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# U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND

## Ground Vehicle Systems Center Fuel Cell Update

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Ground Vehicle Systems Center

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# OVERVIEW

- CCDC GVSC Fuel Cell Technologies Team
  - Description and Brief Project Summary
- Ongoing Project Status
- Fuel Cell Laboratory
- Hydrogen Tank Ballistic Test Data
- Logistics Impact
- Hydrogen Liquefaction
- Cryo-compressed Hydrogen
- Summary

# GROUND VEHICLE SYSTEMS CENTER FUEL CELL TECHNOLOGIES TEAM

## Fuel Cell Technologies Team's Mission

- Explore and evaluate fuel cell power generation technologies and their support equipment that enable tactical advantages for ground vehicle systems.

## Fuel Cell Technologies Team Overview

- Recent and Ongoing projects
  - Solid Oxide Fuel Cell (SOFC) + JP-8 Reformation Auxiliary Power Unit
  - Fuel Cell All Terrain Transport (FCATT, Hydrogen based)
  - General Motors Colorado ZH2 & SURUS
  - Tactical Hydrogen Operational Refueler (THOR) and JP-8 reformation systems
  - GM Hydrogen Ecosystem (Silverado ZH2 + Hydrogen Generation Capability)

- Expertise focused on SYSTEM level development, test, and demonstration. Some limited independent research and development at lowest levels.

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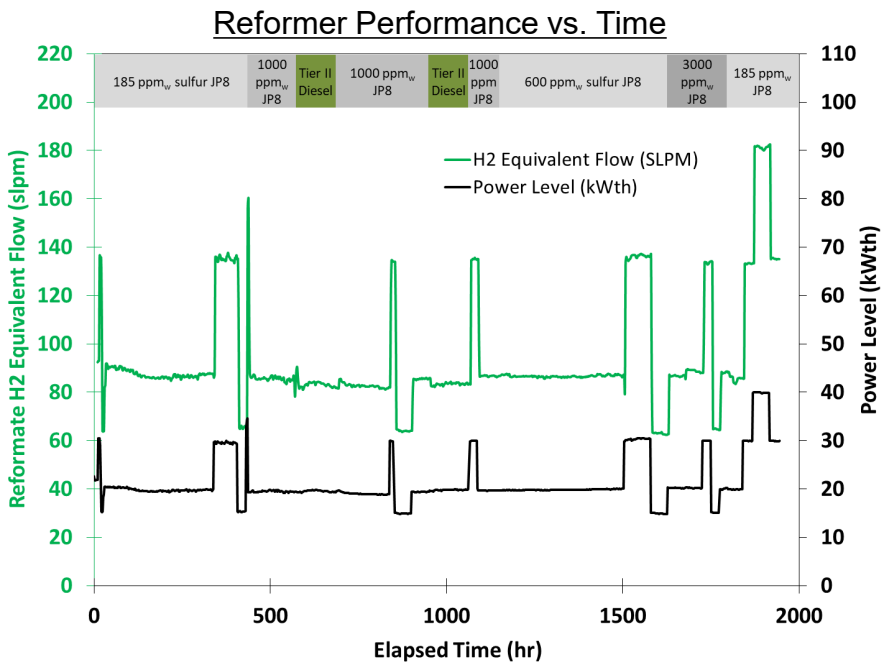
# OSD OPERATIONAL ENERGY CAPABILITY IMPROVEMENT FUND JP-8 FUEL CELL



| Composition (mol%-wet) | |
|---|---|
| $N_2$ | 39.19 |
| $H_2$ | 25.27 |
| CO | 10.77 |
| $CO_2$ | 7.75 |
| $CH_4$ | 0.02 |
| $H_2O$ | 17.01 |

- 2000-hour durability test completed with JP-8 containing from 185ppm to 3000 ppm Sulfur as well as Tier II Diesel with over 30 thermal cycles
- High fuel conversion (99.9%) & LHV-based reforming efficiency (>82%) observed.
- Degradation rate of <5% observed over 2000 hours.
- Reformer successfully implemented in α-system

# CURRENT HYDROGEN GENERATION, DISTRIBUTION, STORAGE, AND DEMONSTRATION

1st Prototype Commercial Fuel Cell Tactical Vehicle

- Obtain soldier feedback within an operational context demonstrating the capabilities of a hydrogen fuel cell powered vehicle
- Use Data and Soldier feedback to shape follow-on fuel cell vehicle efforts

