CELL OPPORTUNITIES CRAWL-WALK-RUN STRATEGY

ZH2 & SURUS – Development Platforms

Electrified Tank- Long Term



Product

Hydrogen Infrastructure

Product

Establish Viable Products Along Development Path, While Developing to Long Term U.S. Army Objectives

Development Objectives:

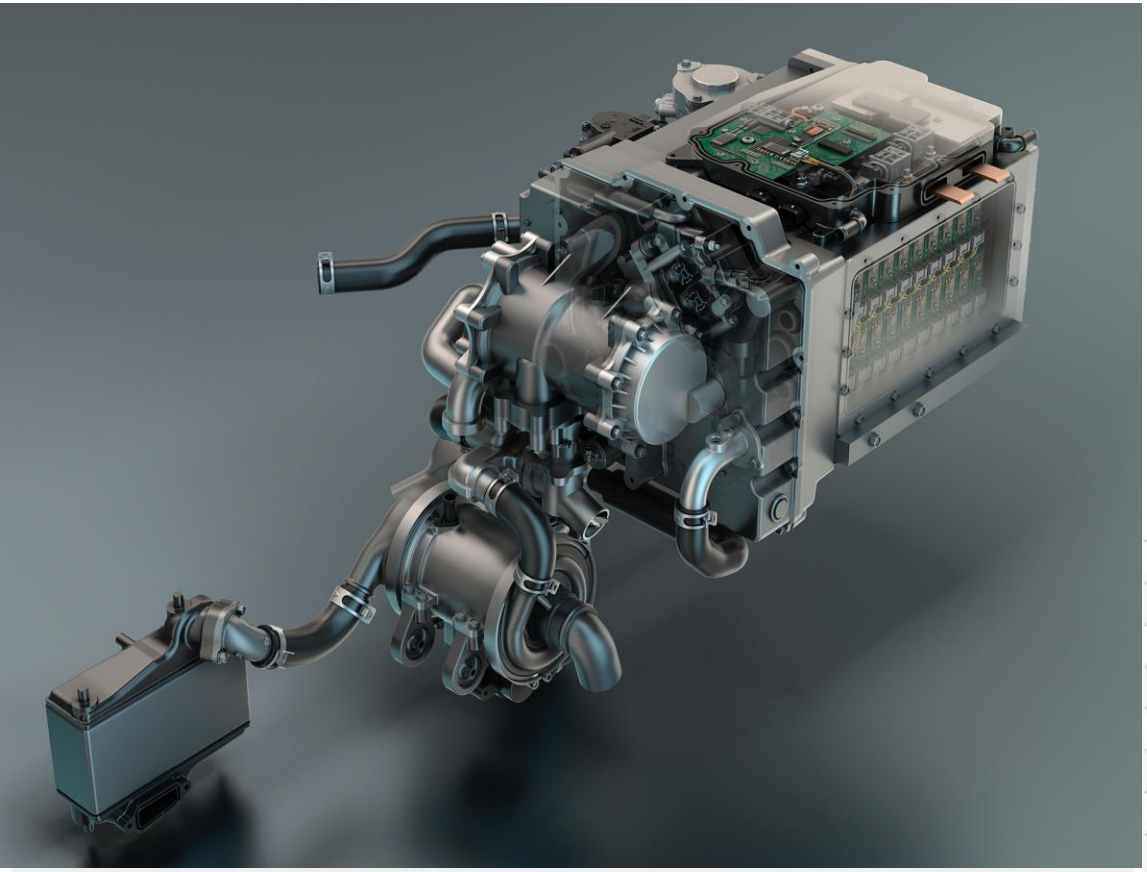
- Refine & Field Test
- Down Range Evaluation
- Dual Drive Motor Capability
- Off-Road Autonomous Controls
- Exportable Power
- Water Capture System
- Refueling Infrastructure Demo

- Introduce Higher Level Autonomous Capability
- Establish Usage Profiles
- Develop Mission Specific Applications
- Four Wheel Steer
- Leader Follower

- Incorporate ZH2 & SURUS Technologies
- Achieve Fully Armored Vehicle with Quiet Operation & Stationary Power Generation

ARMY END-GAME GOAL

Fuel Cell Product Evolution



SPECIFICATIONS	GEN0 FUEL CELL EQUINOX (2006)	GEN1 (2011)	GEN2 (2017)
NET POWER	93 kW	85-92 kW	80kW
DURABILITY	30K MILES @ 1,500 HOURS	150K MILES @ 5,500 HOURS	150K MILES @ 8,450 HOURS
MASS	240 kg	120 kg	LESS THAN 120kg
BIPOLAR PLATE	MOLDED COMPOSITE	STAMPED STAINLESS STEEL	STAMPED STAINLESS STEEL
PRECIOUS METAL	80 GPT	30 G PT	LESS THAN 15 G PT
INTEGRATION	SEMI-INTEGRATED; 440 CELLS	HIGHLY INTEGRATED; 320 CELLS	HIGHLY INTEGRATED ; 304 CELLS
SIMPLIFICATION	> 30 SENSORS	~ 15 SENSORS	~ 15 SENSORS
COST PER UNIT	BASELINE	⬇	⬇⬇

