Closing the ISRU Cycle: Integrated Fuel Cell Deployment

Natural Resources Canada

EVC
ELECTRIC VEHICLE CONTROLLERS LTD.
DC ELECTRIC CONTROL AUTOMATION

PACEAS

2008 Deployment

- ROXYGEN
- Electrolyzer
- Rovers
- RESOLVE
- Lockheed Martin PILOT

- Exercise in team integration and experiment demonstration
- Processing plants had no consumers for the products generated.
- Closed-loop ISRU was not demonstrated.

2010 Deployment

- RESOLVE
- Carbothermal Reactor
- Solar concentrator
- Electrolyzer
- Fuel Cell
- Lo2 and Thrusters
- Rovers and payloads
- Multi Agent Teaming
- Science experiments
- Pneumatic Regolith Delivery
- Sintering

- Closed-loop ISRU demonstration was mandated.
- International co-operation led to experiment compatibility.

Fuel Cell Integration Partners

• Canadian Space Agency	➢ Funding Agency
• Electric Vehicle Controllers Ltd.	➢Project Lead and power conditioning system (output)
• Northern Centre for Advanced Technology	➢Project administration and interface to rover chassis
• Natural Resources Canada	➢Supplied the Fuel Cell and participated in operations and maintenance during deployment
• PACEAS	➢Fuel Cell and sub system Integration
• NASA	➢Provided stationary hydride tanks, electrolysis unit supplied hydrogen to stationary and mobile hydride tanks

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The Fuel Cell Integration Concept

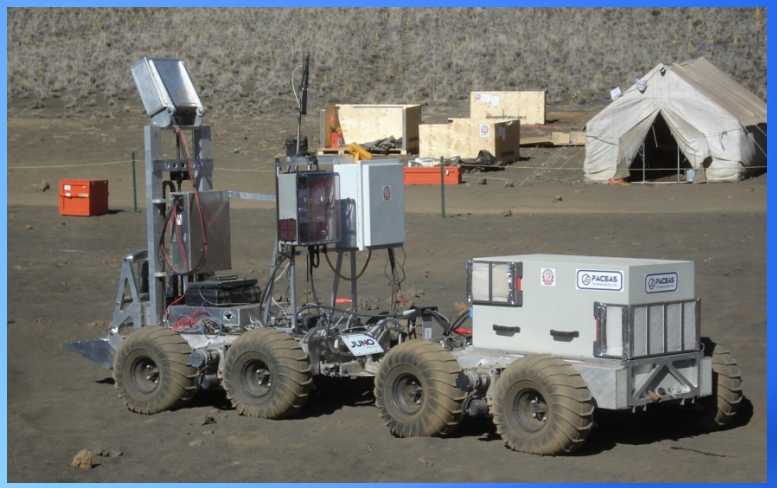
- In static configuration:
  - Fuel cell was powered by hydrogen collected from the electrolyzer and stored in stationary hydride tanks
  - The fuel cell would supply AC power to the Carbothermal Reactor, Electrolyzer and LO2.
- In mobile mode:
  - Mobile Fuel Cell supplied an AC inverter. AC inverter connected to a battery charger and the batteries were charged while the rover was in operation
  - Fuel Cell was powered by hydrogen collected from the electrolyzer and stored in the mobile hydride tanks

Technology Description

- Integrated air breathing hydrogen fuel cell
  - Fuel Cell
  - Overall system controller
  - Energy management system
  - Cooling system
  - Hydrogen leak detection system
  - Hydride storage tanks

Technology Application

- Stationary and mobile and configurations



Optimization

- Three month development cycle
- Fuel Cell was built in 2004
- Fuel Cell system is a first generation prototype
- The unit is an air-breathing Fuel Cell, not capable of operating in non-terrestrial environments
- Fuel Cell was vulnerable to cold temperatures
- Fuel Cell was over-sized for the application
- AC inverters did not deliver to their rated capacity
- Electrolyzer could not fully charge the hydride tanks

Load-Haul-Dump Rover

Processed Tephra

H_2 (gas)

Tephra

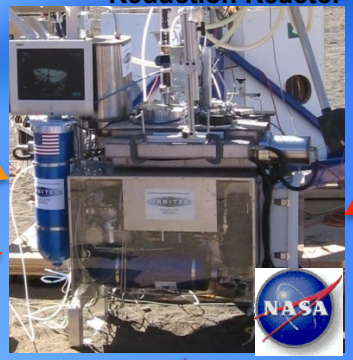
Carbothermal Reduction Reactor

Sunlight

Electricity

Fuel Cell

O_2 (air)



H_2 (gas)

H_2 (gas)

H_2 Hydride Storage

H_2 (gas)

Electricity

Electricity

H_2O (liquid)

O_2 (gas)

Water Electrolysis

H_2 Hydride Storage

H_2 (gas)

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Where to go from here

- Apply lessons learned to understanding potential commercial applications.
- Apply lessons learned to help define the steps necessary for ISRU.
  - Oxygen-breathing fuel cell
  - Optimize fuel delivery system
  - Cold temperature operation
  - Integration to next-generation rover
  - Reduce overall footprint
  - Eliminate AC inverters
  - Develop DC to DC converters – various voltages required

Questions