1st Prototype JP-8 Reformer

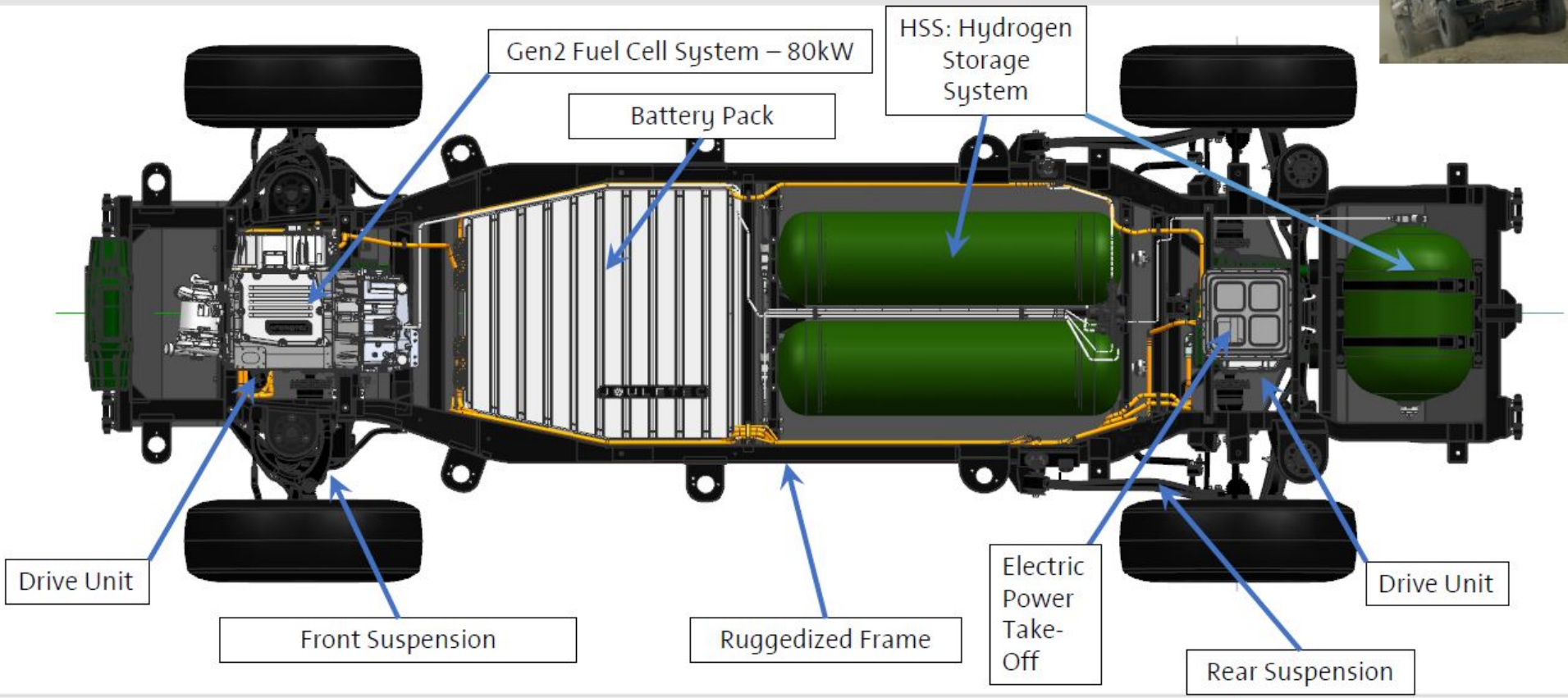
- 18-30 kg H2 per day
- Skid mounted, forklift, 600 lbs
- Low power requirement during operation (~600W)
- Scalable system design

1st Prototype Tactical Hydrogen Operational Refueler (THOR)

- SAE J2601 700 bar T20 fueling
- Contained within a 20 foot ISO shipping container that can be handled by existing Army trucks
- 54 kg of DOT approved hydrogen storage

# NEXT GENERATION

## GM FCEV DEVELOPMENT – SILVERADO ZH2



# SILENT MOBILITY, SILENT WATCH, & EXPORTABLE POWER

Extended Silent Watch
Provides 2.5 kw of export power
For 24 hours on 4kg of H2
(~4gal JP-8 equivalent)

