SYSTEM OPTIMIZATION OF AN ULTRALIGHT ELECTRIC TRANSIT BUS

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This presentation does not contain any proprietary or confidential information

Project ID # 16626

OVERVIEW

- Beginning with a lightweight stainless steel bus body structure and chassis, developed under a HV Materials project, Autokinetics and its collaborators are developing an advanced electric drive propulsion system that will be optimized for maximum fuel economy.
- All of the bus sub-systems are also being evaluated and optimized for additional fuel savings.

RELEVANCE TO 21 CT GOALS

- STATED GOAL:

  "Develop and demonstrate a heavy hybrid propulsion technology that achieves a 60% improvement in fuel economy, on a representative urban driving cycle, while meeting regulated emissions levels for 2007 and thereafter."

- TECHNICAL BARRIER:

  Current transit bus propulsion systems and subsystems are sized for vehicles with a curb weight of over 28,000 lbs.

- FOCUS OF THIS PROGRAM:

  Maximize the synergistic benefits of combining a substantially lighter body and chassis with advanced technology bus propulsion systems and subsystems.

  Successful systems optimization of this ultralight transit bus will result in at least a 3X improvement in fuel economy.

OBJECTIVES

- Perform the integration and optimization of a hybrid or battery/electric propulsion system and various vehicle subsystems into a lightweight bus body.
- Reduce the cost of advanced technology transit buses.

