2004 DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Review Presentation

Fuel Cell Powered Underground Mine Loader Vehicle

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This presentation does not contain any proprietary or confidential information

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Objectives

Project Objectives

- Develop a metal-hydride, fuelcell-powered mine loader equivalent to a Caterpillar-Elphinstone R1300.
- Evaluate the vehicle in an underground mine in Nevada

Past Year Objectives

- Complete Reports Including:
  - Demonstration of an Electrolysis System for Fuelcell Mining Vehicles
  - Best Methods of Hydrogen Transfer
  - Operating Costs of Hydrogen Production
  - Ventilation Benefit Analysis for Canadian Mines
  - Cost Benefit Analysis of US Underground Mines
  - Capital and Recurring Cost Benefit Analysis for Canadian Mines

Objectives – Continued

Past Year Objectives – con't

- Determine Traction Motor
  - Induction versus Brushless Permanent Magnet (BPM)
- Determine Battery-Hybrid Configuration
  - Sizing of batteries to support duty cycle
- Determine Metal-Hydride Amount and Configuration
  - Weight limitation
- Complete Engineering Design

Budget

Phase 1	$ 926,670	
Phase 2	$3,165,400	
Phase 3	$4,525,303	
Total:	$8,617,373	
Total DOE Funds:	$4,239,198	49.2%
Total NRCan Funds:	$ 599,500	7.0%
Placer Dome Funds:	$ 225,000	2.6%
Newmont Mining Funds:	$ 100,000	1.2%
Total In-Kind Cost Share:	$3,453,675	40.0%
FY04 DOE Funds:	$1,550,000	46.7%
FY04 Contractor Funds:	$1,770,000	53.3%
FY04 Total:	$3,320,000	

Technical Barriers and Targets

- DOE Technical Barriers for Technology Validation
  - A. Vehicles
    - Demonstration of complete system
  - B. Storage
    - On-board metal-hydride storage
  - C. Hydrogen Refueling Infrastructure
    - On-site hydrogen production by electrolysis

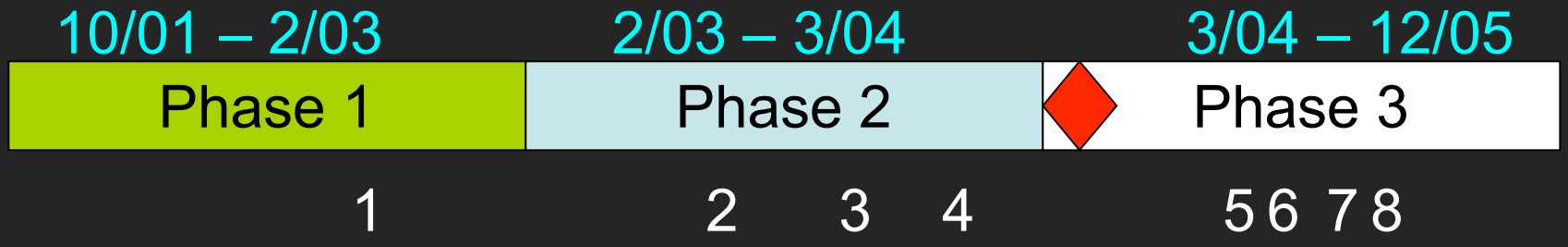
Approach

- Perform cost-benefit analysis
- Determine operational duty cycle
- Conceptual design
- Detailed engineering design
- Risk assessment
- Fabricate subsystems
- Vehicle integration and test
- Demonstration of vehicle underground

Project Safety

- Risk assessment to identify operational safety and health risks
- Individual failure mode and effects analysis (FMEA) on subassemblies
- Regulatory review including MSHA acceptance
- Lessons learned from DOE Fuelcell-Powered Underground Mine Locomotive Project Risk Assessment