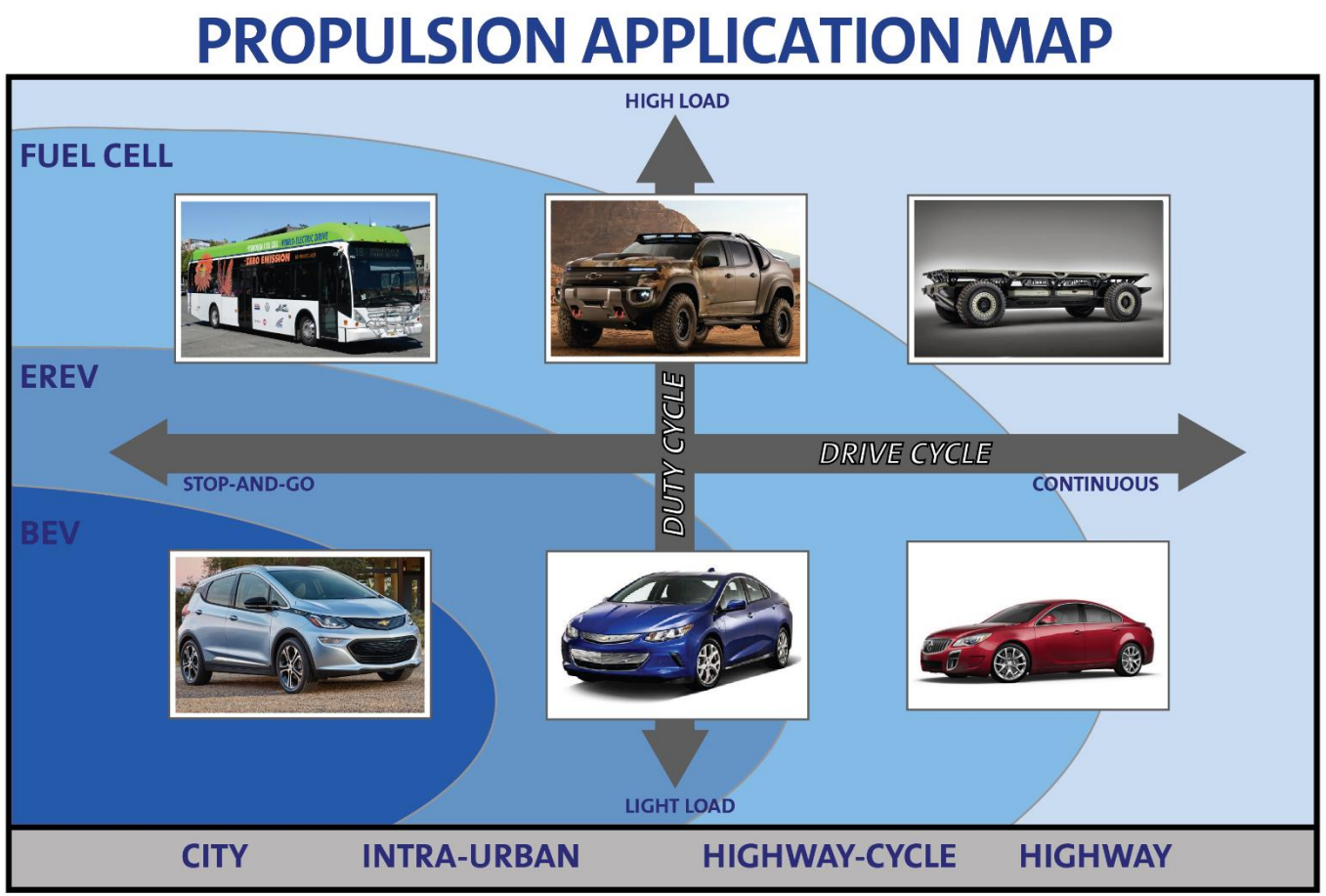
Fuel Cell Manufacturing Investment

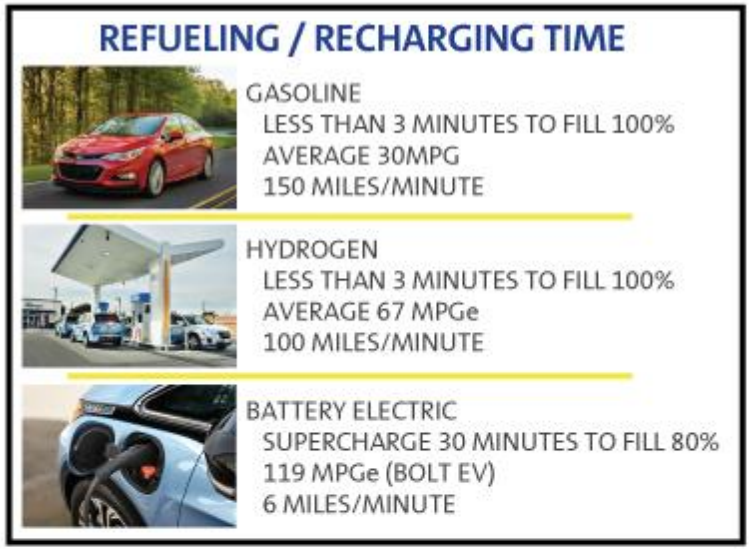
GENERAL MOTORS | HONDA

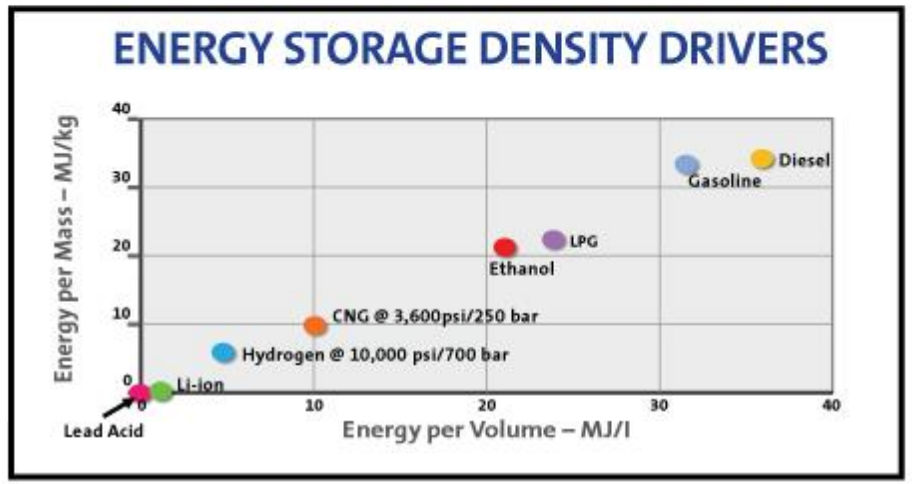
OBJECTIVE: Scale, Increased Speed, Maximized Learnings

- 50:50 Manufacturing Joint Venture (GM & Honda)
- Product based upon shared Gen 2 development program
- Announced January 30, 2017
- Manufacturing Location: Brownstown Township, MI
- $85 Million initial investment, creating new manufacturing jobs
- Production equipment currently being developed & installed
- Extensive automation
- Cost reduction through design iterations & scale economies
- Technology becoming affordable for automotive applications

Electrified Propulsion Application Map







Reducing Convoys & Associated Risks

Major Convoy Payloads

- JP8 Fuel
- Water
- Ammunition
- Power generation systems
- Mission-critical equipment
- Vehicle repair parts
- People

Concepts and Technologies with Solutions from GM

- Fuel cell Propulsion
- Electrification
- Autonomous Driving (L/F)
- Exportable Electric Power
- Vehicle Modularity

✓ Greatly increasing efficiency
✓ Reduce Detectability through Noise Reduction
✓ Fast re-fueling
✓ Saving Lives

"Advanced propulsions technologies like fuel cell and autonomous are critically required by the Army to minimize risk to the warfighter as a result of the current need for large convoys of inefficient manned vehicles."

- **Major General Robert Dyess (R), Deputy Director Army Capabilities Integration Center**

A long U.S. military convoy moving inside southern Iraq, March 21, 2003.

