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U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND

Ground Vehicle Systems Center Fuel Cell Update

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Fuel Cell Technologies, Ground Vehicle Power & Mobility

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.

DISCLAIMER

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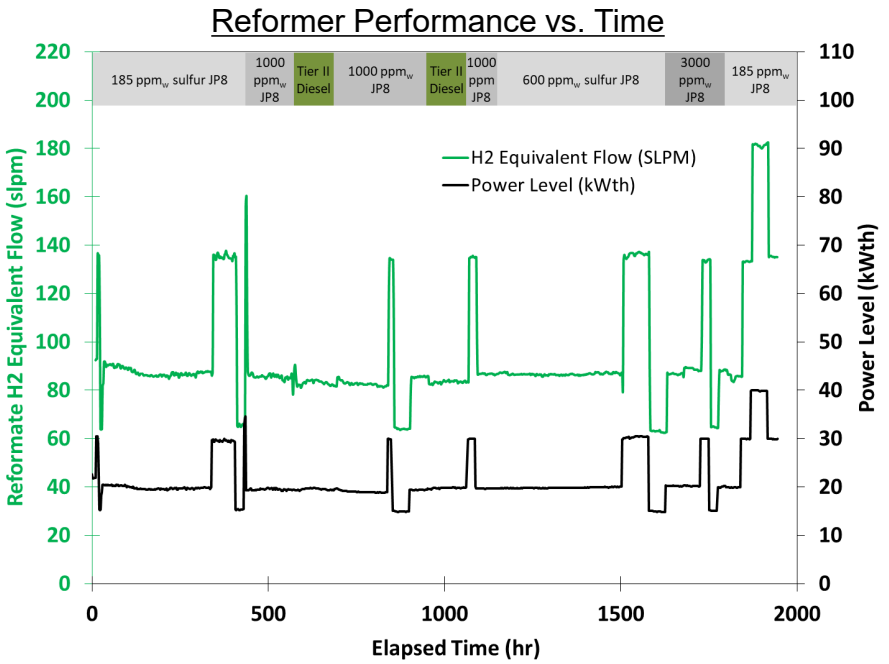
OSD OPERATIONAL ENERGY CAPABILITY IMPROVEMENT FUND JP-8 FUEL CELL