Project Timeline



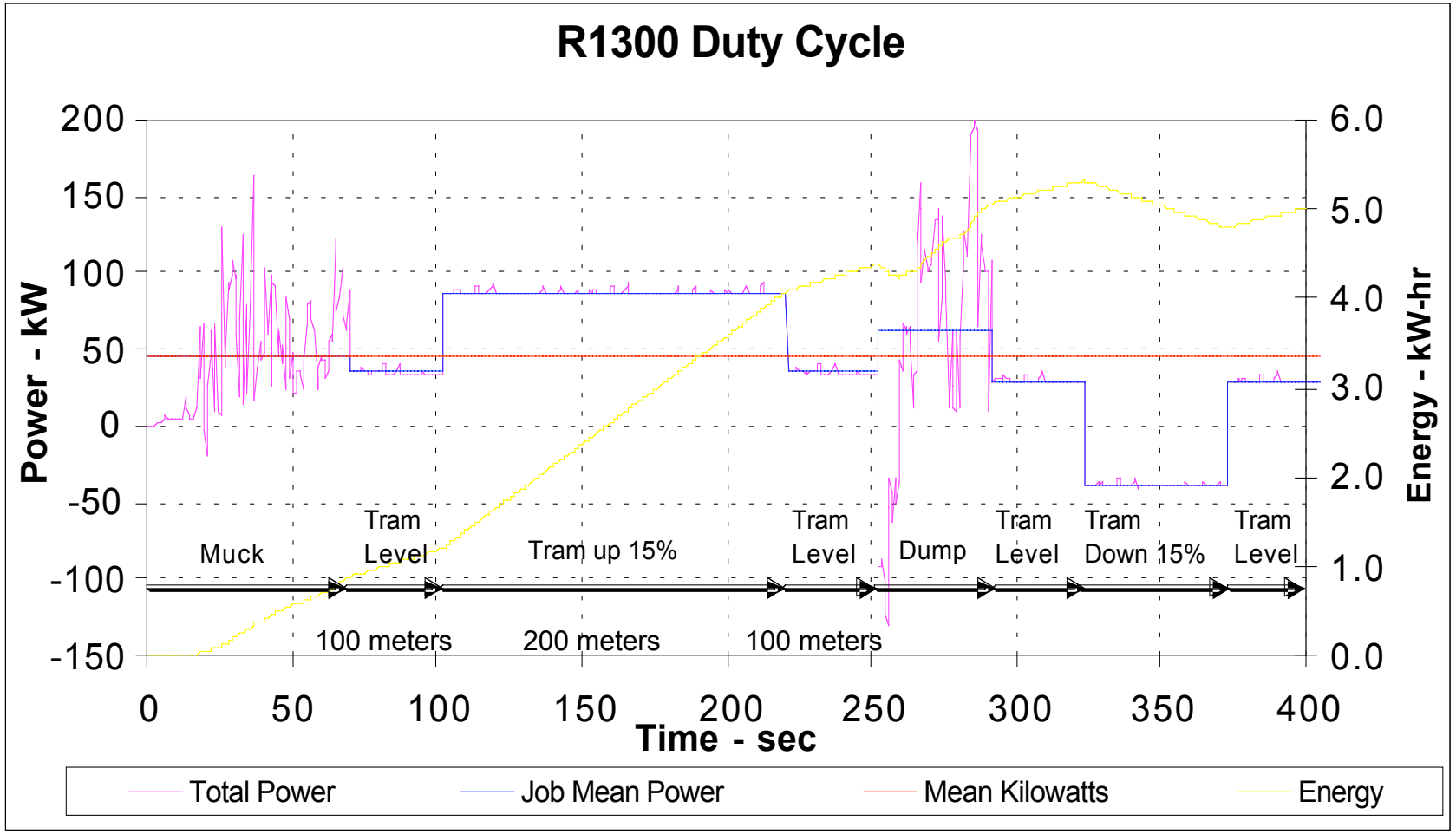
- Phase 1- Cost Benefit Analysis and Preliminary Design
  - 1 Demonstrate electrolyzer refueling station
- Phase 2 – Detailed Engineering Design
  - 2 Receive R1300 diesel loader
  - 3 Select battery-hybrid configuration and regenerative braking
  - 4 Receive 87 kW gross continuous fuelcell stacks
- Phase 3 – Fabrication, Integration, and Demonstration
  - 5 Deliver 150 kW battery-fuelcell hybrid powerplant
  - 6 Deliver metal-hydride storage (15kg H_2)
  - 7 Vehicle integration and test
  - 8 Underground demonstration (3 mines)