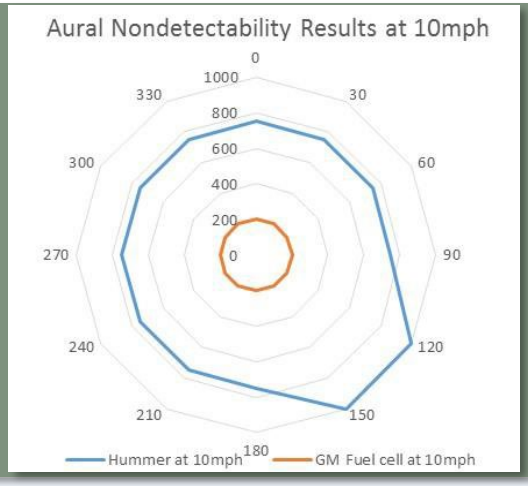
**ZH2 in its Undetected Distance from Objective during Night Ops**

*"If we can creep up on the enemy and can do it stealthily in our vehicle, we can accomplish our mission more efficiently."*

*"We can get closer into enemy territory undetected, making our vehicle weapons and call for support more lethal."*

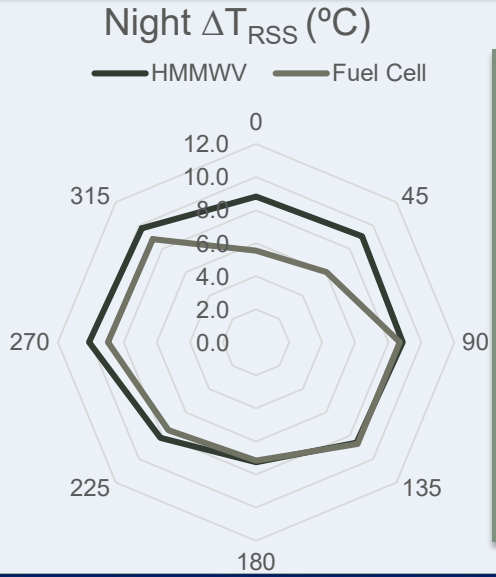
***Fuel Cells Enable Silent Mobility and Extended Silent Watch***

# SIGNATURE MANAGEMENT: ACOUSTIC AND THERMAL BENEFITS




***By comparing two like vehicle systems (Colorado ZH2 & HMMWV) the fuel cell vehicle has a 75-90% improvement for its acoustic signature.***

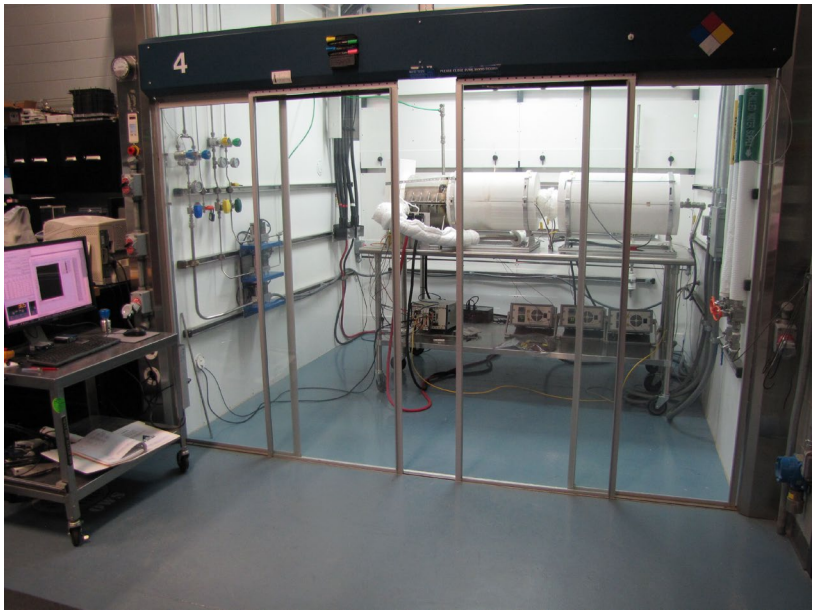
***With an integrated approach, 100m non-detectability at 10mph is achievable***

