

# FUELCELL LOCOMOTIVES FOR ZERO-EMISSIONS URBAN RAIL



Our fuelcell-hybrid switcher platform, above, is based on the commercial diesel-battery hybrid Green Goat™. (Photo courtesy of RailPower Hybrid Technologies)

**Arnold R. Miller, PhD**  
President  
Vehicle Projects LLC  
Denver, Colorado, USA

**Statewide Railyard Agreement  
Technology Symposium**

El Monte, California  
28 November 2007



*DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.*

Copyright © 2007 by Vehicle Projects LLC



## *WHY FUELCELL LOCOMOTIVES?*

- **Catenary-electric locomotives have good environmental characteristics at the vehicle but are the least energy efficient and most costly type**
- **Diesel-electrics are more efficient and have a less costly energy infrastructure but exhibit high chemical and acoustic emissions at the vehicle**
- **Fuelcell locomotives couple the best advantages of both and are the key to zero-chemical, low-acoustic emissions electric locomotives in low population-density areas**





## *PROJECT OBJECTIVES*

**An industry-government partnership is developing and will demonstrate a fuelcell-hybrid switcher locomotive leading to commercial locomotives that:**

- Reduce air and noise pollution in urban rail applications, including yard-switching associated with seaports. (To be demonstrated in the LA Basin)
- Serve as a mobile backup power source (“power-to-grid”) for military bases and civilian disaster relief efforts. (To be demonstrated at Hill AFB, Utah)



# HIGH-POWER FUELCELL VEHICLE DEVELOPMENT

Vehicle Projects LLC has a unique history (since 1998) of developing large fuelcell vehicles