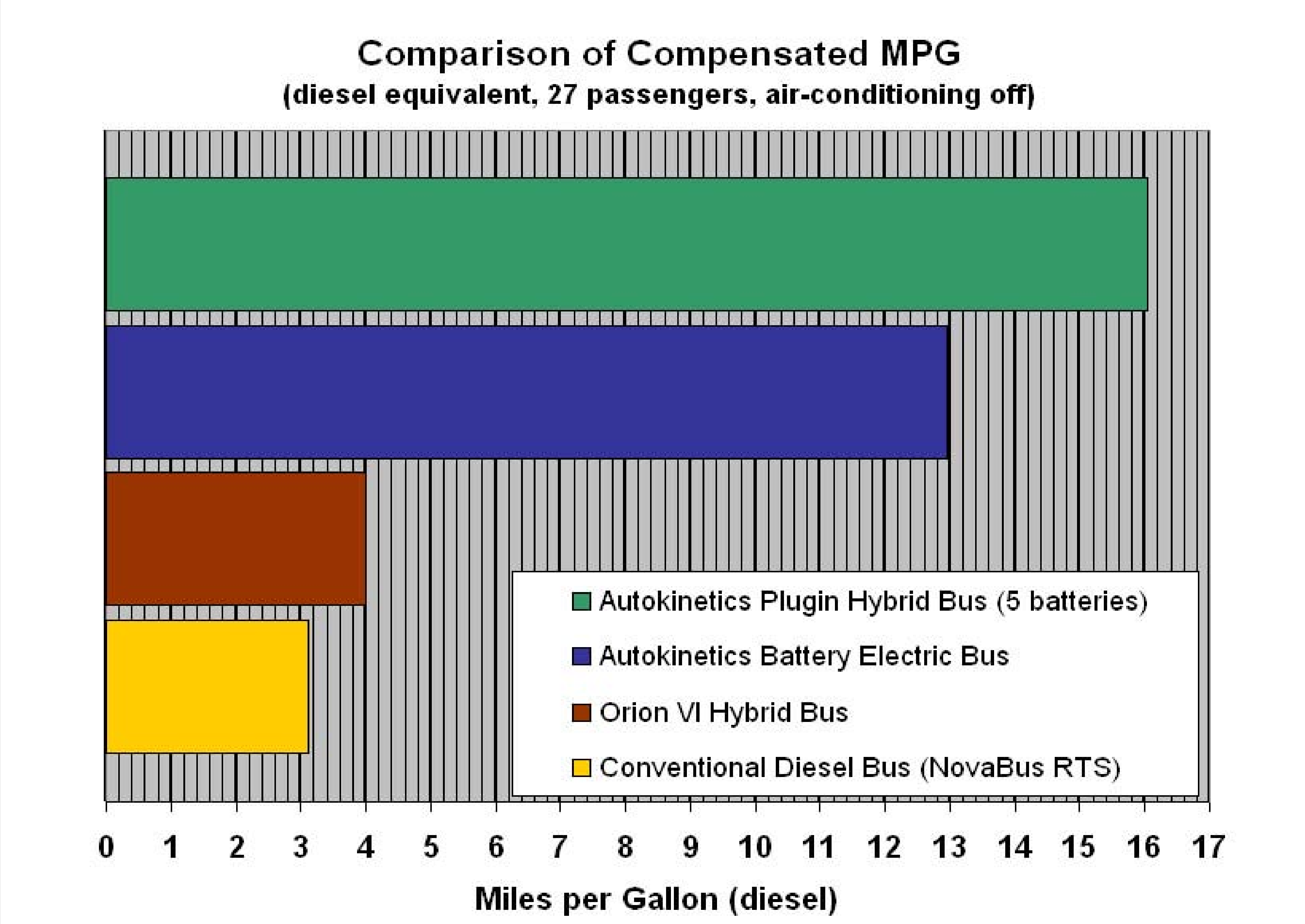
APPROACH

- Conduct ADVISOR and GREET computer simulations of a number of different types of propulsion systems to predict performance and energy efficiency.
- After identifying the most promising propulsion system architecture, use computer simulations to evaluate and select the individual components with the best combination of performance and affordability.
- Purchase and install the integrated propulsion system.
- Design or select optimized vehicle subsystems such as seats, glass, air conditioning, etc.
- Purchase or fabricate and install all vehicle subsystems.
- Evaluate the performance and make modifications, if necessary.