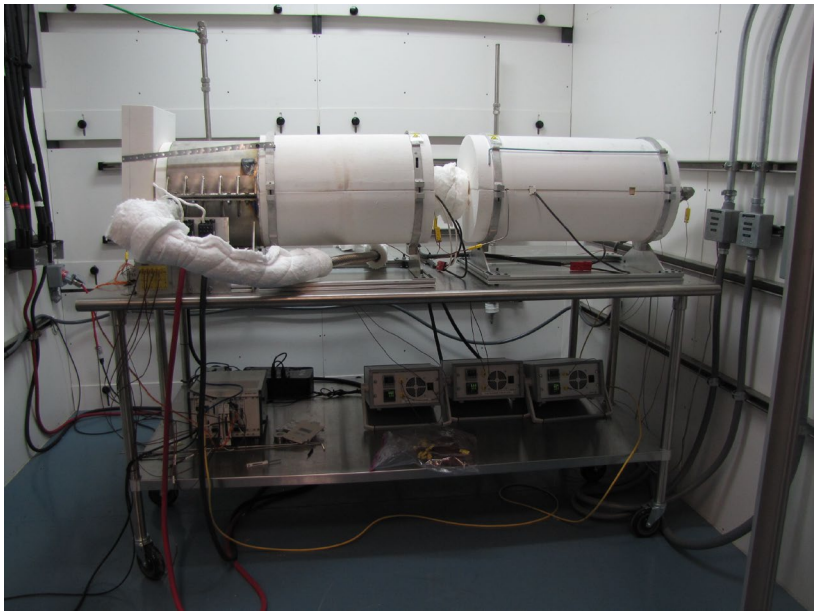



***The use of fuel cells and electric drive shows promise to lowering thermal signatures but must be part of an integrated signature design***

***"If we can get within a 100 meters of the enemy undetected, we take away their ability to call in for airstrike and artillery support" by CPT Traitses 4th ID***

# FUEL CELL LAB SOFC STACK TESTING





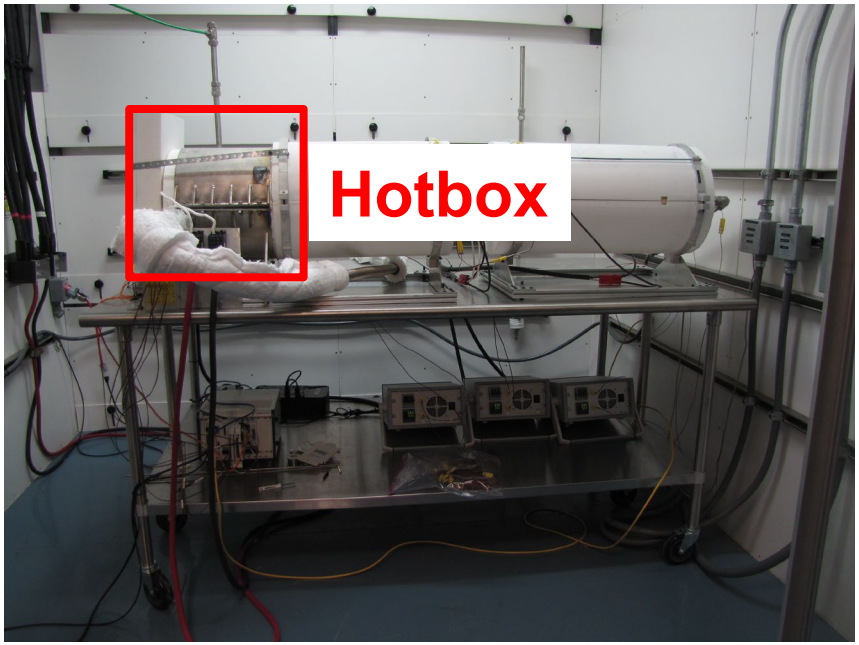
## SOFC Testing Equipment:

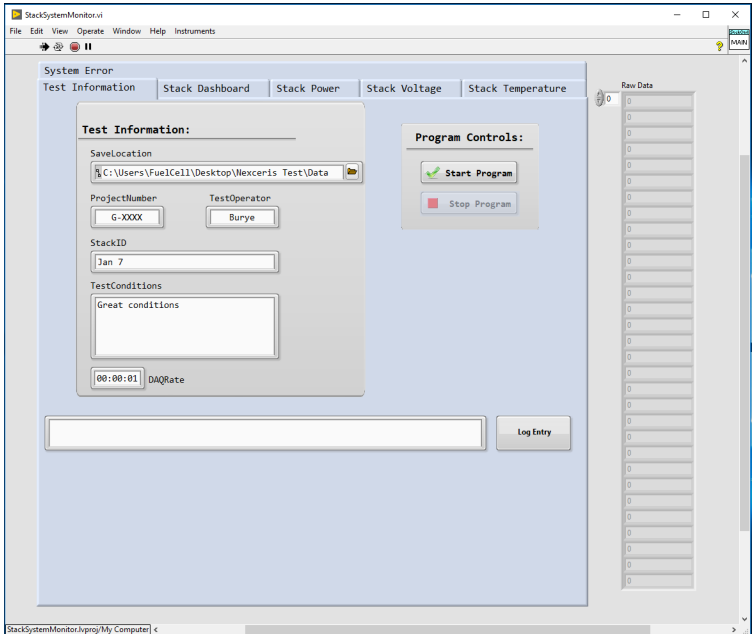
- 1 Hotbox
- 2 Cathode Gas Heaters
- 1 Anode Gas Heater
- 3 Mass Flow Controllers
- Electrical Load Bank