Technical Accomplishments/Progress

Detailed design includes:

- Fuelcell-battery hybrid powerplant
- 70 kW continuous, 140 kW peak (net)
- Removable metal-hydride storage
- Regenerative braking
- 340 kW (450 hp) DC BPM traction motor
- Separate 100 kW hydraulic BPM motor

Technical Accomplishments/Progress



Drawing Courtesy Southwest Research Institute and Vehicle Projects LLC

Technical Accomplishments/Progress

Fuelcell Stacks Manufactured by Nuvera Fuel Cells Inc.

- 87 kW gross (total)
- 290 V, 300 A full load
- Air pressure 2.0 bara
- H_2 pressure 2.2 bara
- Air stoichiometry 2.0
- Operating temp 60-75° C
- Air RH = 80-100% @ 70° C
- External air humidification
- Fuel loop dead-end mode
- Weight 280 kg
- Volume 220 L

Technical Accomplishments/Progress

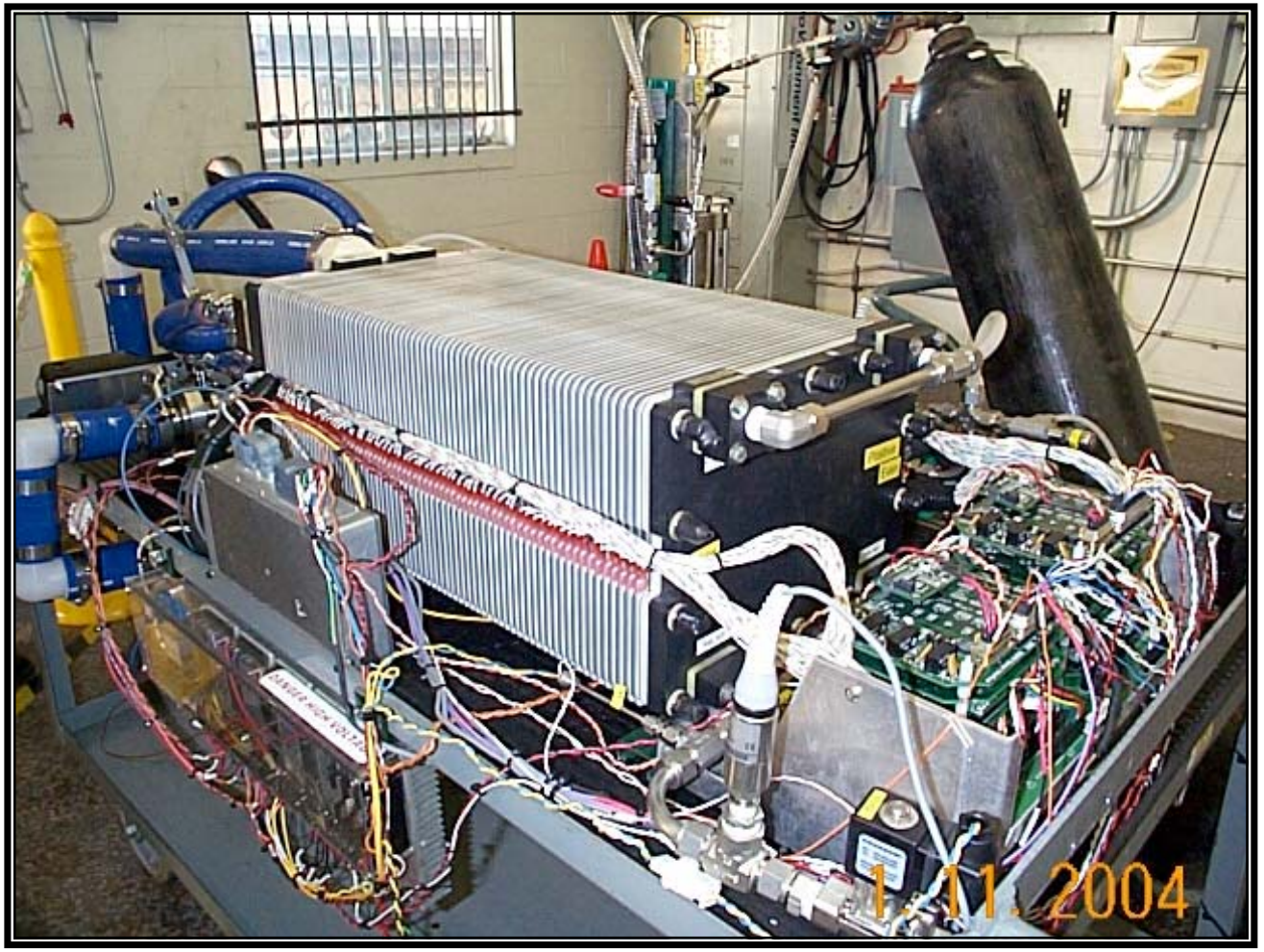
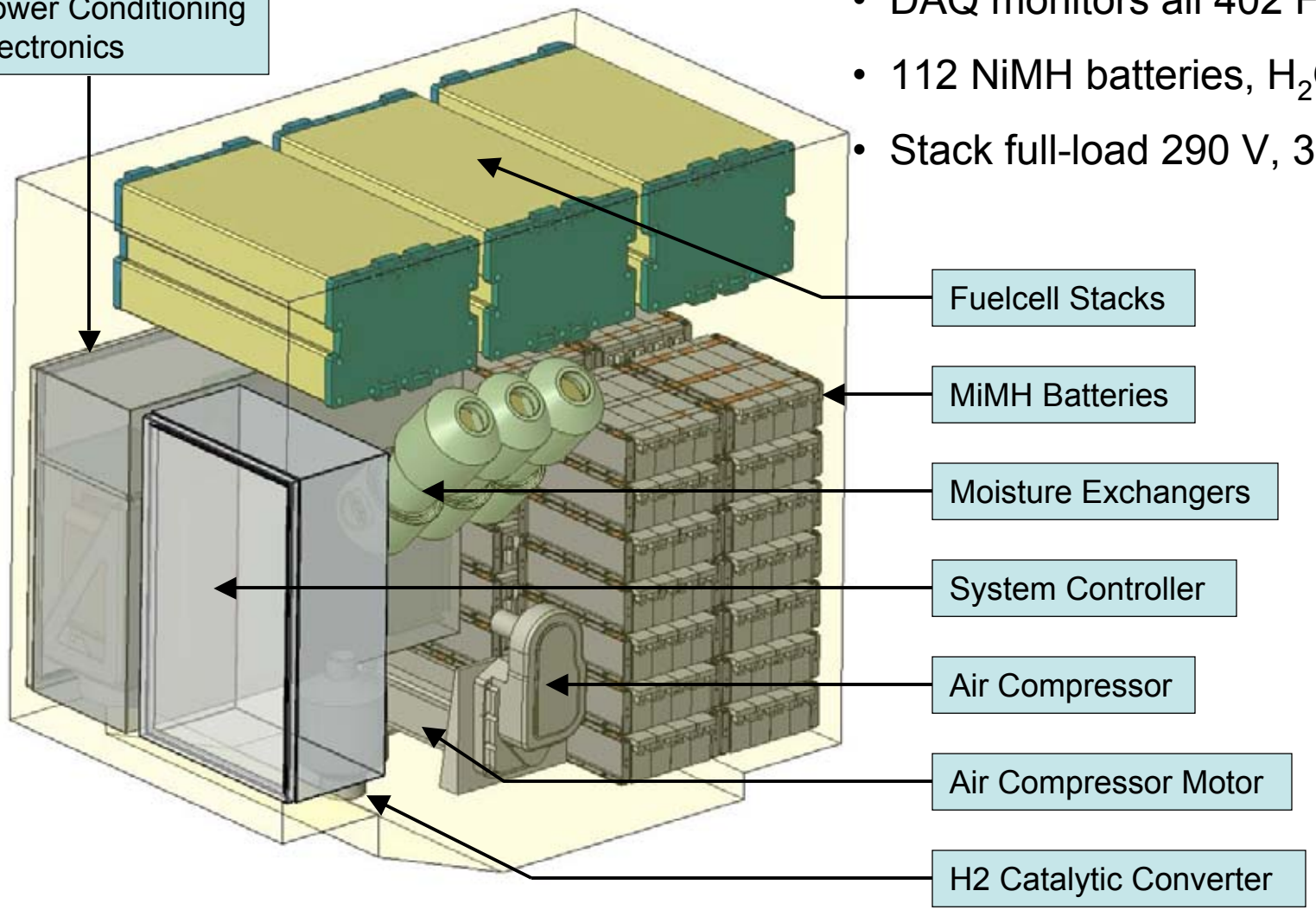