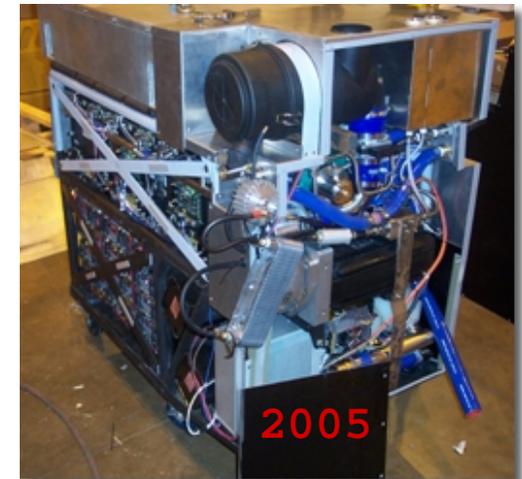
Fuelcell mine locomotive, a non-hybrid



Fuelcell loader final assembly



Diesel mine loader prior to conversion to fuelcell power



Loader's fuelcell-battery hybrid powerplant





# *PROJECT CONSORTIUM*



**American Superconductor (pending)**

**Ballard Power Systems**

**BNSF Railway Company**

**Defense Gen. & Rail Equipment Center  
(DGRC)**

**Dynetek Industries**

**RailPower Hybrid Technologies**

**Transportation Technologies Center, Inc**

**University of Nevada – Reno**

**US Army (NAC)**

**Vehicle Projects LLC**

**Washington Safety Management  
Solutions**