GM FCEV Development – Colorado ZH2

Content

Chassis
Colorado ZR2

Propulsion System
Equinox Fuel Cell

Body
Uniquely Styled

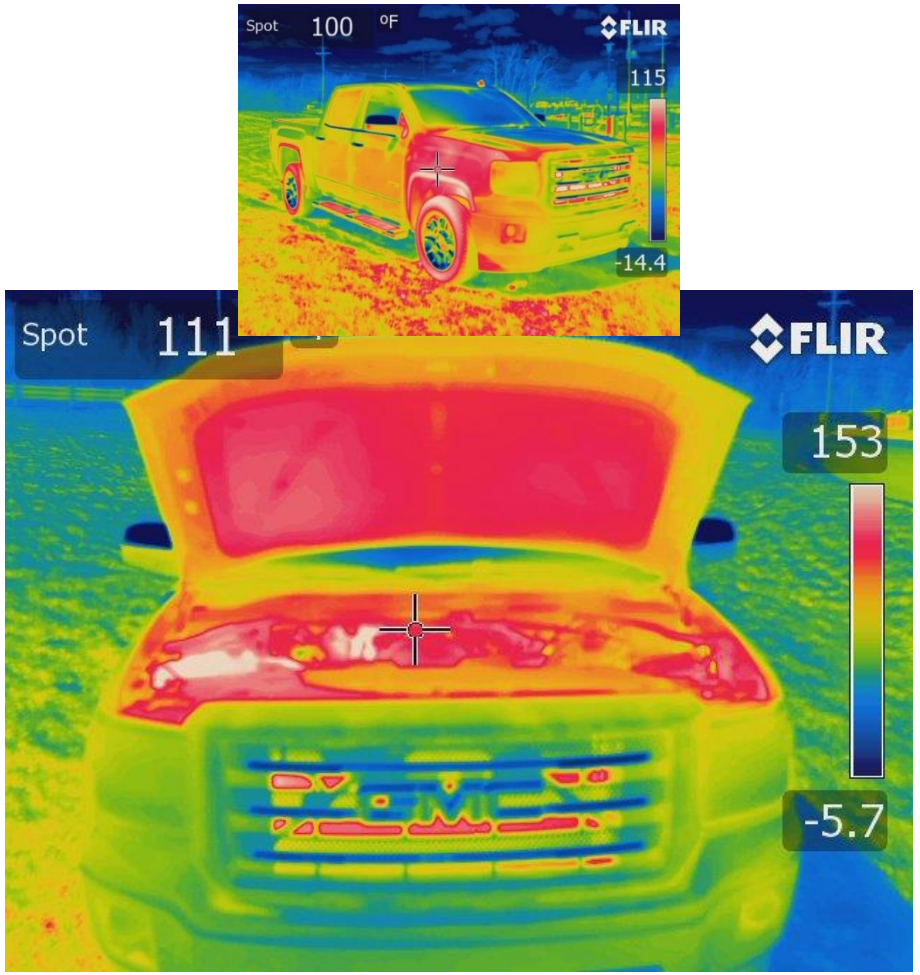
Performance

Range
Up to 200 miles

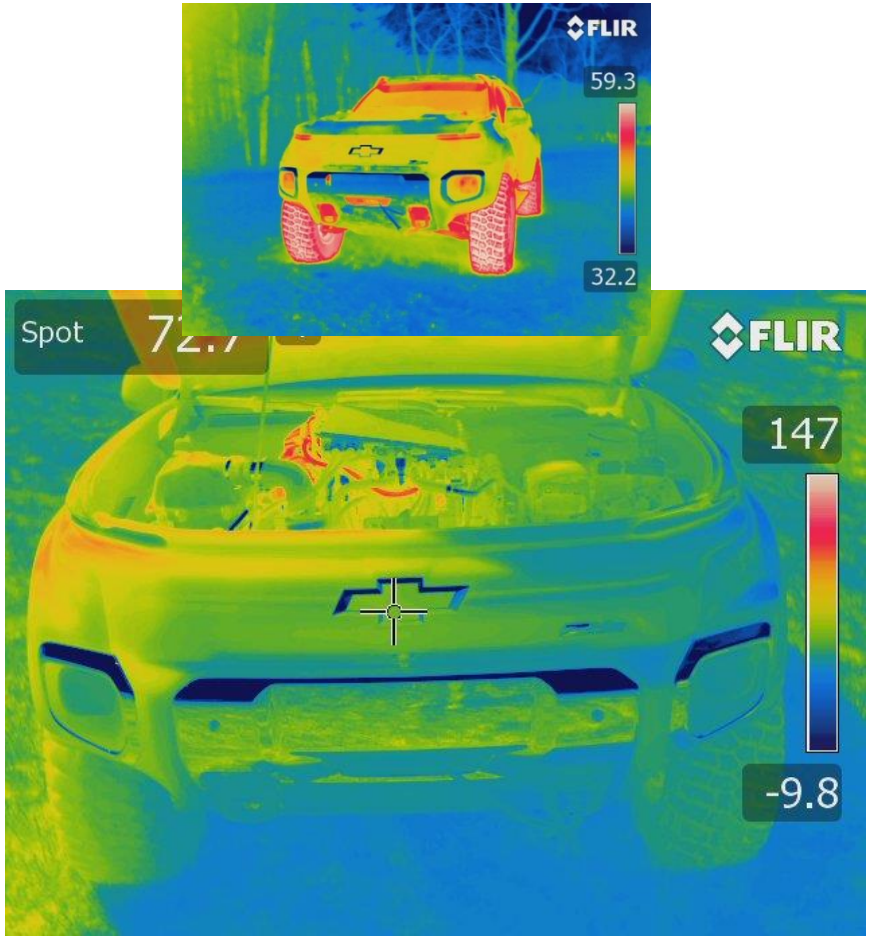
***Acceleration* (0 - 60 mph)**
17 seconds