Photo Courtesy Vehicle Projects LLC

Fuelcell Stacks Bench Tested at AeroVironment Inc.

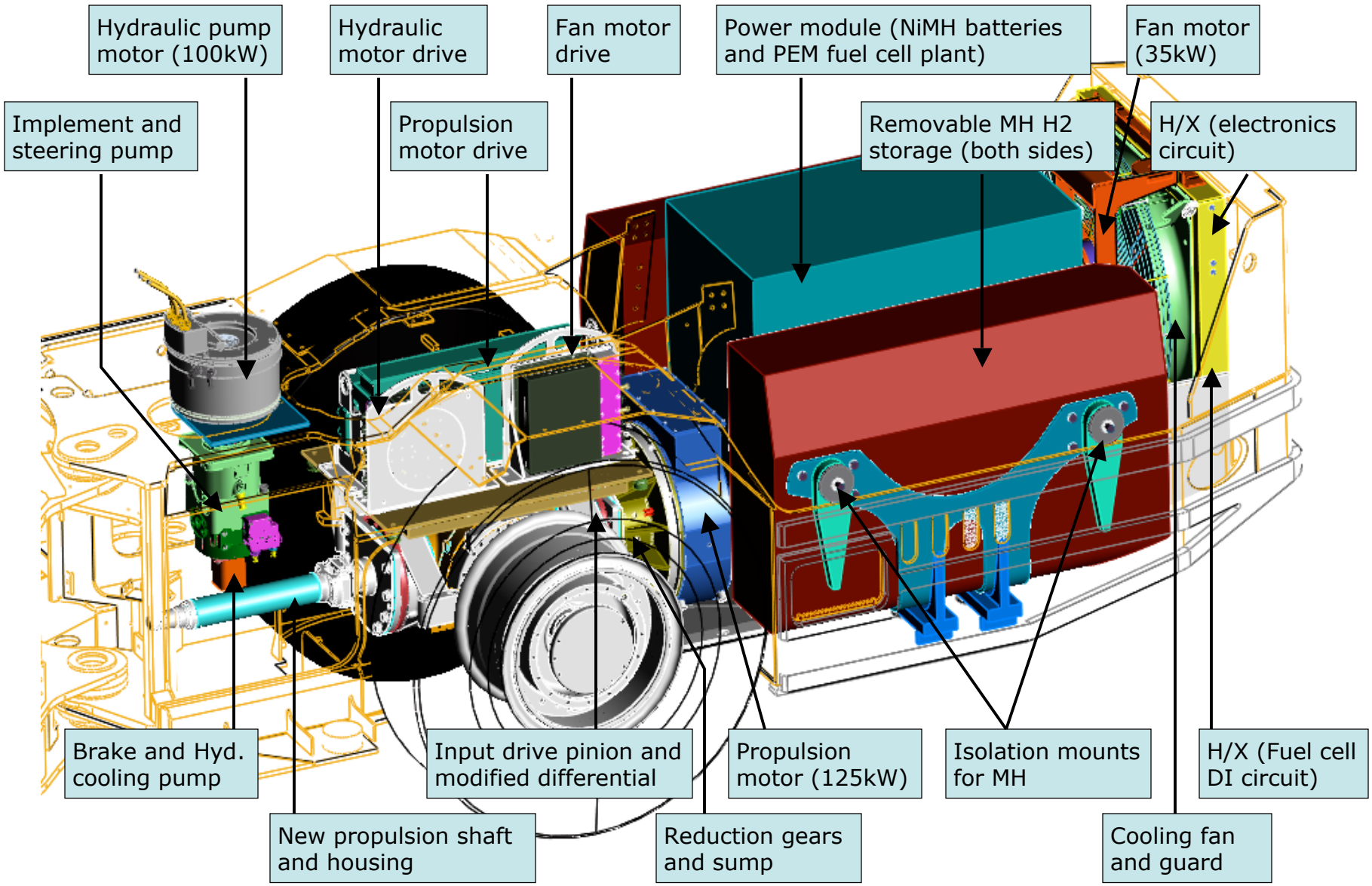
Technical Accomplishments/Progress

- DAQ monitors all 402 FC cells
- 112 NiMH batteries, H_2O cooled
- Stack full-load 290 V, 300 A (gross)



Drawing Courtesy AeroVironment Inc.