**Power electronics**

**Fuelcell stack modules**

**Industry funding; fabrication; vehicle  
integration; testing; yard demo**

**Advising on military applications; power-  
to-grid demonstration**

**Hydrogen storage**

**Manufacture of Green Goat platform**

**Railway safety regulations**

**Refueling system design**

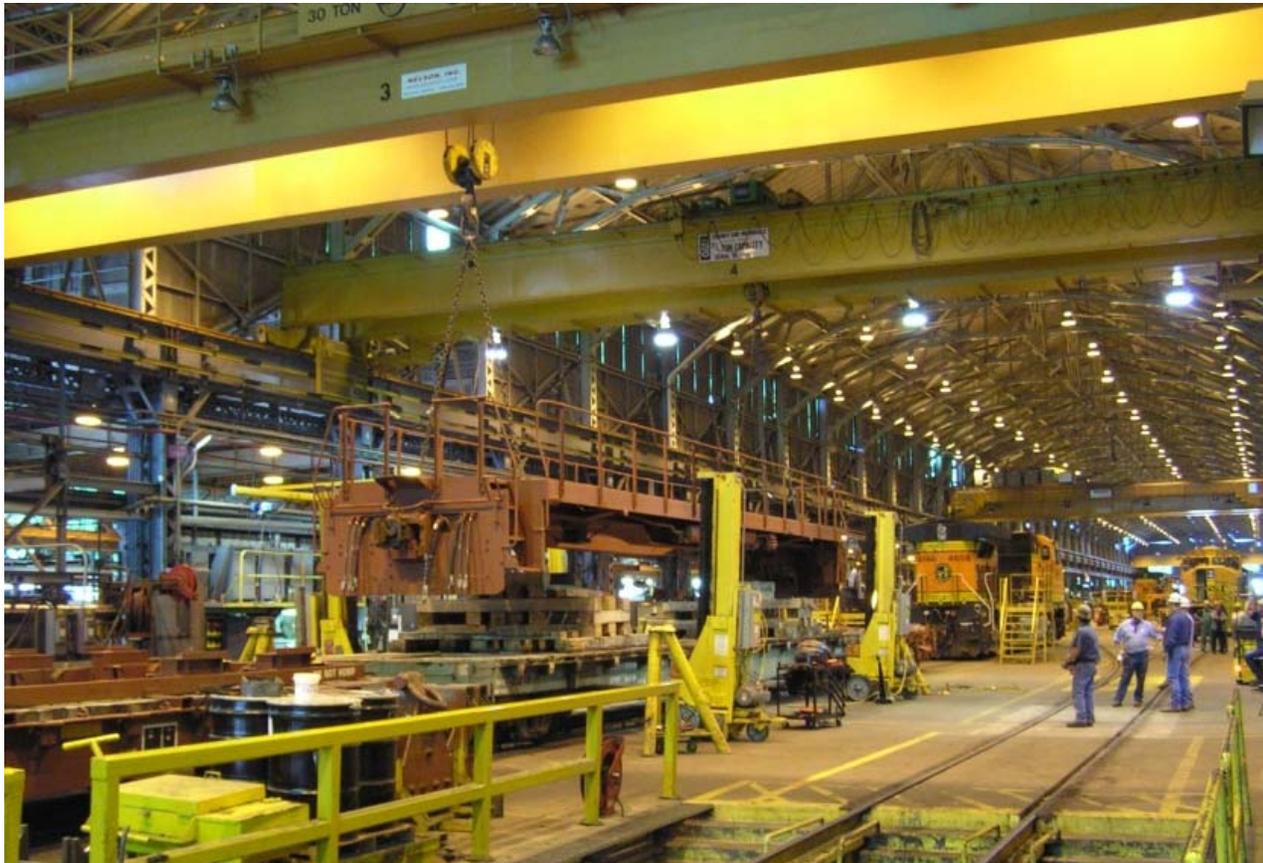
**Project oversight**

**Engineering design; project management**

**Safety analysis**

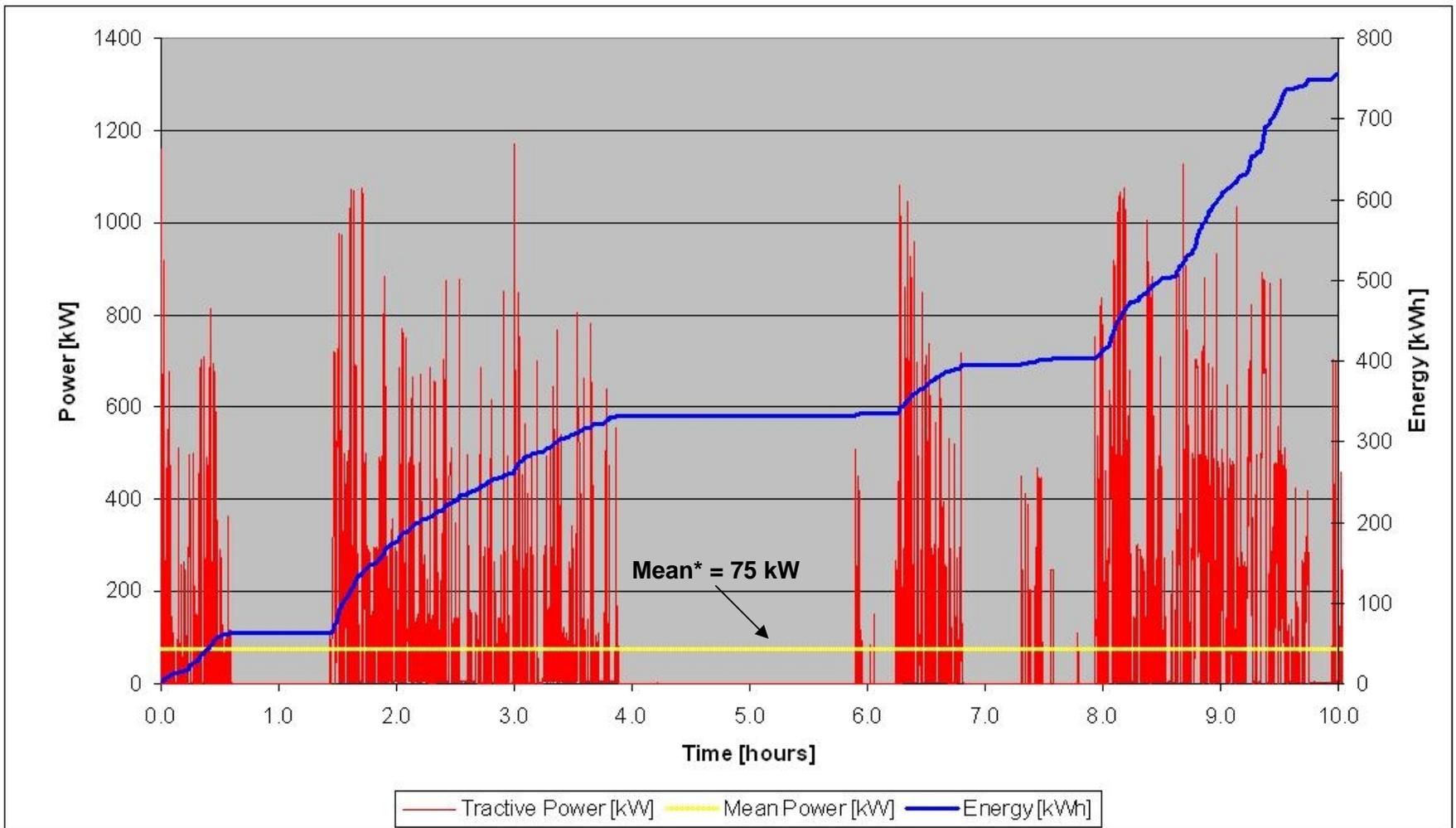


# *BNSF TOPEKA RAIL SHOP*



Most aspects of fuelcell-vehicle construction will be executed at the BNSF Topeka Rail Shop, including powerplant fabrication, vehicle integration, powerplant testing, and locomotive testing and debugging

