FUELCELL RAIL

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Background

FUELCELL MINE LOCOMOTIVE

- **Completed 2002**
- **3.6 metric tons**
- **17 kW PEM fuelcells**
- **3 kg hydrogen as metal hydride**

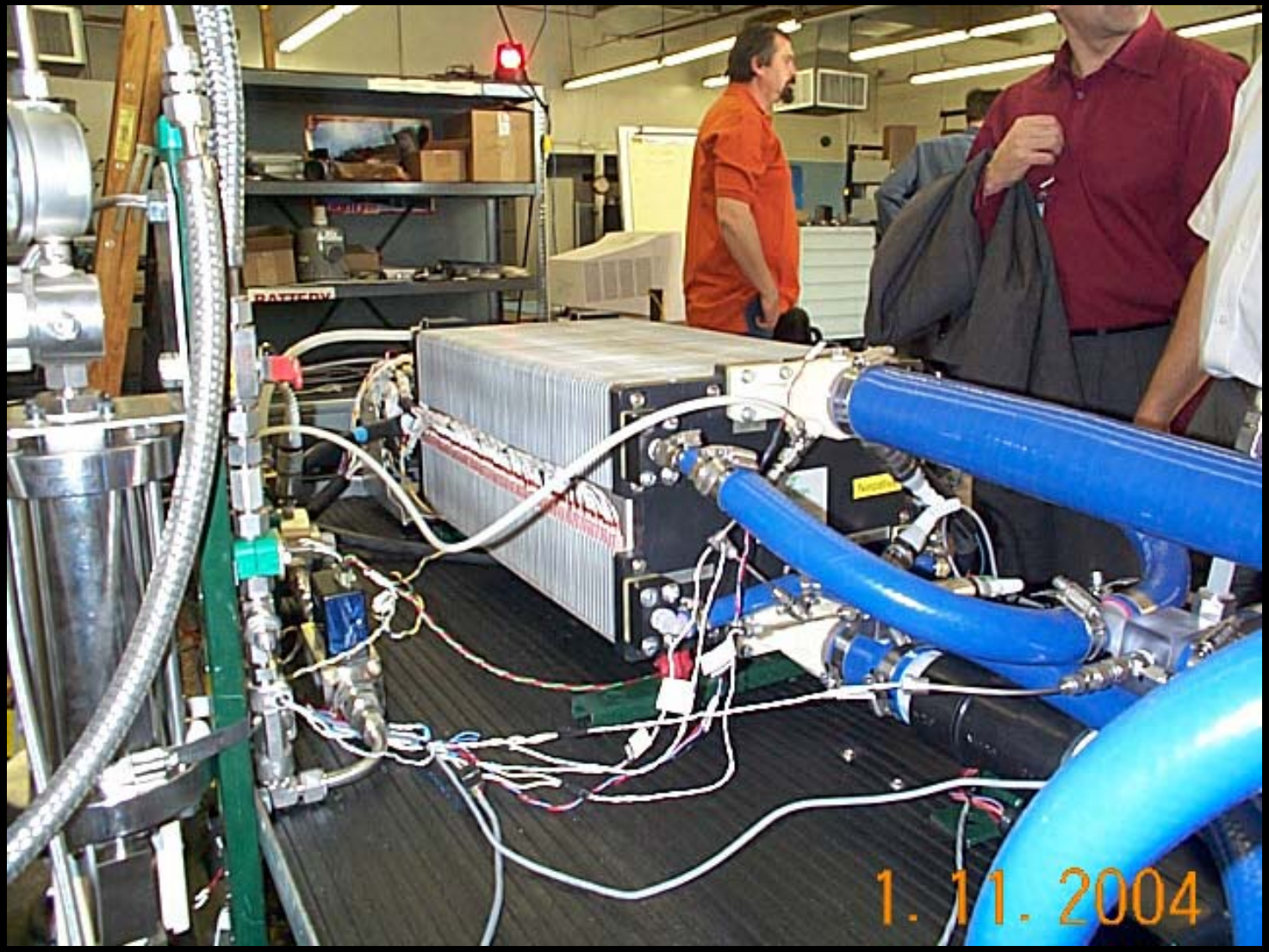
Background

FUELCELL MINE LOADER

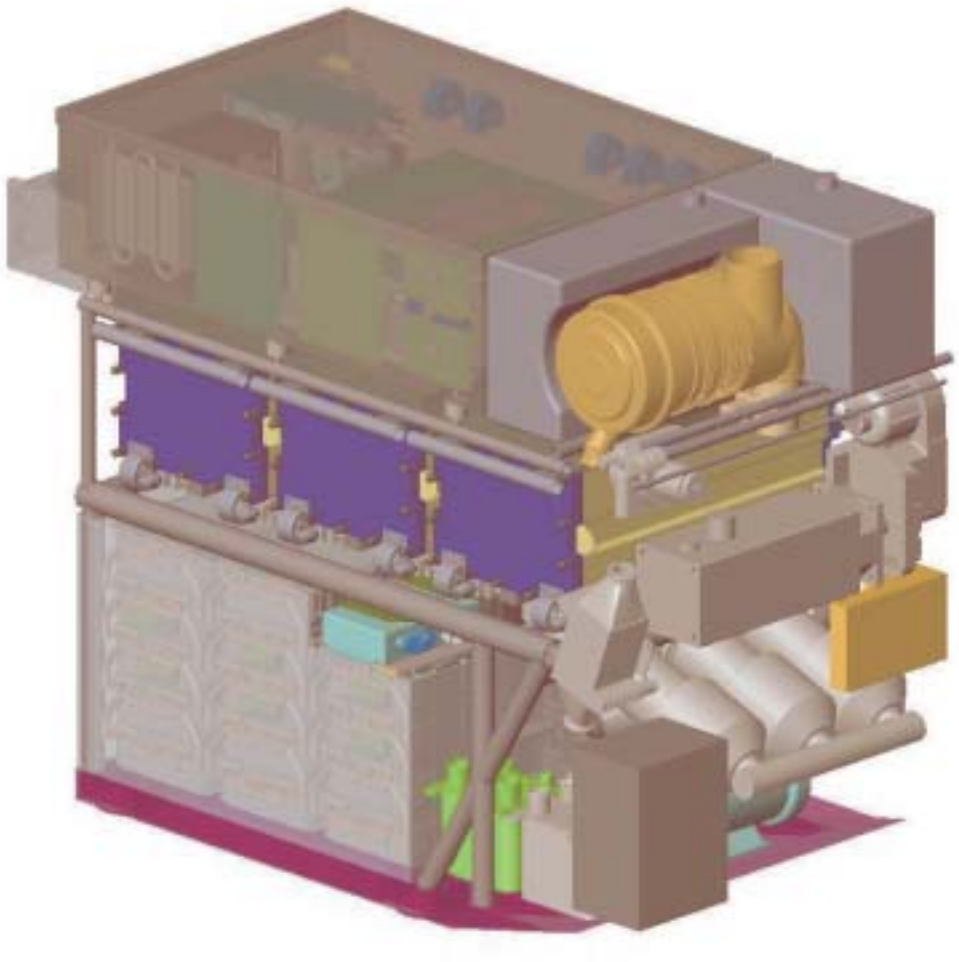
- **23 metric tons**
- **160 kW (max) fuelcell-battery hybrid**
- **90 kW (cont) PEM fuelcells**
- **15 kg hydrogen as metal hydride**

