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

March 19, 2019

Christopher Colquitt
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

2005 Chevrolet Silverado with Two Fuel Cell Systems & Drive Motors

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

2018 to Present Battlefield Capable Hydrogen Production, distribution and dispensing system. Build of one Silverado ZH2 fuel cell electric vehicle.
U.S. ARMY FUEL CELL OPPORTUNITIES CRAWL-WALK-RUN STRATEGY

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

ZH2 & SURUS – Development Platforms

Electrified Tank - Long Term

Establish Viable Products Along Development Path, While Developing to Long Term U.S. Army Objectives
# Fuel Cell Product Evolution

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NET POWER</td>
<td>30 kW</td>
<td>65-92 kW</td>
<td>80 kW</td>
</tr>
<tr>
<td>DURABILITY</td>
<td>30K MILES @ 1,500 HOURS</td>
<td>150K MILES @ 5,000 HOURS</td>
<td>150K MILES @ 5,400 HOURS</td>
</tr>
<tr>
<td>MASS</td>
<td>240 kg</td>
<td>120 kg</td>
<td>LESS THAN 120kg</td>
</tr>
<tr>
<td>Bipolar Plate</td>
<td>MOLDED COMPOSITE</td>
<td>STAMPEDE STAINLESS STEEL</td>
<td>STAMPED STAINLESS STEEL</td>
</tr>
<tr>
<td>Precious Metal</td>
<td>80 GPT</td>
<td>36 GPT</td>
<td>LESS THAN 15 G PT</td>
</tr>
<tr>
<td>Integration</td>
<td>SEMI-INTEGRATED; 440 CELLS</td>
<td>HIGHLY INTEGRATED; 128 CELLS</td>
<td>HIGHLY INTEGRATED; 384 CELLS</td>
</tr>
<tr>
<td>Simplification</td>
<td>&gt; 39 SENSORS</td>
<td>~ 15 SENSORS</td>
<td>~ 15 SENSORS</td>
</tr>
<tr>
<td>Cost Per Unit</td>
<td>BASELINE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

**PROPULSION APPLICATION MAP**

- **FUEL CELL**
- **EREV**
- **BEV**

**REFUELING / RECHARGING TIME**

- **GASOLINE**
  - LESS THAN 3 MINUTES TO FILL 100%
  - AVERAGE 30 MPG
  - 150 MILES/MINUTE

- **HYDROGEN**
  - LESS THAN 3 MINUTES TO FILL 100%
  - AVERAGE 67 MPGe
  - 100 MILES/MINUTE

- **BATTERY ELECTRIC**
  - SUPERCHARGE 30 MINUTES TO FILL 80%
  - 119 MPGe (BOLT EV)
  - 6 MILES/MINUTE

**ENERGY STORAGE DENSITY DRIVERS**

- Graph showing energy per mass and energy per volume for various fuels:
  - Gasoline
  - Diesel
  - Ethanol
  - LPG
  - Hydrogen @ 3,600 psig/250 bar
  - Hydrogen @ 30,000 psig/700 bar
  - Lead Acid

**HYDROGEN FUEL CELL SOLUTIONS**

- Zero Swish
- Maximum Capability
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

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

- Gen2 Fuel Cell System – 80kW
- Battery Pack
- HSS: Hydrogen Storage System
- Drive Unit
- Electric Power Take-Off
- Ruggedized Frame
- Front Suspension
- Rear Suspension
- Drive Unit
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.fuelcellsworks.org/local-stations/

**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

**HYDROGEN USAGE**

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

**SAFETY**

- Safe production, storage, transport, & utilization
- H2 standards proficiency
-ziej engineering and natural gas
- Established industry

- 35 open retail stations in CA,
  18 going online soon
- Recharges fuel cell electric vehicles in about 5 minutes
- Hydrogen: a clean, safe, reliable, & flexible energy carrier
Centralized Fueling Concept

**Hydrogen Ecosystem With GVSC**

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

**Commercial**

- Hub (natural gas feedstock)
  - Spoke
  - Spoke

**Military**

- Rear Operating Base (JP8 feedstock)
  - Forward Operating Location #1
  - Forward Operating Location #2
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
- 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
Reformer for diesel/JP8 feedstock

Compression, Storage, Dispensing

“Hub”
20' ISO Container
- Fill FCEVs
- Fill mobile trailers

Mobile Fueling Trailer
- Fill FCEVs

“Spokes”

Mobile Fueling Trailer
- Fill FCEVs
VIDEO LOCATION:

https://www.gmdefense llc.com/
SURUS

ONE CHASSIS

ONE PROPULSION SYSTEM

MANY VEHICLE SOLUTIONS

SILENT UTILITY ROVER UNIVERSAL SUPERSTRUCTURE
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