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

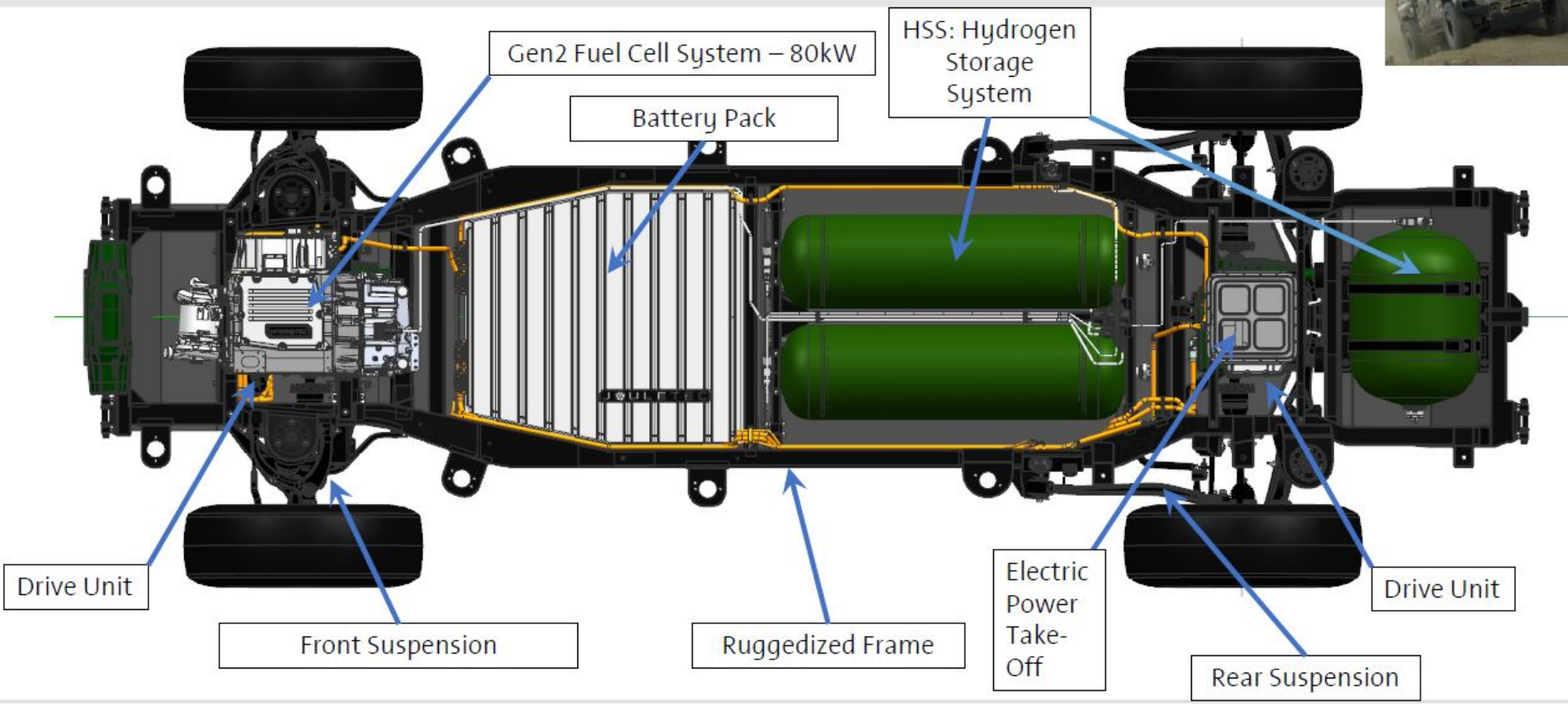
- 18-30 kg H2 per day
- Skid mounted, forklift, 600 lbs
- Low power requirement during operation (~600W)
- Scalable system design

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)

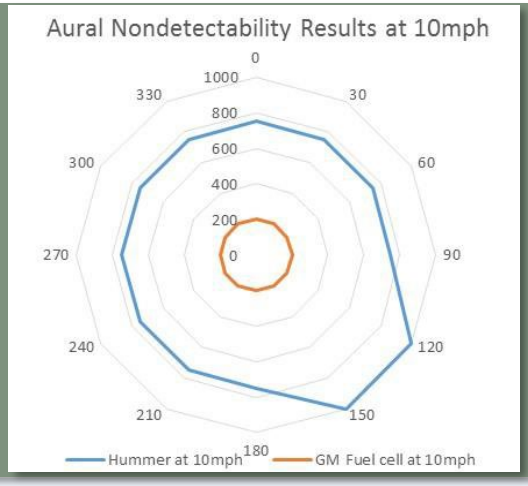
ZH2 in its Undetected Distance from Objective during Night Ops

"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."

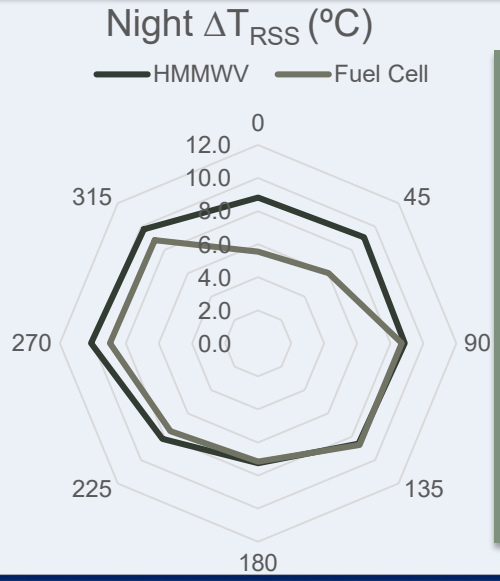
Fuel Cells Enable Silent Mobility and Extended Silent Watch

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.