Technical Accomplishments/Progress

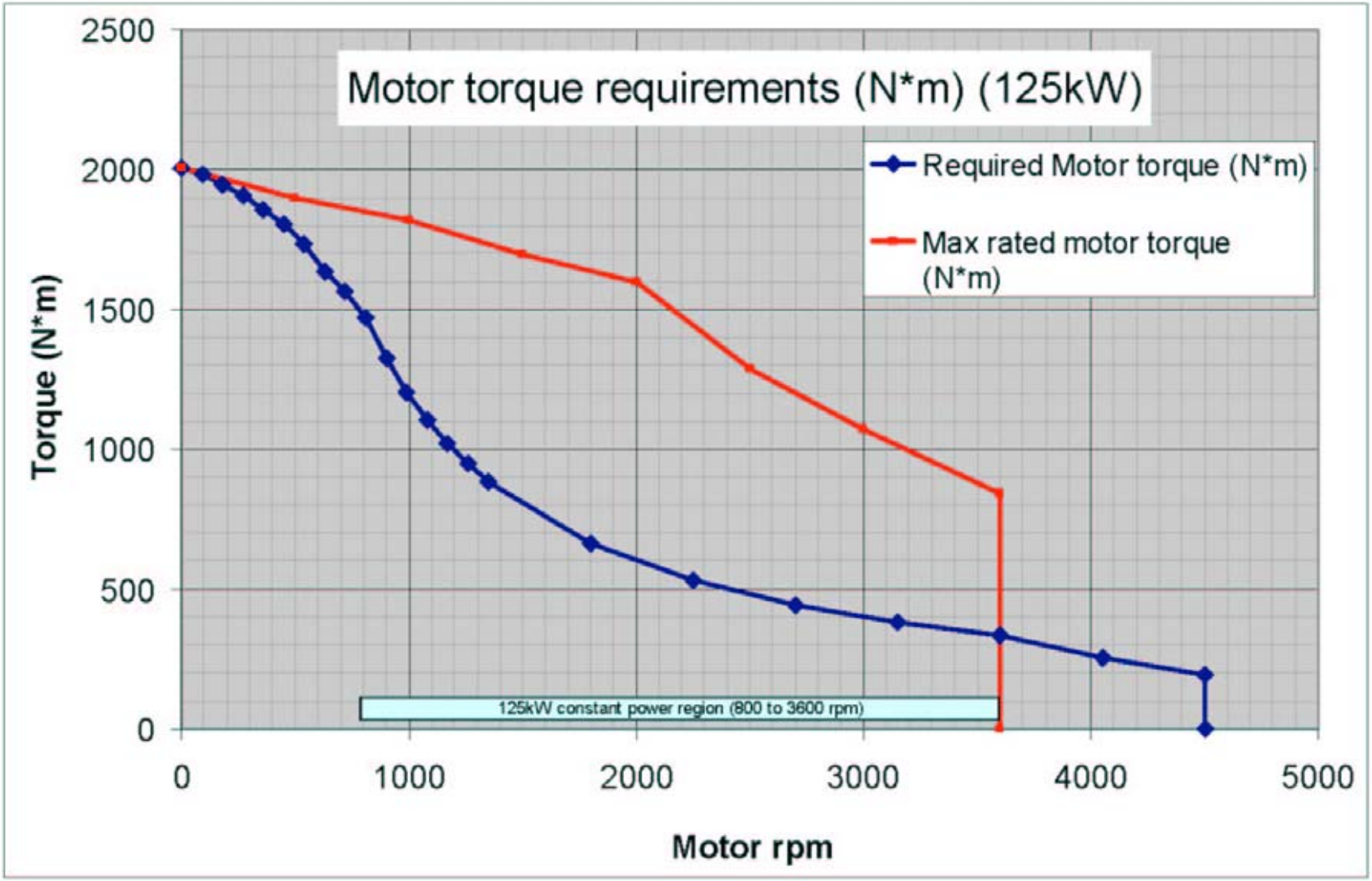


Drawing Courtesy Caterpillar Inc.

Technical Accomplishments/Progress

- Battery configuration
  - Cobasys (formerly Ovonics) NiMH batteries
  - Single battery rated at 12 V, 8.5 AH
  - 56 in series of 2 each in parallel
  - Module rated at 672 V, 17 AH, 11.42 kWH nominal
  - Maximum battery power up to 2 minutes will provide additional 65 – 70 kW