## SOFC Testing Utilities:

- Nitrogen Gas Supply (from outside tank)
- Hydrogen Gas Supply (from tube trailer)
- Air Gas Supply (from building air)
- 208V and 120V Power Inside Fume Hood

# FUEL CELL LAB SOFC STACK TESTING




## SOFC Equipment:

- Approx. Interior Hotbox Stack Area:
  - 9.6 inch x 9.6 inch x 8.9 inch
- Eight (8) Stack Voltage Taps
  - 3 Cells/Tap, # Expandable
- Five (5) Stack Thermocouples
  - # Expandable
- Seven (7) Gas Heater Thermocouples

## Computer Data Recording Capabilities:

- LabView Data Recording Program
- Input Specific Testing Recipes Capability
- Data Recorded:
  - Stack Overall Power
  - Overall Stack Min/Max Voltage
  - Stack Tap Voltages
  - Stack and Gas Temperatures
  - Gas Flow Rates

# CONTROL

Test#
3
Test Article
EMPTY QUANTUM
TYPE IV
Date
5/24/17
Round
7.62

# CONTROL

# API VIDEO

# API DAMAGE

H2 GAS
Type 4 Container
P/N: 108184
Manufactured: 2007/12
S/N: D075001G
DO NOT USE AFTER: 2013/12
Number of Filling Cycles: 5,000
Service Pressure: 70 MPa (10,153 psig) @ 15°C (59°F)
This container should be visually inspected after a motor vehicle accident or fire and at least every 35 months or 58,000 km (36,040 miles), whichever comes first, for damage and deterioration.
If there is a question about the proper use, installation, or maintenance of this container, contact:
Quantum Technologies Inc.
17872 Cartwright Rd
Irvine, CA 92614 USA
949-399-4500
For use only with the container manufacturer's approved pressure relief devices and valves.
QUANTUM

# RPG VIDEO

# RPG ENTRANCE SIDE

# RPG EXIT SIDE

# C4

# C4

# US ARMY APPLICATIONS

## Army Vehicles are Heavy and Energy-Intensive

Main Battle Tank (M1A2 SEPV3)
Weight: >66 tons
➔**Est. >250 kg H2**

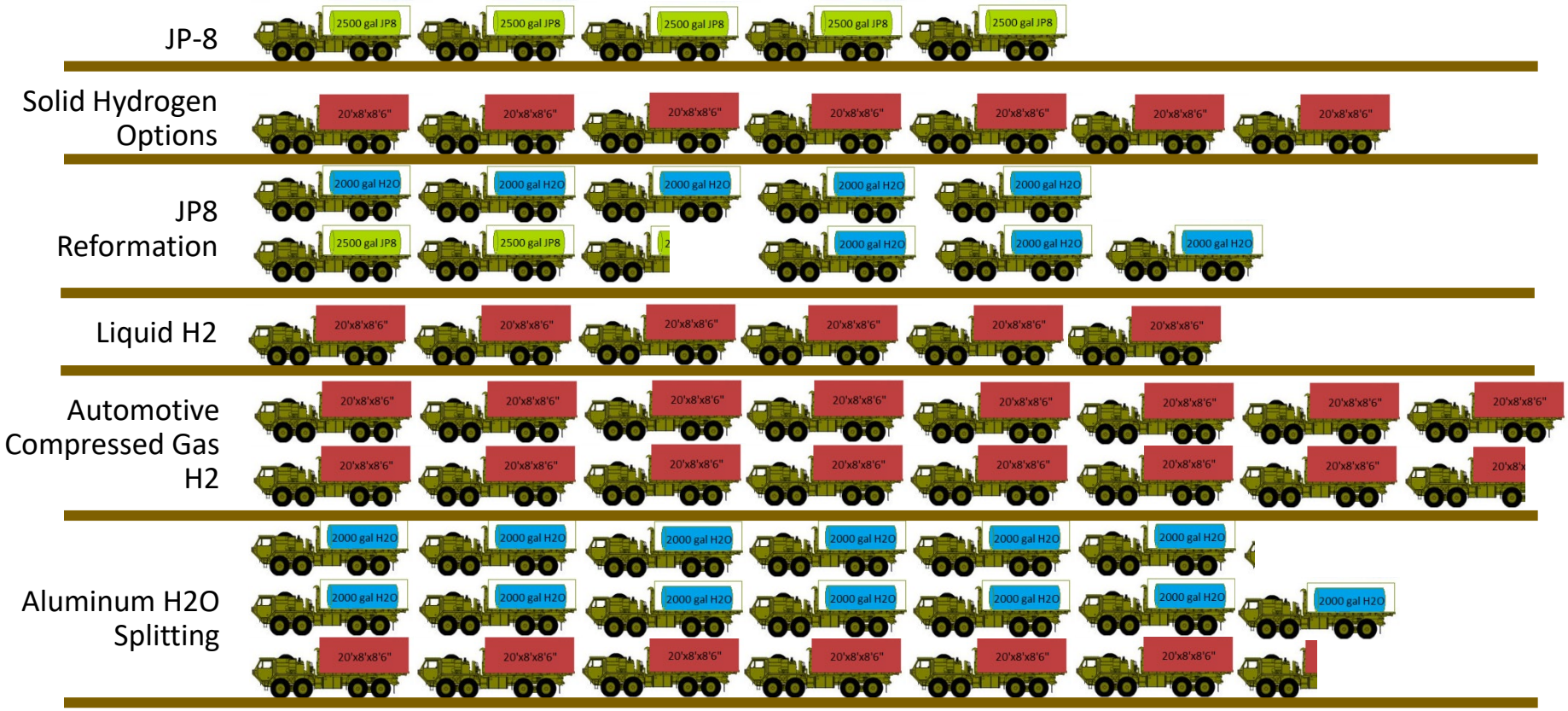
Off-Road Heavy Transport (HEMMT, M977…)
Weight: >35 tons
➔**Est. >80 kg H2**