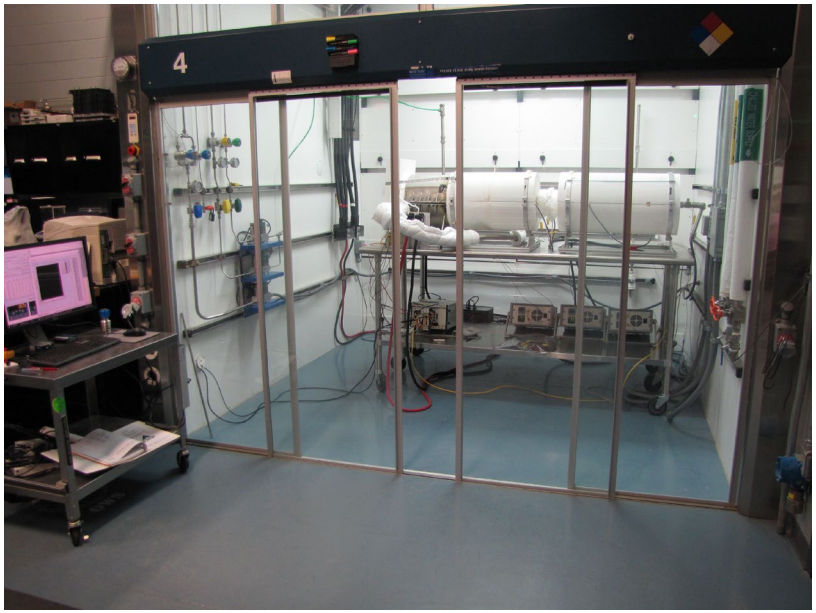
With an integrated approach, 100m non-detectability at 10mph is achievable

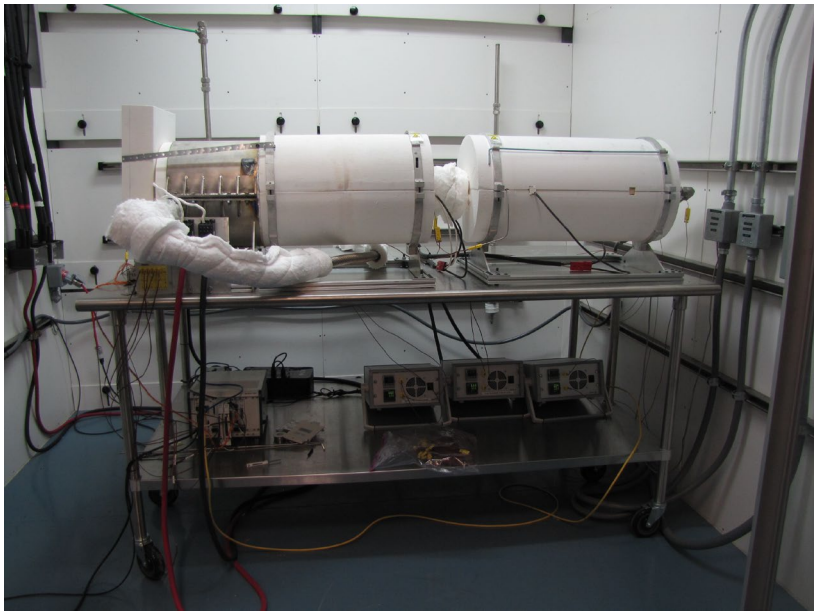


The use of fuel cells and electric drive shows promise to lowering thermal signatures but must be part of an integrated signature design