- Perform initial testing.

ACCOMPLISHMENTS

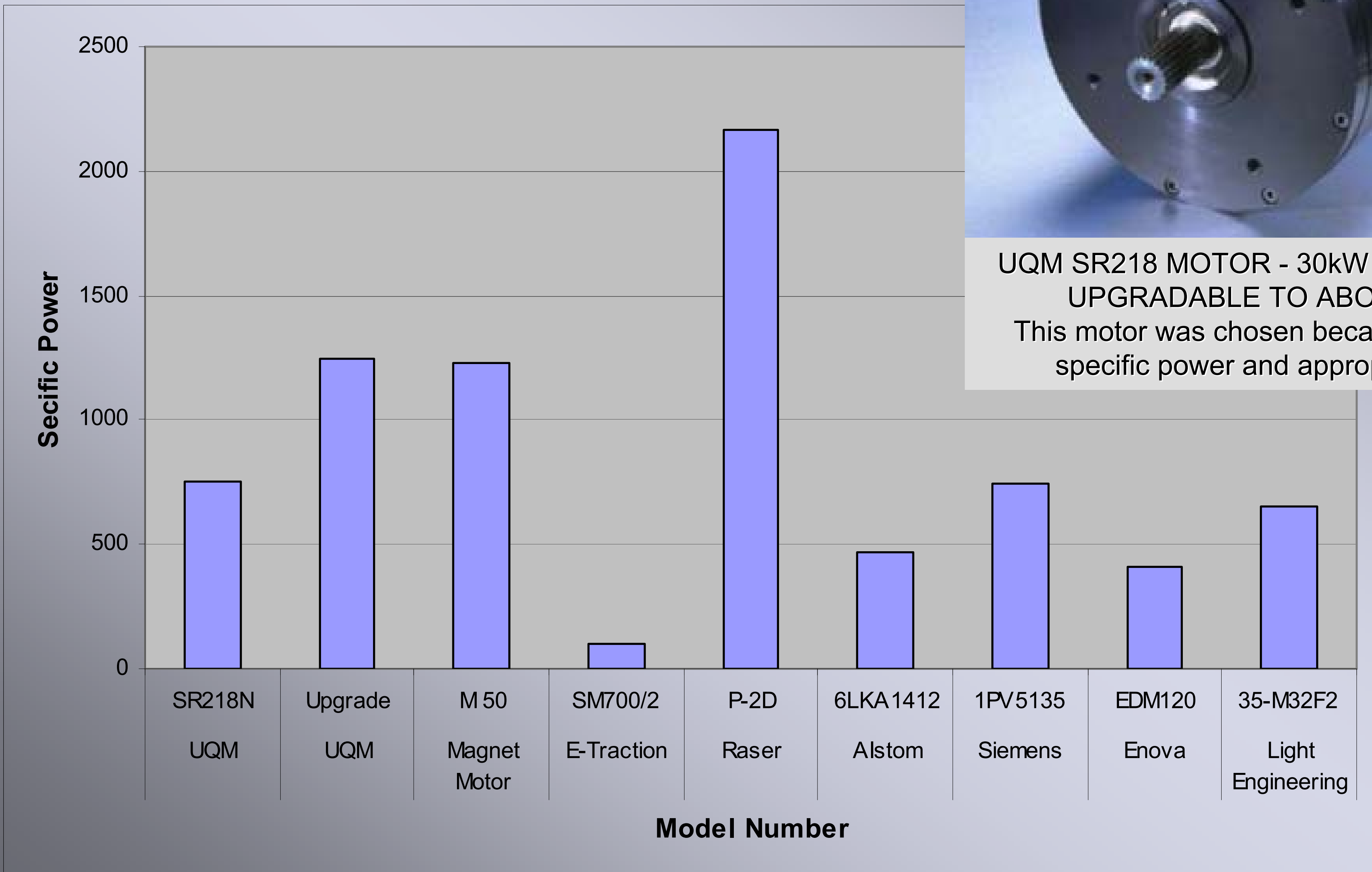
- Completed propulsion system modeling and simulation indicating potential for 3X improvement in fuel economy.
- Completed evaluation and selection of traction motors and controllers.
- Completed design and selection of energy storage system.
- Completed design and selection of components for diesel generator unit.
- Completed selection and acquisition of vehicle controller.
- Completed design of cooling and hydraulic subsystems.
- Completed design, fabrication, and installation of driver's station.
- Fabricated and installed all windows and emergency exits.