Family of Medium Tactical Vehicles (M1078…)
Weight: >14 tons
➔**Est. >35 kg H2**

Joint Light Tactical Vehicle
Weight: >7.5 tons
➔**Est. >25 kg H2**

Over 30 Platforms weighing up to 100 tons
Approximate “extra space” onboard = None
Preferred weight change = reduction in weight
Acceptable range change = Increase only

# HYDROGEN LOGISTICS OPTIONS ON A LARGE SCALE




M1120 LHS Capacities, no trailers. Corrected for improved fuel consumer efficiency and H2 to JP-8 energy difference.
Compression of H2 and fuel consumed by M1120 ignored.

# MAGNETOCALORIC HYDROGEN LIQUEFACTION

Magnetocaloric Hydrogen Liquefaction

- Leverage the discoveries and past work from the Fuel Cell Technology Office Project

Investigating potential path forward

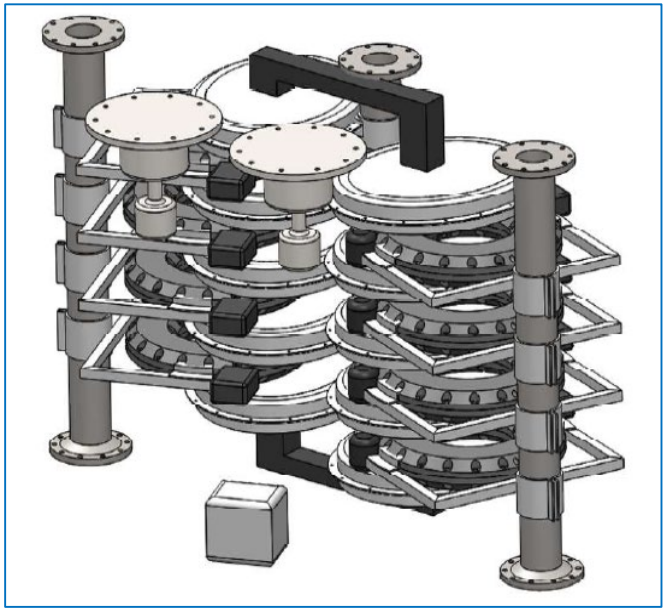
- Reduced cost hydrogen liquefaction hardware
- Reduced energy input requirements

Design Phase (50-100kg/day)