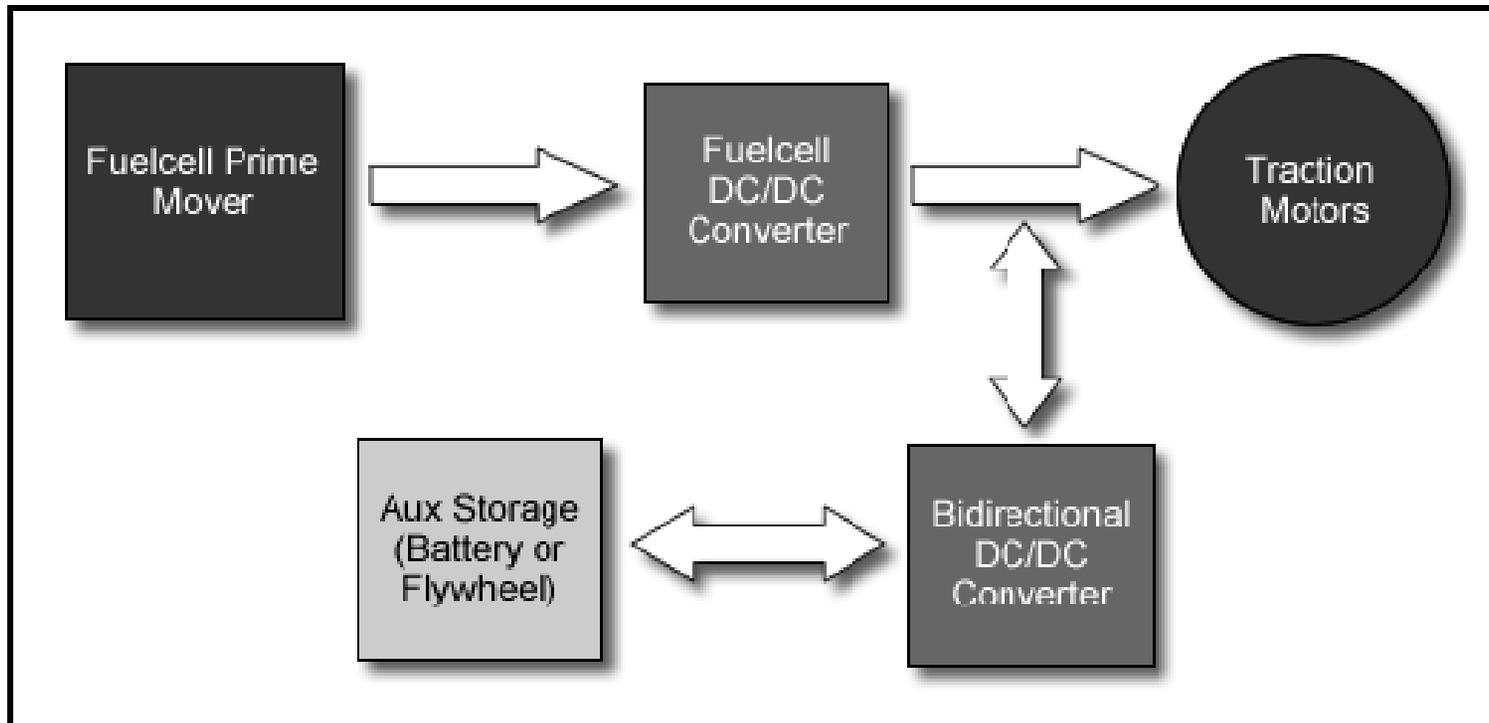
# DUTY CYCLE OF A YARD SWITCHER (PHL)



\*Mean power computed over 20-h interval



# FUELCELL HYBRID POWERTRAIN



Power of prime mover and auxiliary power/energy device is additive.