"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





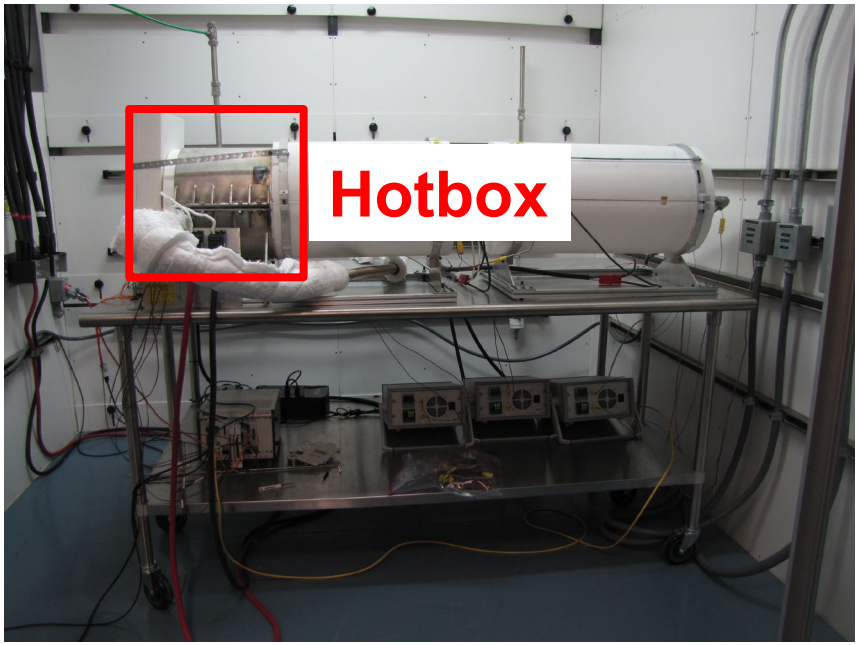
SOFC Testing Equipment:

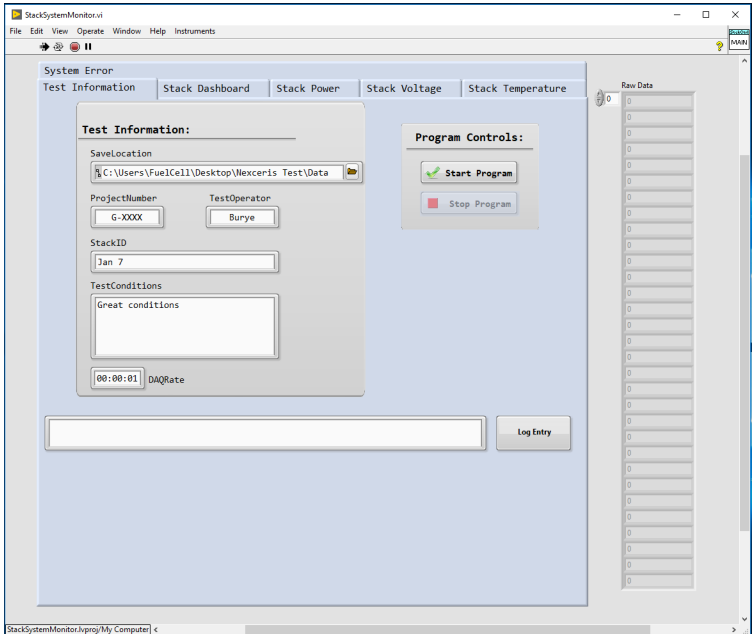
- 1 Hotbox
- 2 Cathode Gas Heaters
- 1 Anode Gas Heater
- 3 Mass Flow Controllers
- Electrical Load Bank

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
5/24/13
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 36 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
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**