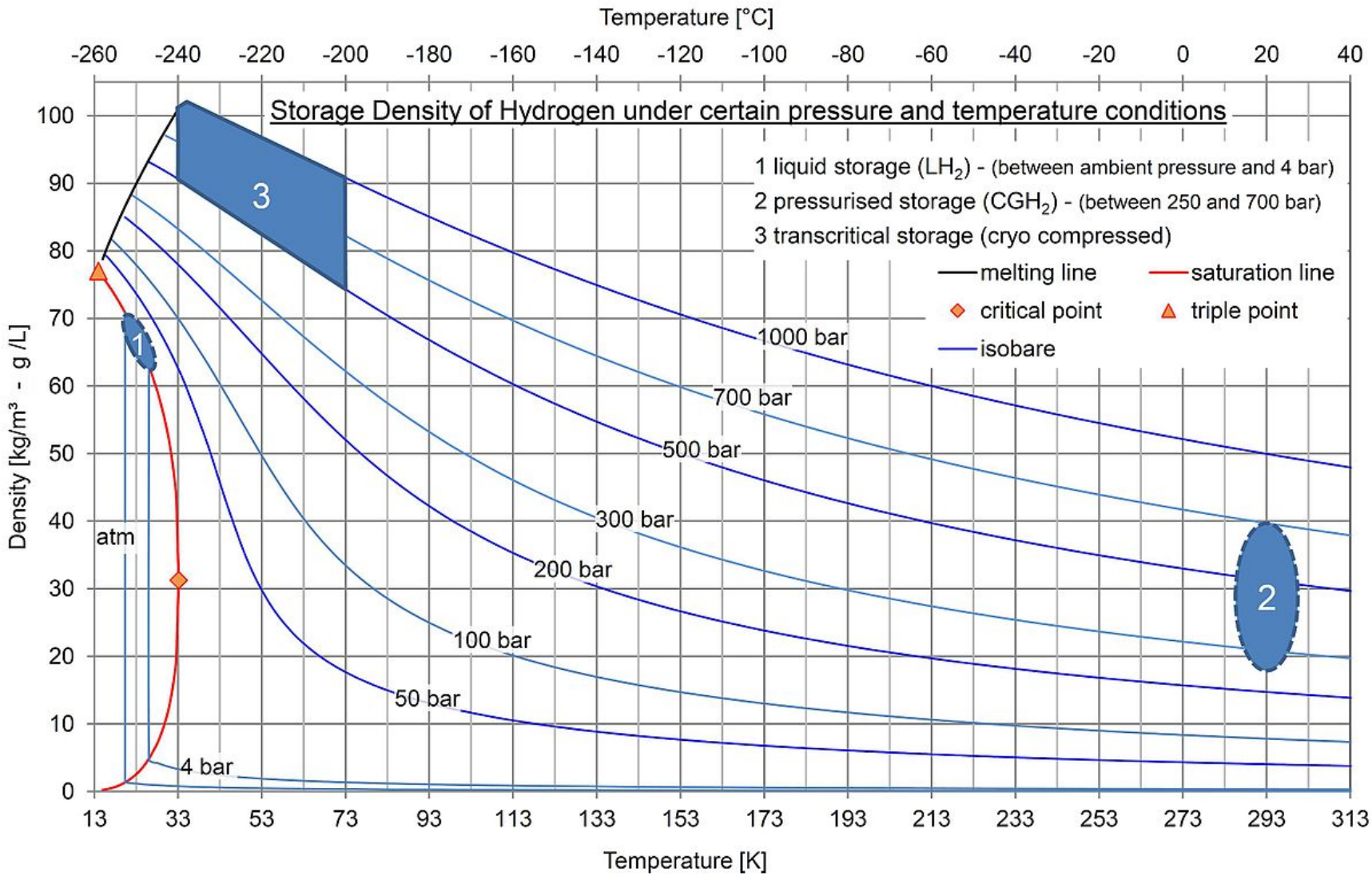
- Multiple stages (3-4)
- 2-3 layers of materials per stage
- Cargo container for transportation

Demonstration Phase (50-100kg/day)

- Build, test, and demonstrate the system
- Identify commercial partners
- Design a 1-2 tonne/day system