# FUELCELL SWITCHER PLATFORM



Left-front view



Operator controls



Traction control equipment

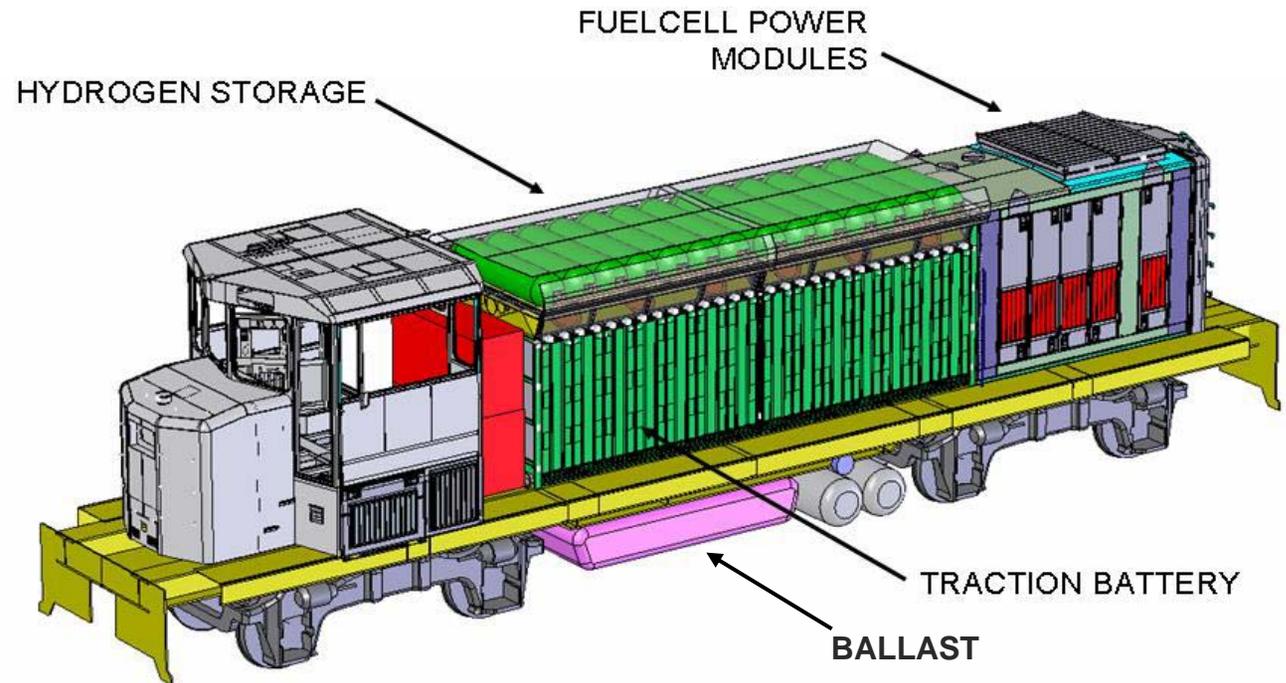


Right-rear view

Photos courtesy of RailPower Hybrid Technologies

# CAD MODEL OF FUELCELL-HYBRID SWITCHER

Our locomotive's fuelcell prime mover provides 250 kW of continuous power for traction or power-to-grid, and the auxiliary lead-acid traction battery allows transients in excess of 1 MW. Fuelcell and lightweight compressed-hydrogen storage are derived from the Citaro transit bus, widely used in European cities.



# SAFETY AND PUBLIC ACCEPTANCE



Joint Research Centre



Photo 3 - Time: 1 min, 0 sec - Hydrogen flow is subsiding, view of gasoline vehicle begins to enlarge



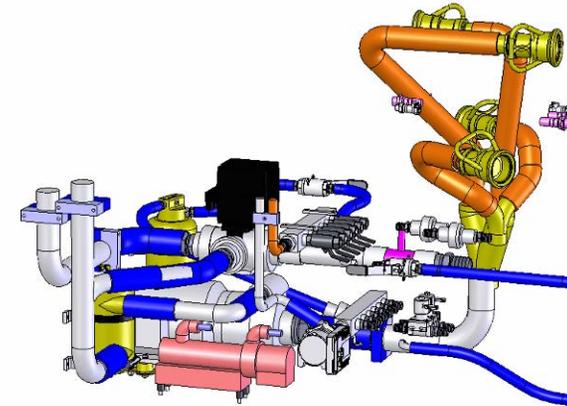
Photo 4 - Time: 1 min, 30 sec - Hydrogen flow almost finished. View of gasoline powered vehicle has been expanded to nearly full screen

Source: Dr. M.R. Swain, University of Miami, <http://evworld.com/library/Swainh2vgasVideo.pdf>