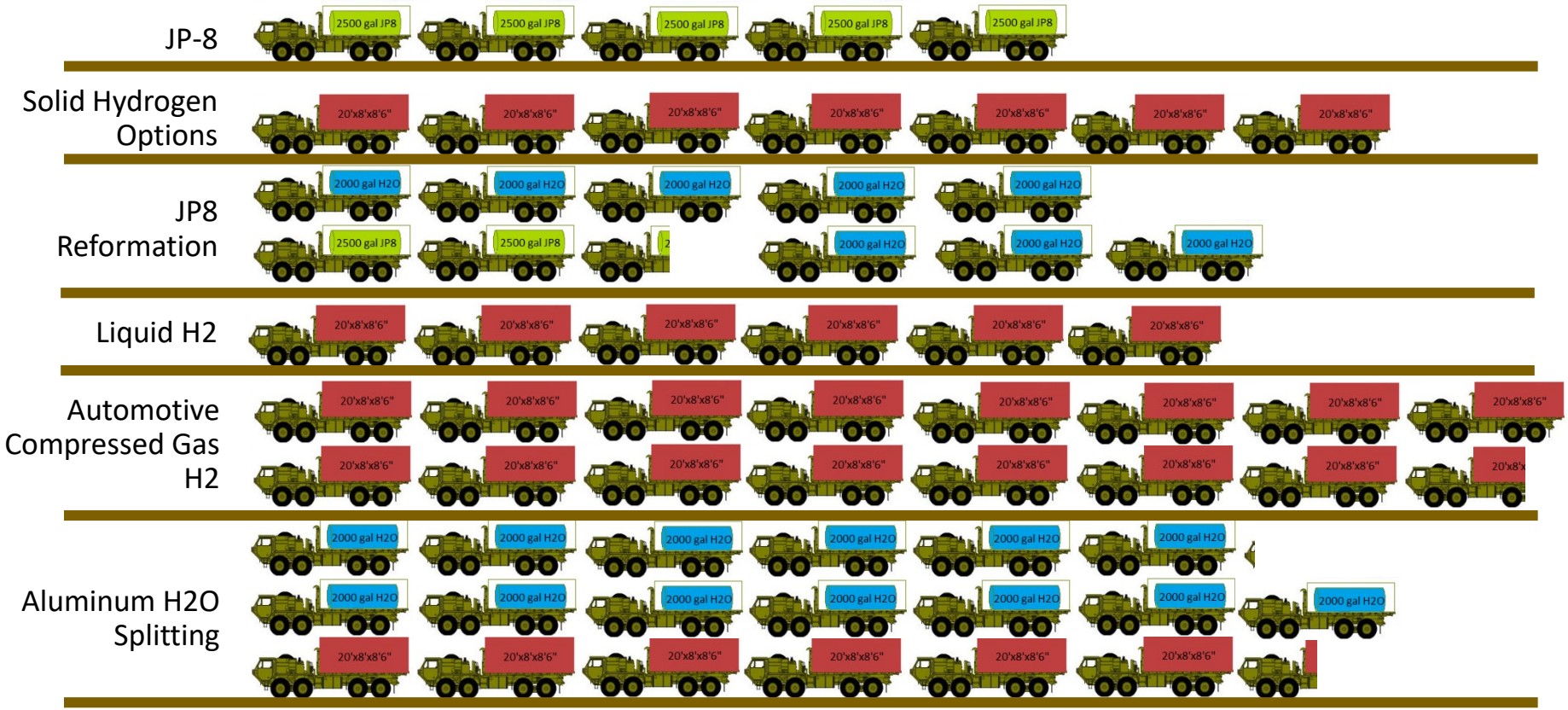
Off-Road Heavy Transport (HEMMT, M977…)
Weight: >35 tons
➔**Est. >80 kg H2**

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

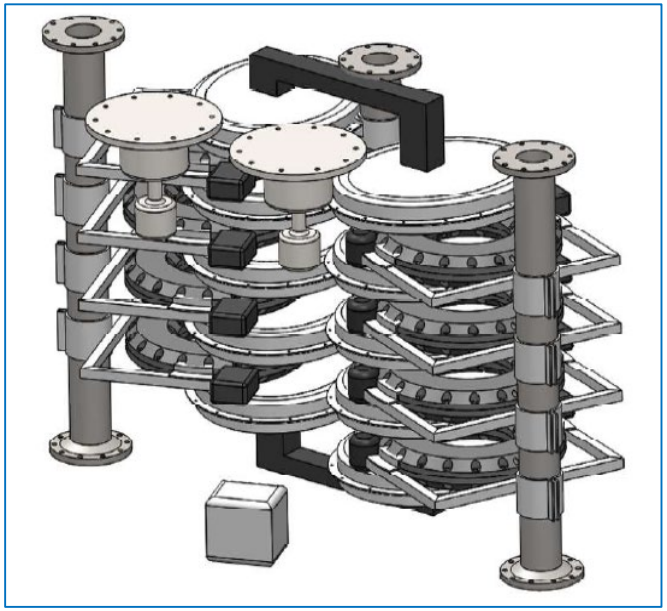
- Reduced cost hydrogen liquefaction hardware
- Reduced energy input requirements

Design Phase (50-100kg/day)