# CRYO-COMPRESSED HYDROGEN



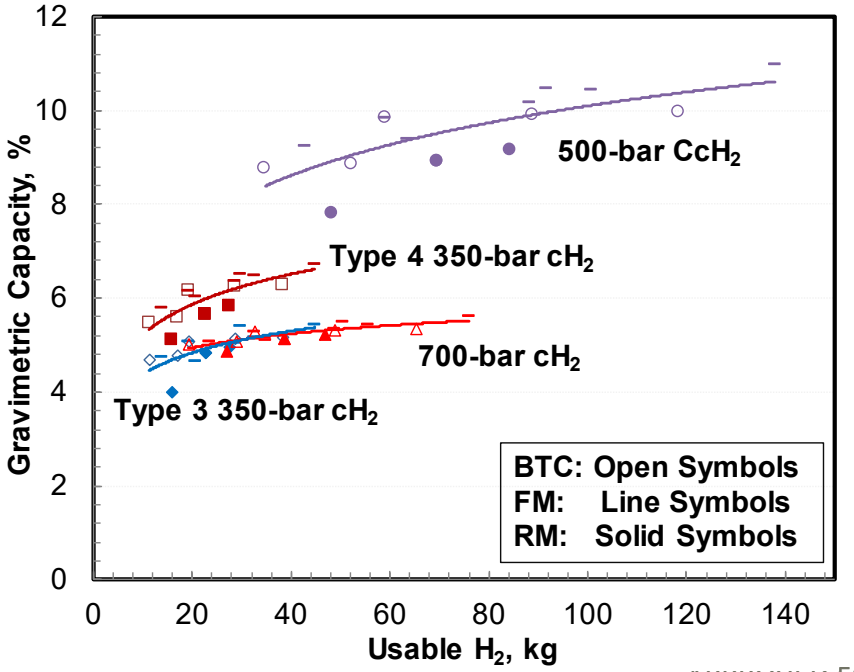

By ILK Dresden, Moritz Kuhn - http://www.ilkdresden.de/en/service/research-and-development/project/hydrogen-test-area-at-ilk-dresden/, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=41458600

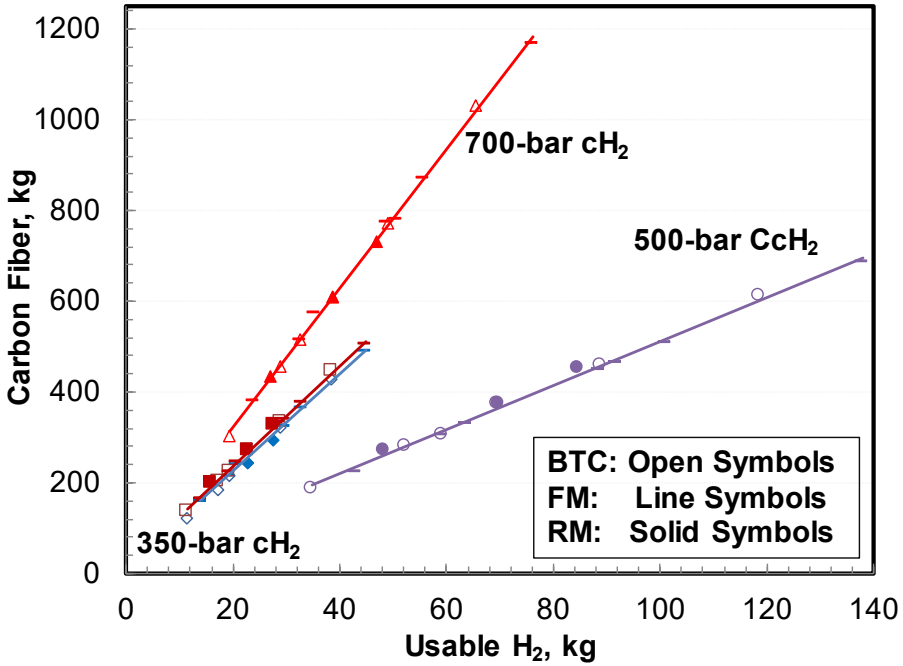
# CRYO-COMPRESSED HYDROGEN

| Layout | Tank Volume (L) | Number of Tanks | Gravimetric Capacity (%) | | | |
|---|---|---|---|---|---|---|
| | | | $cH_2$ 350-bar | | $cH_2$ 700-bar | $CcH_2$ |
| | | | Type 3 | Type 4 | Type 4 | 500 bar |
| BTC | 246 - 415 | 2, 3, 4 | 4.7 - 5.2 | 5.5 - 6.3 | 5.0- 5.3 | 8.8 - 10.0 |
| FM | 301 - 968 | 2 | 4.7 - 5.4 | 5.8 - 6.7 | 5.1 - 5.6 | 9.2 - 11.0 |
| RM | 172 - 298 | 4 | 4.0 - 5.0 | 5.1 - 5.8 | 4.9 - 5.2 | 7.8 - 9.2 |

Ongoing work with Argonne National Lab

- High storage densities
- Low carbon fiber requirements



# SUMMARY

GVSC's Fuel Cell Technologies team must address a wide range of applications and their support

Heavily leveraging ongoing and future work being done by the Department of Energy

High gravimetric and volumetric solutions are a necessity due to maintaining vehicle capabilities, limited available space, logistics burden.

GVSC believes a multi-prong approach is required as H2 storage matures.

# THANK YOU

For more info:
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