Top speed
62 mph

ZH2 Heat Signature Testing

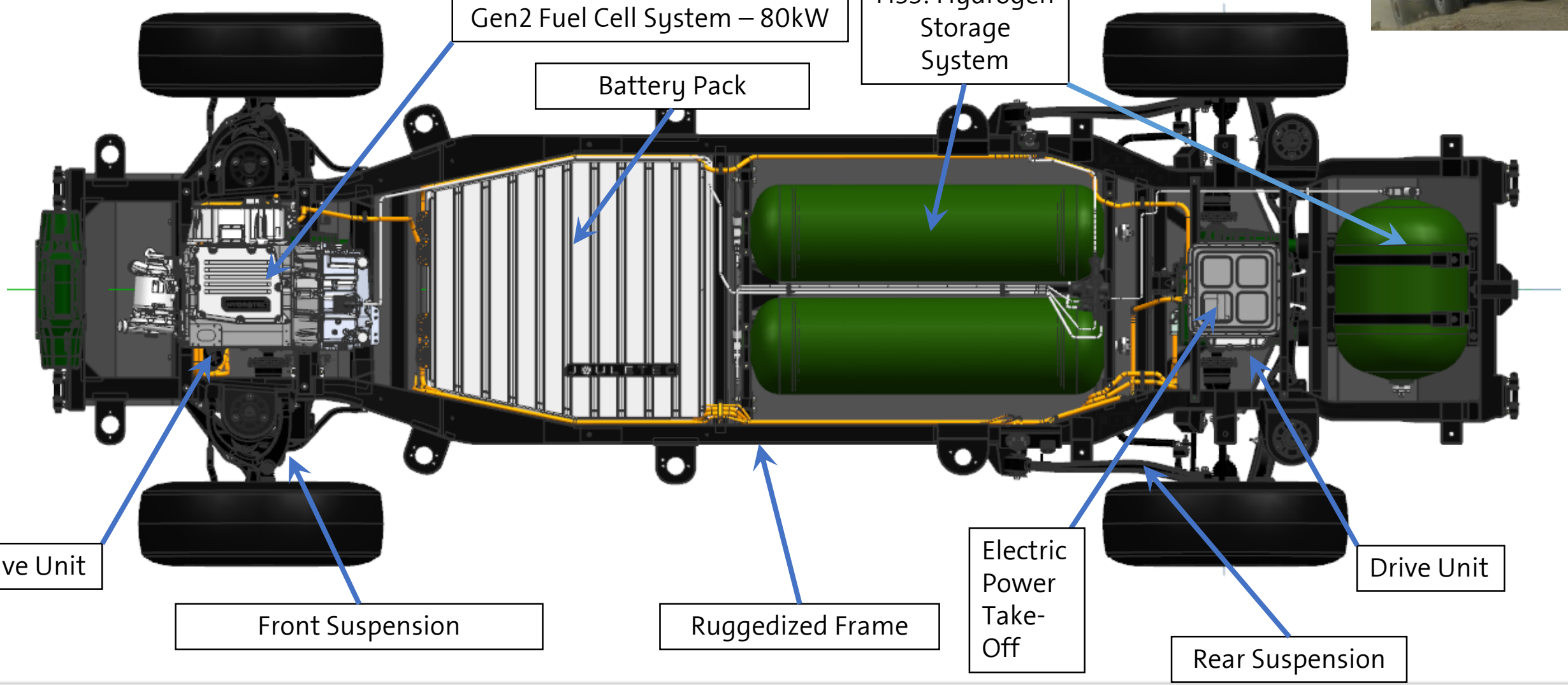


Sierra Gasoline Engine



ZH2 Hydrogen Fuel Cell

GM FCEV DEVELOPMENT – SILVERADO ZH2



ZH2 ROLLING CHASSIS DISPLAYED @ AUSA 2018

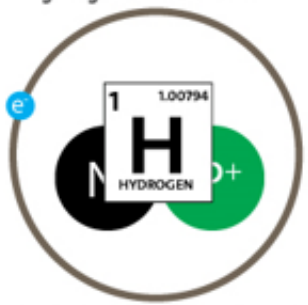
SILVERADO ZH2 ANIMATION

VIDEO LOCATION:

https://www.gmdefensellc.com/

Hydrogen Infrastructure - Commercial

Hydrogen -- the universal energy transfer
Hydrogen fuels the stars



Lightest element of the periodic table
Is an energy carrier rather than energy source

HYDROGEN STATIONS IN THE WORLD

https://www.afdc.energy.gov/locator/stations/ h2stations.org

HYDROGEN PRODUCTION

99% OF ALL HYDROGEN TODAY IS PRODUCED THROUGH FOSSIL FUEL REFORMING

3 Pathways to producing ZERO EMISSION HYDROGEN

- STEAM BIO-METHANE REFORMING WITH CARBON CAPTURE & STORAGE OR UTILIZATION
- ELECTROLYSIS USING ELECTRICITY FROM RENEWABLES
- GASIFICATION OF BIOMASS