REAR VIEW OF BUS WITH GLASS



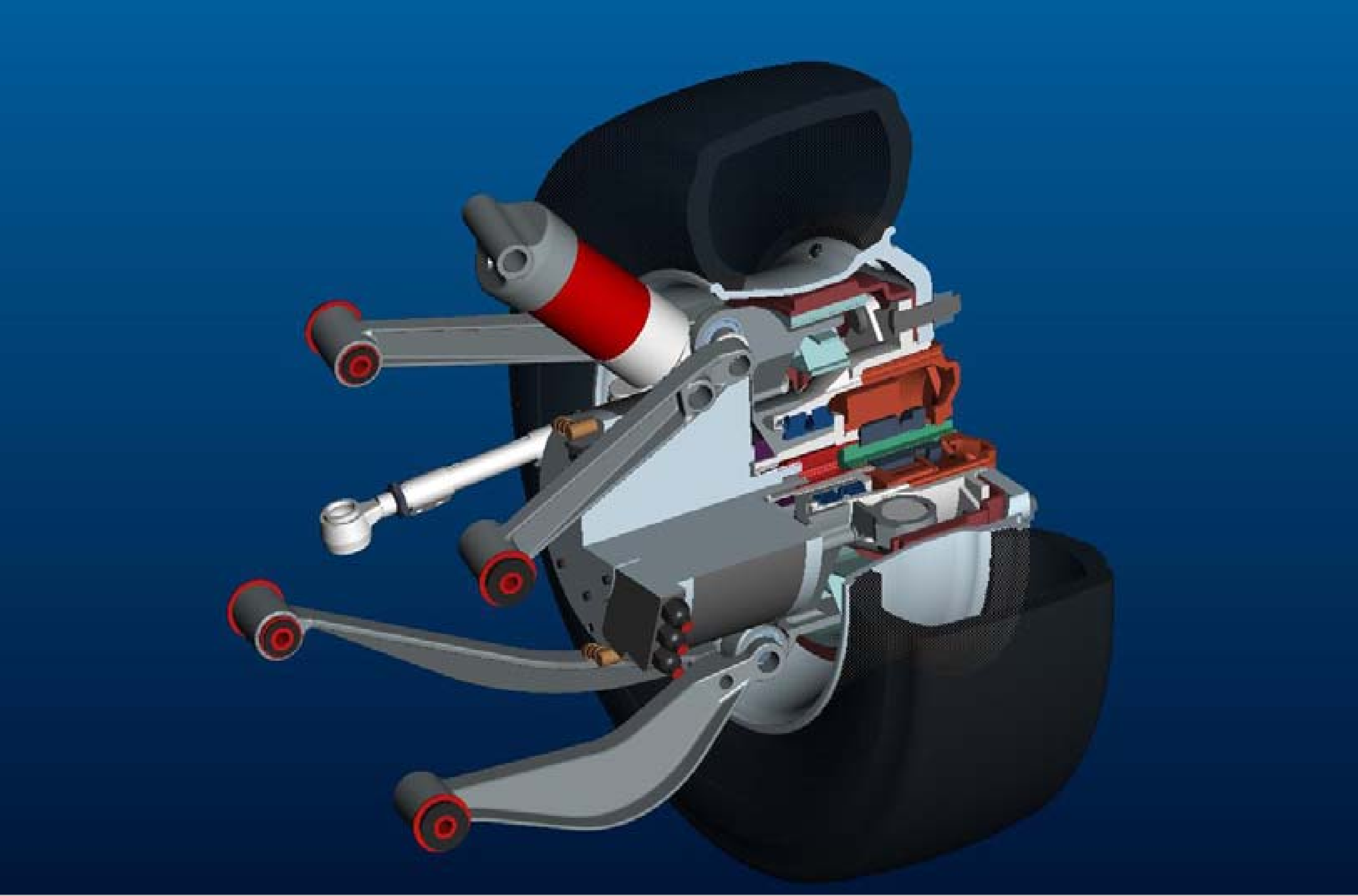
This comparison chart was generated by modifying the results of the NREL ADVISOR program to account for the greater well-to-tank losses inherent in the generation of electricity. The GREET program from ANL was used to determine the total well-to-wheels energy consumption. This was then used to determine an adjustment factor of 0.50 for electricity.