Caterpillar-Elphinstone diesel base vehicle

FUELCELL STACK UNDER TEST



LOADER FUELCELL POWERPLANT



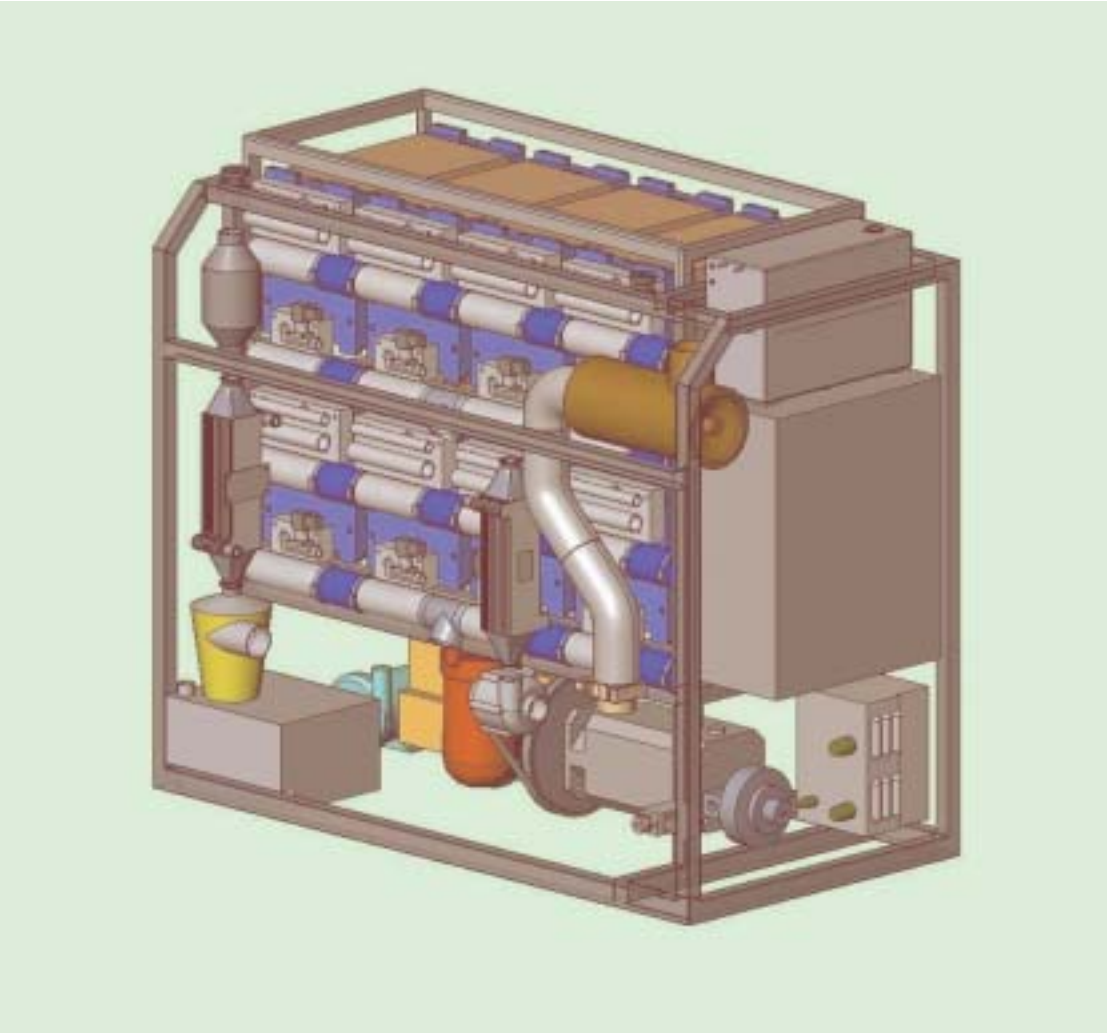
Overview

FUELCELL LOCOMOTIVE

- **109 metric-ton road-switcher**
- **1.2 MW (gross) fuelcell power**
- **No traction battery**
- **250 kg hydrogen storage**

Photo of diesel-electric base vehicle by Shane Deemer

LOCO 150 KW POWERPLANT MODULE



RAILWAY LOCOMOTIVE ISSUES

- **Energy security (mainly of imported oil)**
  - Diminishing reserves
  - Political instability of exporting regions
- **Energy cost**
  - Fuel cost/efficiency
  - Fuel price: volatile, high, increasing
- **Emissions–particulate and acoustic noise**
- **Infrastructure cost for electrification**
  - Coal or nuclear could solve above problems except efficiency
  - Cost prohibitive for low population density

HYDROGEN STORAGE

Commercially Established Methods

- **Direct Storage of Hydrogen**
  - Compressed gas
  - Liquid
  - Reversible metal hydrides
- **Onboard Reforming of Feedstock**
  - Hydrocarbons, for example, methane (CH_4)
  - Methanol
- **Onboard Dissociation of Ammonia (NH_3)**

PROS AND CONS

- **Positive**
  - Hydrogen and ammonia are renewable (nuclear primary energy)
  - Highest efficiency of the technologies
  - Zero vehicle emissions, low acoustic noise
  - Relatively low infrastructure cost
- **Neutral**
  - Safety
  - Performance
- **Negative**
  - Present high capital cost of fuelcells and hydrogen storage
  - Requires establishment of a new fuel infrastructure

PROGNOSTICATIONS

- **Primary energy: Nuclear, especially thermal water splitting**
- **Onboard fuel**
  - Advanced metal hydrides for subways (for safety)
  - Advanced metal hydrides for switchers and light rail (depot-centric)
  - Ammonia, methanol, or LNG for line-haul, high-speed, or commuter rail
- **Fuelcell types**
  - PEM for switchers, subways, and light rail (for power density)
  - PEM or SOFC (efficiency) for line-haul, high-speed, or commuter rail
- **Hybridity**
  - Battery or flywheel for subways and light rail (for accel/deccel with all axles powered)
  - None for switchers, line-haul, high-speed, and commuter rail

CONCLUSIONS

- **Fuelcell locomotives potentially offer the best of two worlds:**

  (1) Flexibility, efficiency, and low infrastructure cost of the diesel-electric locomotive

  (2) Zero vehicle emissions, low noise, and oil-independence of the catenary electric locomotive

- **The US should commence development of this technology ⇒ energy security, efficiency, environmental quality**