DISTRIBUTION AND STORAGE

- GASEOUS/LIQUEFIED TRANSPORT
- SHIP TRANSPORT
- LIQUID FOR TRANSPORT
- PUMPING THROUGH PIPELINE
- PRESSURIZED TANK STORAGE
- UNDERGROUND STORAGE
- AQUIFER STORAGE

HYDROGEN USAGE

Feedstock for industrial applications
Refining of biofuels, methanol, & processing
Energy carrier

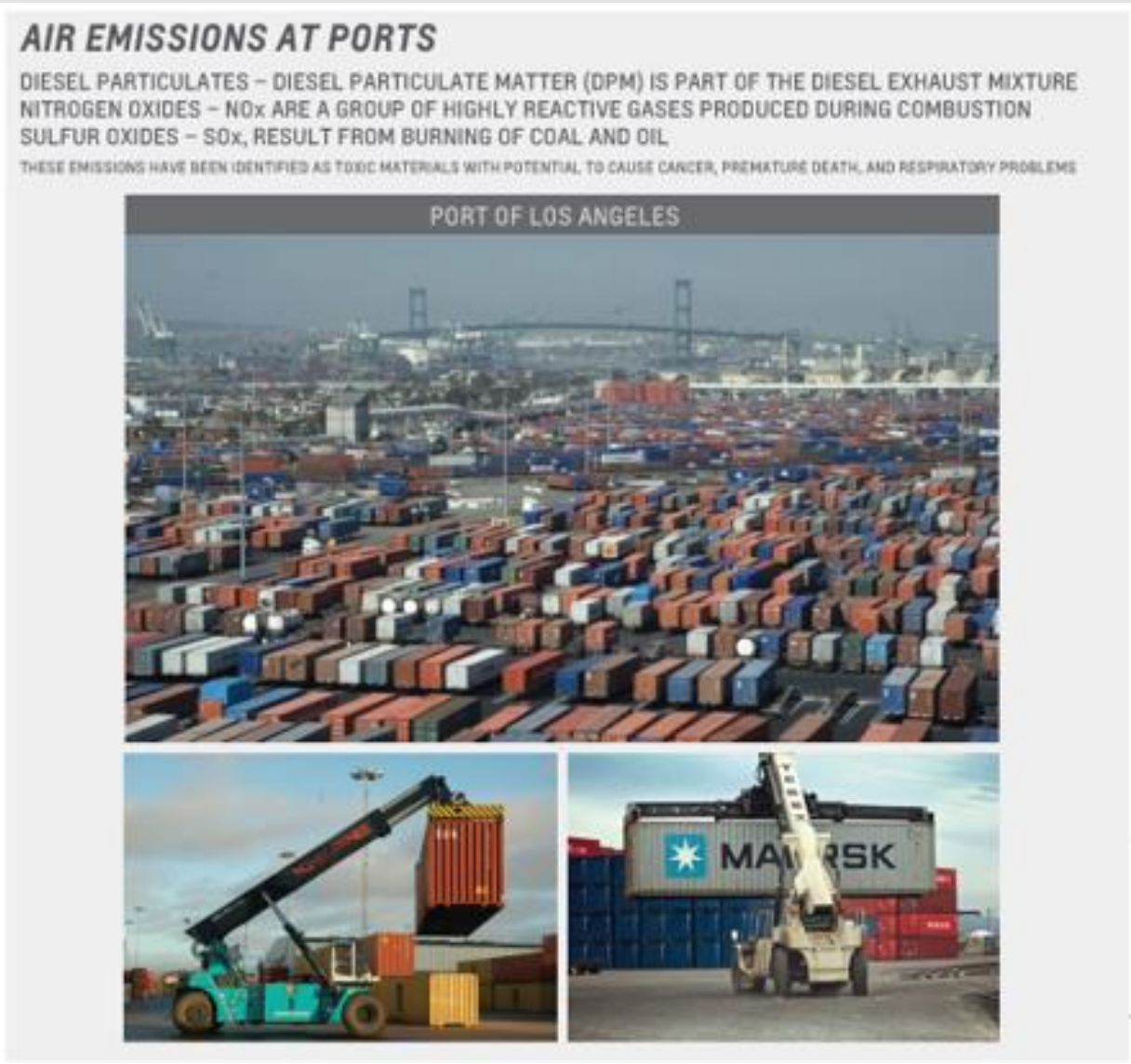
SAFETY

- SAFE PRODUCTION, STORAGE, TRANSPORT, & UTILIZATION
- SIMILAR FLAMMABLE PROPERTIES AS GASOLINE AND NATURAL GAS
- ESTABLISHED INDUSTRY USE