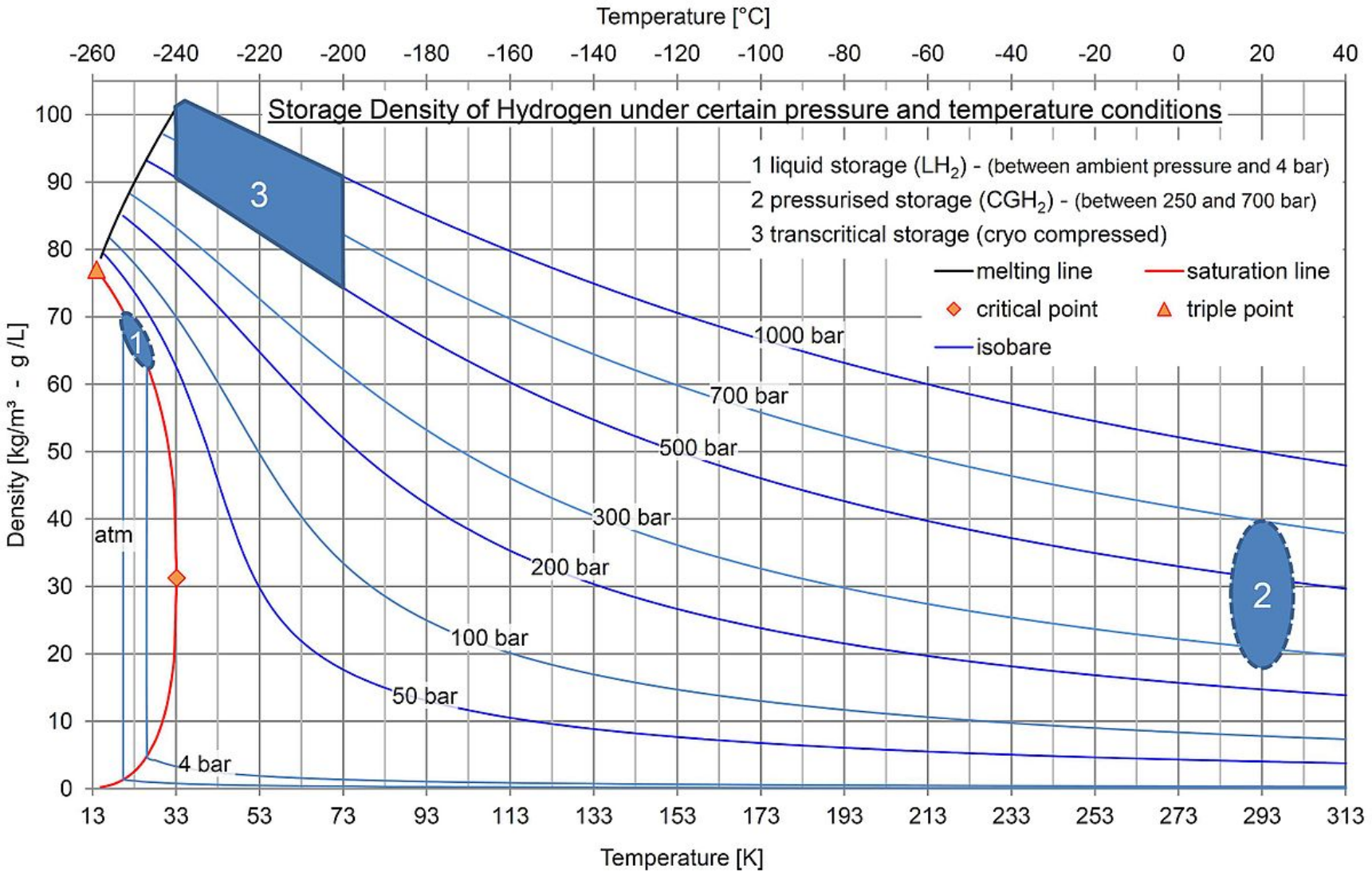
- Multiple stages (3-4)
- 2-3 layers of materials per stage
- Cargo container for transportation

Demonstration Phase (50-100kg/day)