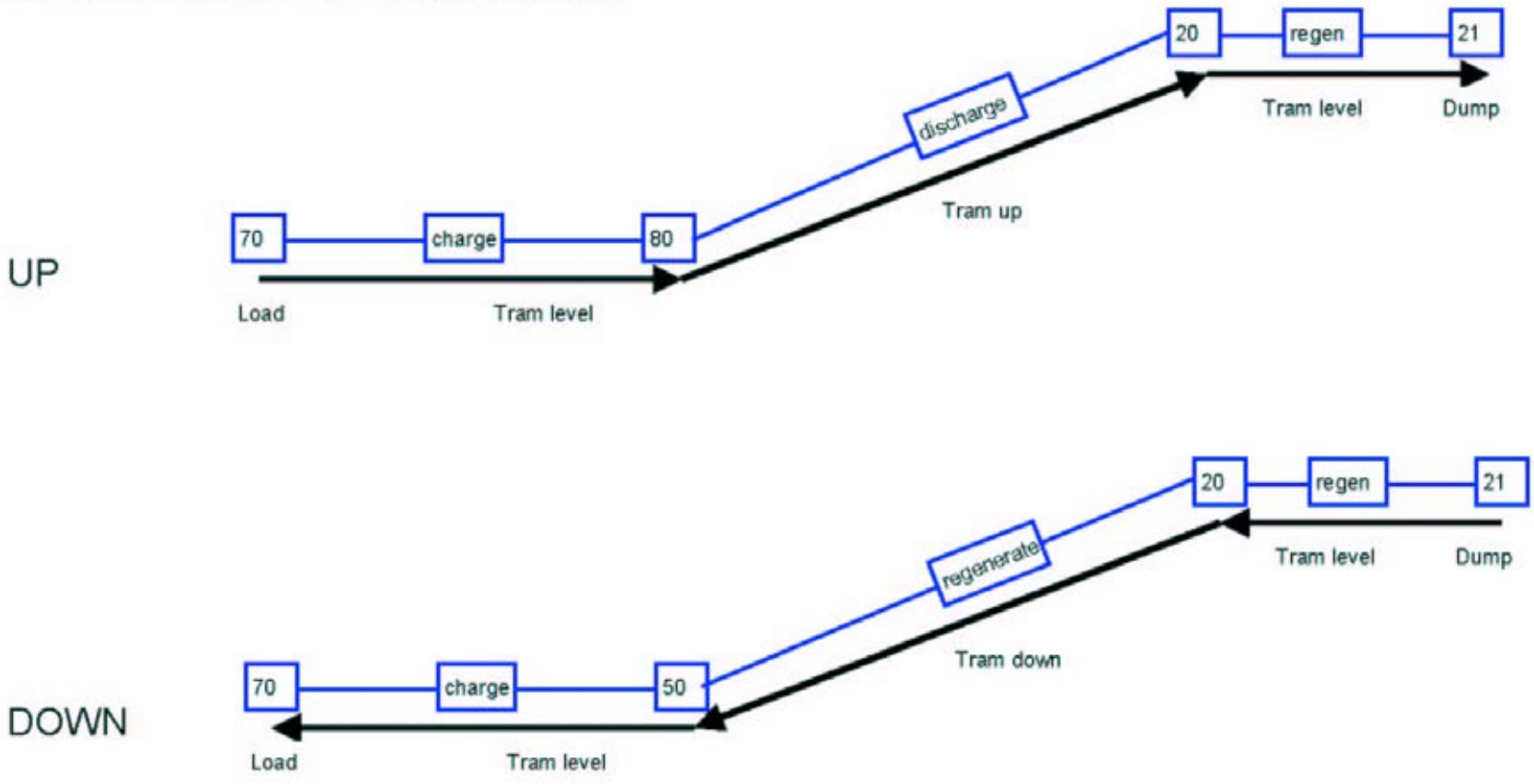
Technical Accomplishments/Progress



Drawing Courtesy Caterpillar Inc.

Technical Accomplishments/Progress

Assume battery is cycled from 20 to 80% during each cycle.
80% leaves head-room for regen braking.



Interactions and Collaborations

Engineering and Manufacturing

• AeroVironment Inc.	Balance of Plant
• Caterpillar Inc.	Vehicle Integration
• Caterpillar-Elphinstone	R1300 LHD Loader
• DRS-Technologies	Traction Motor
• HERA Hydrogen Storage	Metal-Hydride Storage
• Modine Manufacturing Co.	Heating and Cooling
• Nuvera Fuel Cells Inc.	Fuelcell Stacks
• Stuart Energy	Hydrogen Refueling Station

Interactions and Collaborations

Engineering and Consulting

• Hatch	Risk Assessment, Regulatory
• Placer Dome Technical Services	End-User Oversight
• Southwest Research Institute	Duty Cycle / Energy Modeling
• WSMS	Hydrogen Risk Analysis

Academia

• University Nevada – Reno	Ventilation Evaluation
• Carleton University	Software Simulation

Interactions and Collaborations

Government

• CANMET (Canadian)	Tech. Transfer, Demo Oversight
• MSHA	Regulatory Oversight

End-Users

• Agnico-Eagle Mines Ltd.	Mine Demonstration
• Newmont Mining Corporation	Mine Demonstration
• Placer Dome Ltd.	Mine Demonstration

Responses to Previous Year Reviewer's Comments

Project not presented last year

Future Work

- Remainder of FY 2003
  - Fabrication/Assembly of Fuelcell Powerplant, Metal-Hydride Storage
  - Loader Teardown and Preparation
  - Test Traction Motor and Reduction Gear
  - On-going Risk Assessment and Regulatory Review
- FY 2004
  - Vehicle Integration
  - Vehicle Commissioning
  - Complete Risk Analysis and Regulatory Review
  - Underground Mine Demonstrations (3 mines)