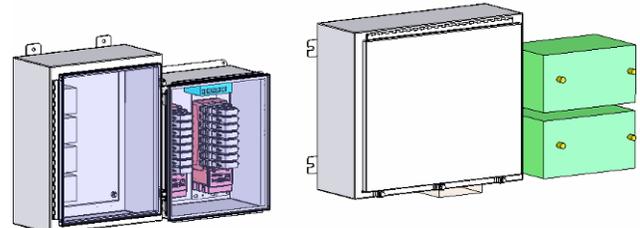


# POWER MODULE

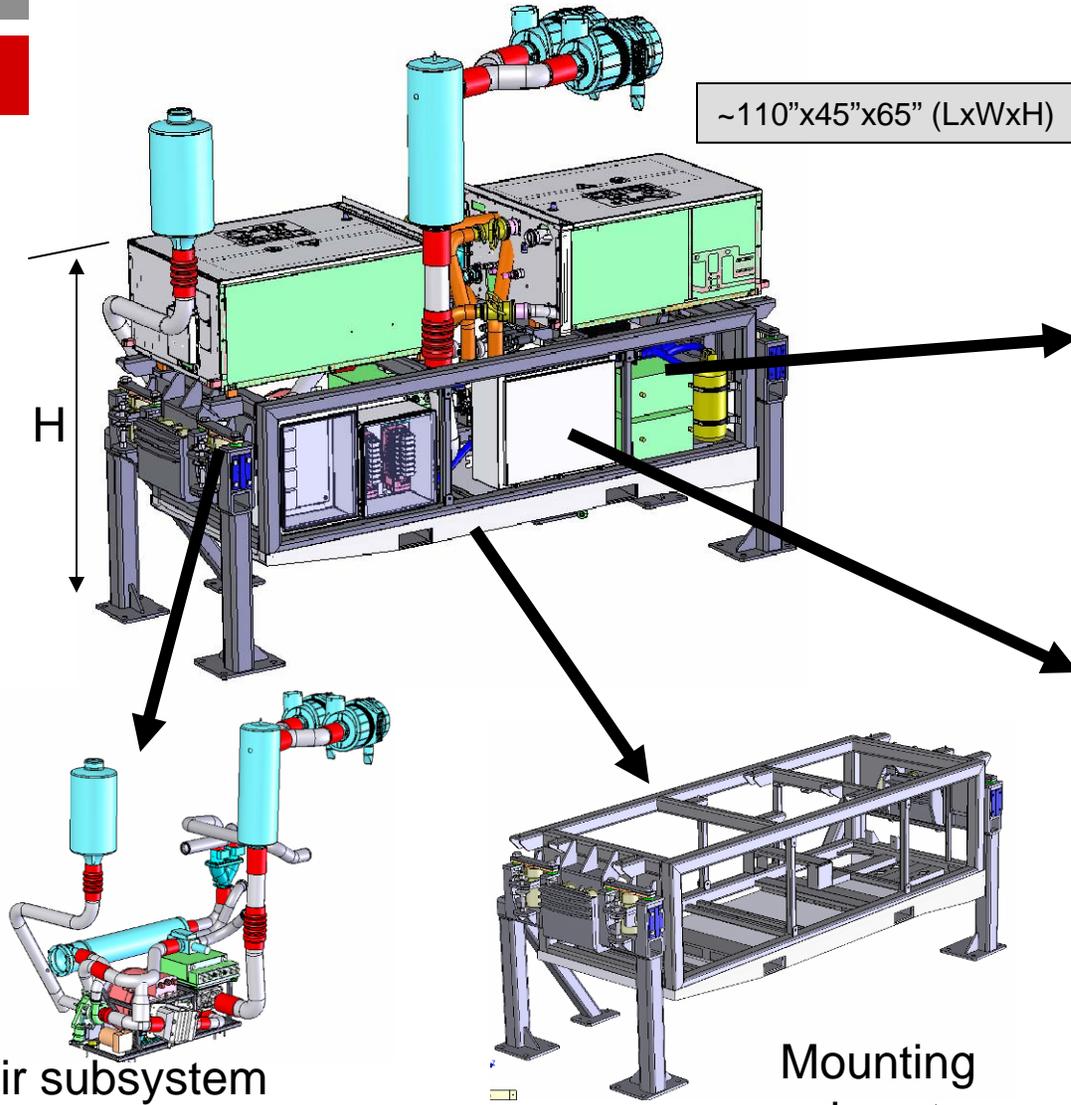
~110"x45"x65" (LxWxH)



Cooling subsystem



Electrical subsystem



Air subsystem

Mounting subsystem





## *SUMMARY AND PROJECT STATUS*

- **Contributing to fast pace of project:**

- Vehicle platform is based on Green Goat™ diesel-battery hybrid switcher
- Powerplant and hydrogen-storage are based on Citaro™ fuelcell transit bus
- Private funding (BNSF Railway) supported project startup

- **Vehicle Projects LLC is executing fuelcell-vehicle engineering design**

- **Status as of October 2007:**

- Preliminary analysis of onboard hydrogen storage safety -- COMPLETE
- Fabrication of Green Goat platform -- COMPLETE
- Engineering design -- COMPLETE
- Ballard and Dynetek sales agreements -- COMPLETE
- Army contract – COMPLETE
- Fabrication, assembly, and testing of fuelcell powerplant in Topeka – UNDERWAY





## *FINANCIAL SUPPORT*

**US Department of Energy, Hydrogen Program**

**US Department of Energy, Office of Industrial Technologies**

**Government of Canada, Action Plan 2000 on Climate Change**

**Natural Resources Canada, Emerging Technologies Program**

**US Department of Defense, Defense Logistics Agency**

**Government of Japan, Railway Technical Research Institute**

**BNSF Railway Company**

**Fuelcell Propulsion Institute**

**Corporate cost-share contributors**