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



CRYO-COMPRESSED HYDROGEN



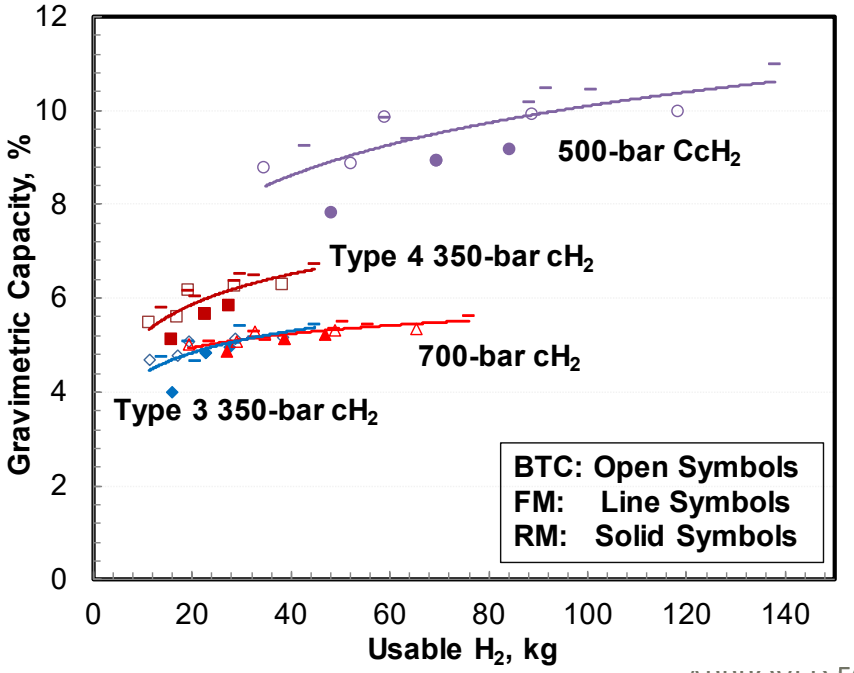
By ILK Dresden, Moritz Kuhn - http://www.ilkdresden.de/en/service/research-and-development/project/hydrogen-test-area-at-ilk-dresden/, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=41458600

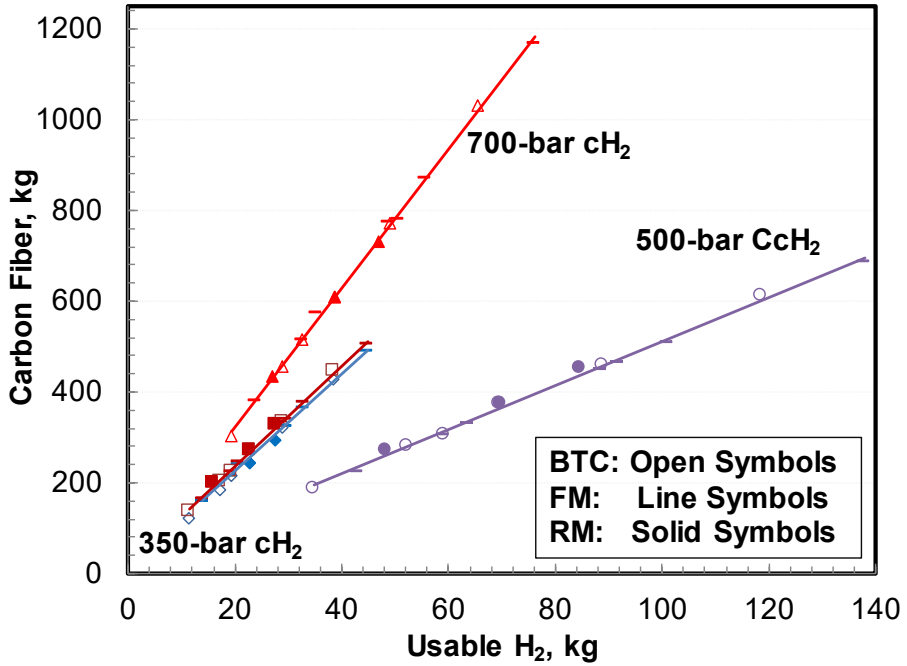
CRYO-COMPRESSED HYDROGEN

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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