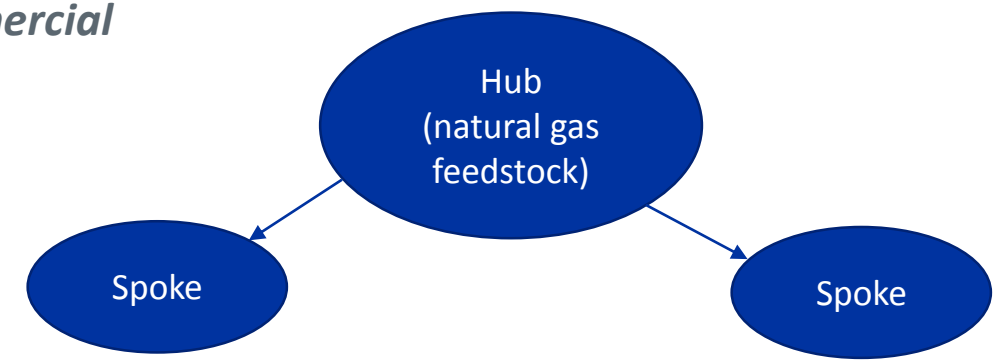
CALIFORNIA RETAIL HYDROGEN INFRASTRUCTURE

- 35 OPEN RETAIL STATIONS IN CA, 18 GOING ONLINE SOON
- RECHARGES FUEL CELL ELECTRIC VEHICLES IN ABOUT FIVE MINUTES
- HYDROGEN: A CLEAN, SAFE, RELIABLE, & FLEXIBLE ENERGY CARRIER

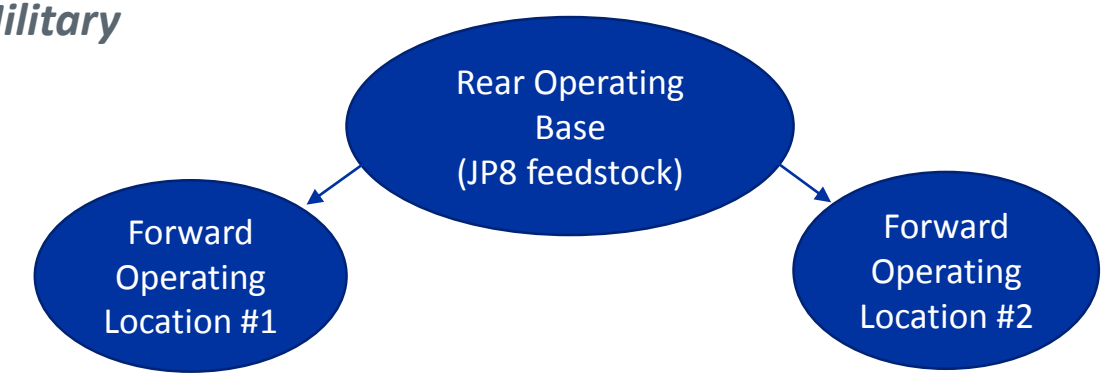
Centralized Fueling Concept



Commercial



Military



Hydrogen Ecosystem With GVSC

Evaluate commercial H2 production and fueling methods, and next-gen FCEV for applicability in military space as an "integrated solution"

Hydrogen Generation and Distribution Concept

Concept: Convert any feedstock into hydrogen and utilize "hub and spoke" model for hydrogen production, storage, and distribution. Showcase concept of bringing fuel to FCEVs for operations in austere environments

Numerous Feedstocks for H2

- Water
- Natural Gas
- Diesel (JP8)
- Aviation Fuel (JP5)
- Biogas

Project comprehends down selection of JP8 feedstock, 1 ZH2, "Hub" refueler, and 2 "Spoke" mobile trailers

Electrolysis

-OR-

Reformer for diesel/JP8 feedstock

Compression, Storage, Dispensing

"Hub"

20' ISO Container
- Fill FCEVs
- Fill mobile trailers

"Spokes"

Mobile Fueling Trailer
- Fill FCEVs

Mobile Fueling Trailer
- Fill FCEVs

HYDROGEN ECOSYSTEM ANIMATION

VIDEO LOCATION:

https://www.gmdefensellc.com/

SURUS

SILENT
UTILITY
ROVER
UNIVERSAL
SUPERSTRUCTURE

ONE CHASSIS

ONE PROPULSION SYSTEM

MANY VEHICLE SOLUTIONS

SURUS TECHNOLOGY

Autonomous
Production Sensor Capabilities

Over 400mi Range
3 minute Fast Refueling

Exportable Power
50-100 kW

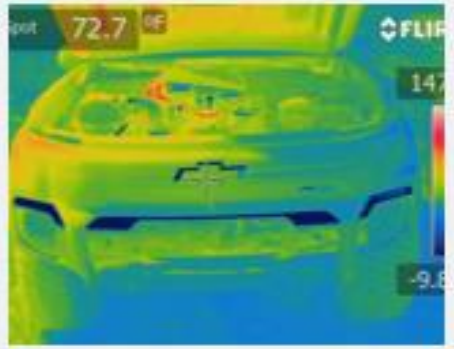
Flexible Utility
Cargo Deck

HYDROTEC Fuel Cell
Water Recovery System

4WD/4 Wheel-Steer
Electric Drive

Multimatic
Dynamic Suspension

Minimized Detection
Noise & Thermal Signature



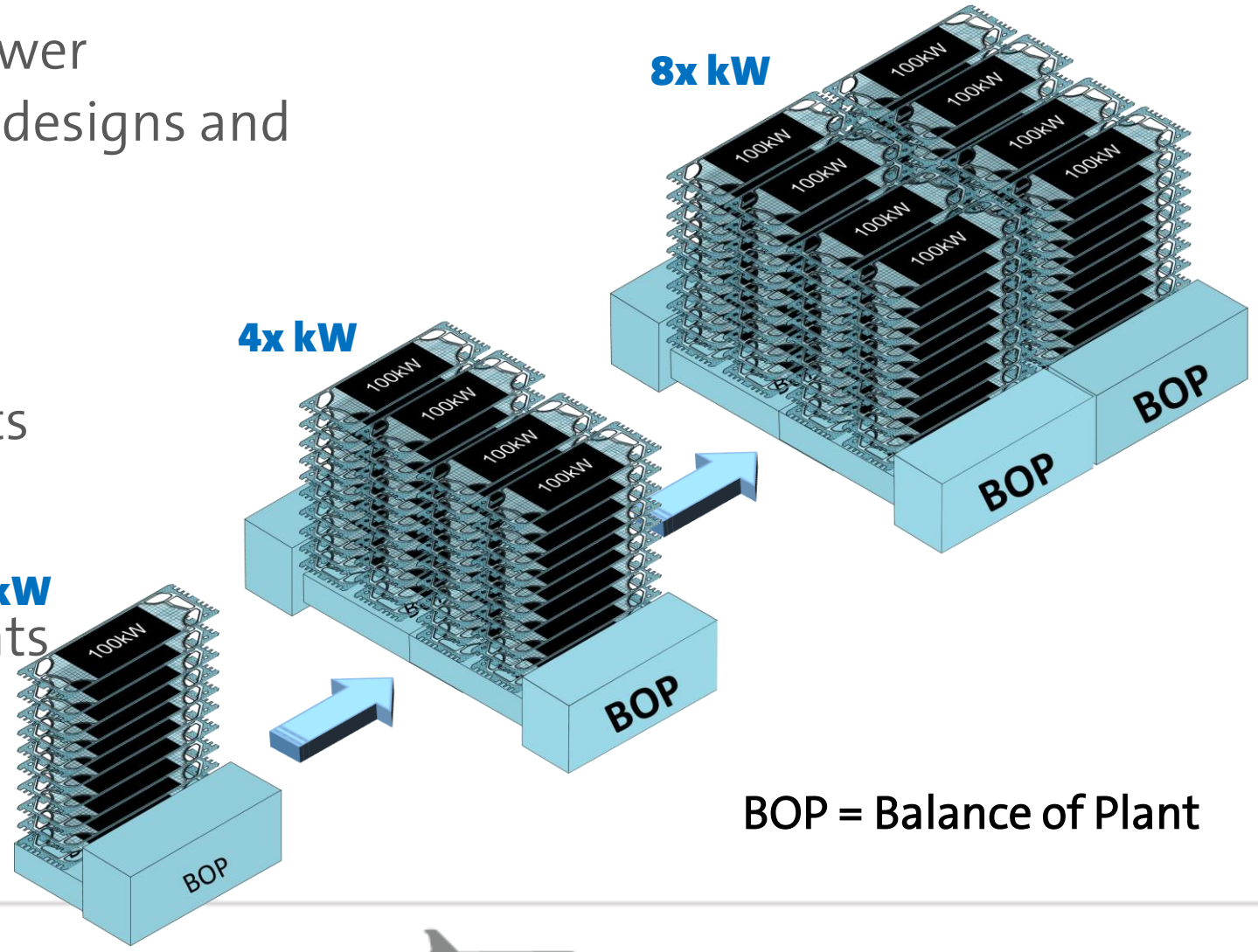
SCALABLE MULTI-PLATFORM FUEL CELL ARRAY

Highly scalable fuel cell array

- For propulsion or stationary power
- Utilize commercial component designs and manufacturing methods

Design and Controls Focus:

- Modularity
- Maximize common components
- Fault tolerance
- High power density
- Extreme operating environments
- Field serviceable



BOP = Balance of Plant