TRACTION MOTOR SELECTION



UQM SR218 MOTOR - 30kW CONTINOUS - UPGRADABLE TO ABOUT 60kW
This motor was chosen because of its high specific power and appropriate size.

Comparison of Specific Power of Various Traction Motors
(note: Raser is not commercially available)



REAR SUSPENSION SHOWING TRACTION MOTOR AND PLANETARY GEAR REDUCER

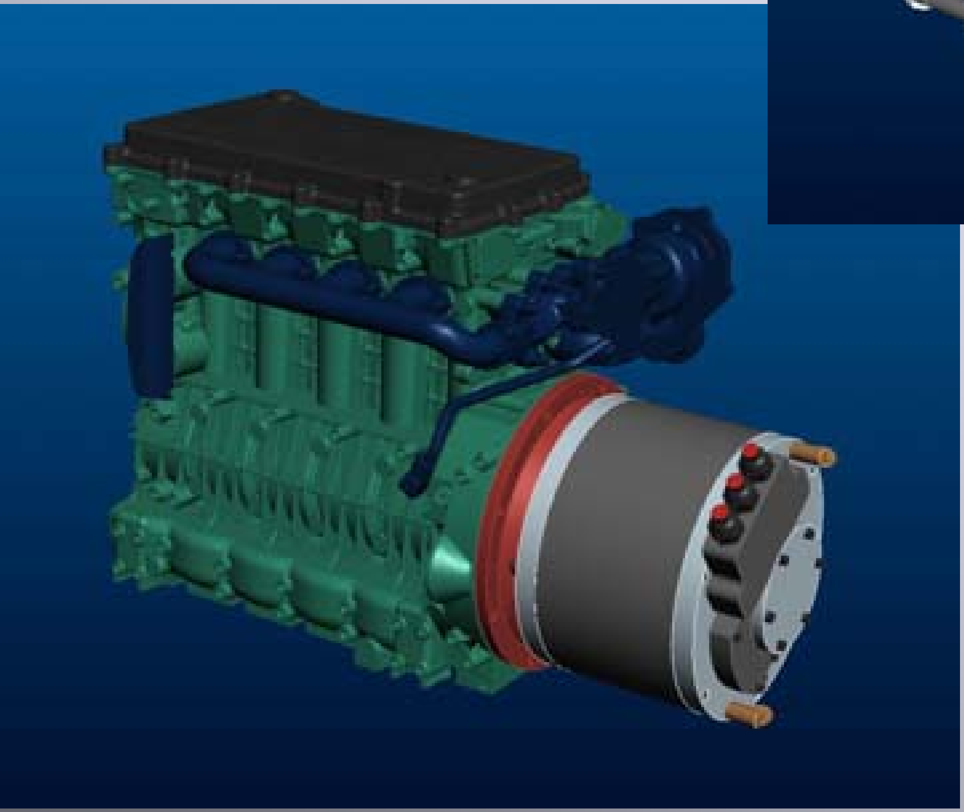
BATTERY COMPARISON

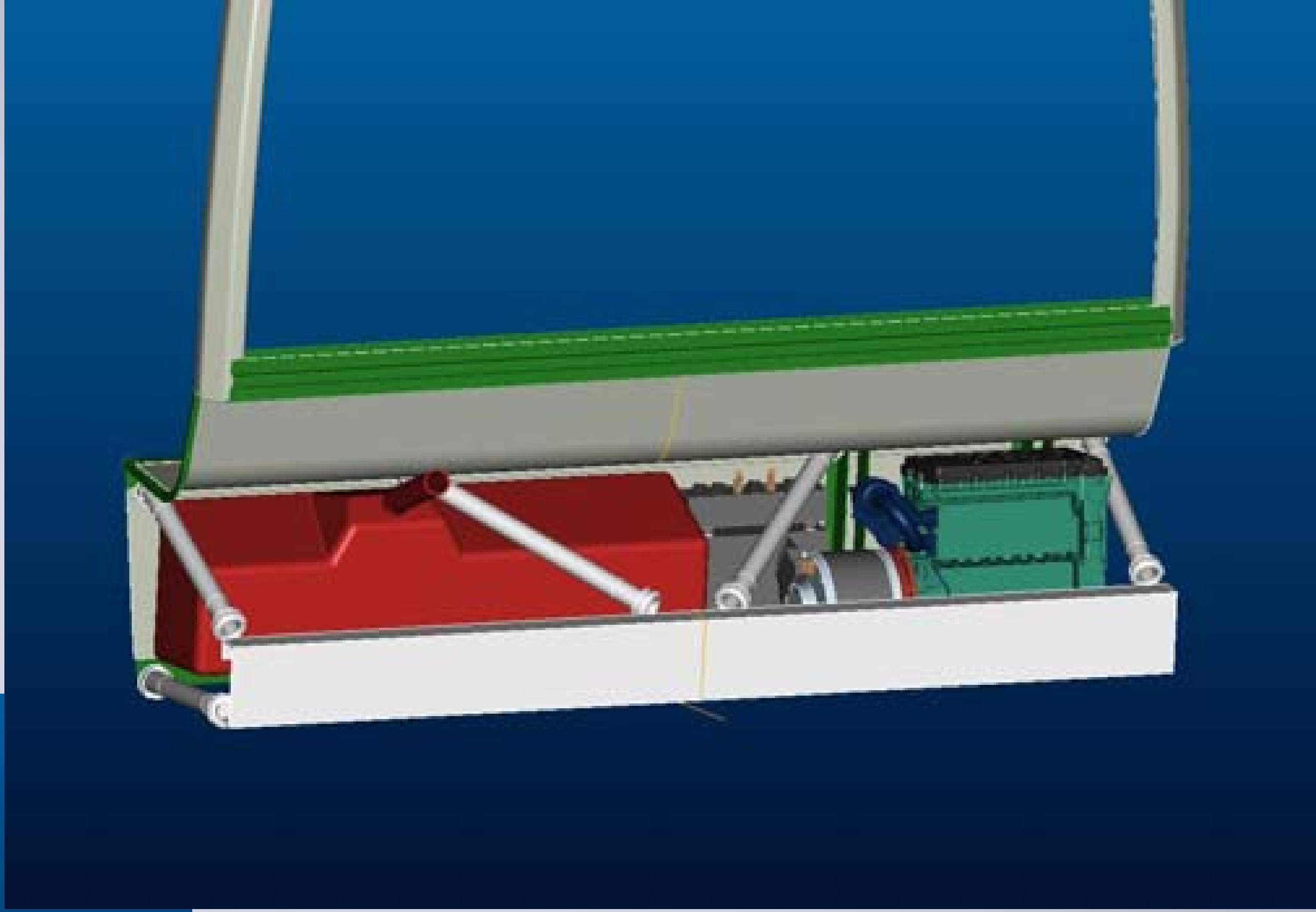
Battery Type	Specific Energy (Wh/Kg)	Energy Density (Wh/L)	Specific Power (W/Kg)	Cycle Life	Cycle Depth (%)	Cost ($/KWh)
Advanced Lead Acid	35-48	80	130-200	500-800	70	100-150
Nickel Metal Hydride	50-80	120	150-250	600-1500	75	300-550
Nickel Cadmium	35-57	57	50-200	1000-2000	75	300-500
Lithium-Ion	100-150		250	400-1200	80	800
Lithium Polymer	100-155	250	200-350	400-600	80	700
Sodium Nickel Chloride	100	148	170	1200-2500	90	300

The ZEBRA Z37 Battery (20 kWh) was chosen due to its high specific energy, deep cycle capabilities, and reasonable cost

BATTERY ELECTRIC PROPULSION SYSTEM SHOWING 10 ZEBRA Z37 SODIUM NICKEL CHLORIDE BATTERIES

Hatz 1.4 liter Diesel with
UQM SR218 Generator





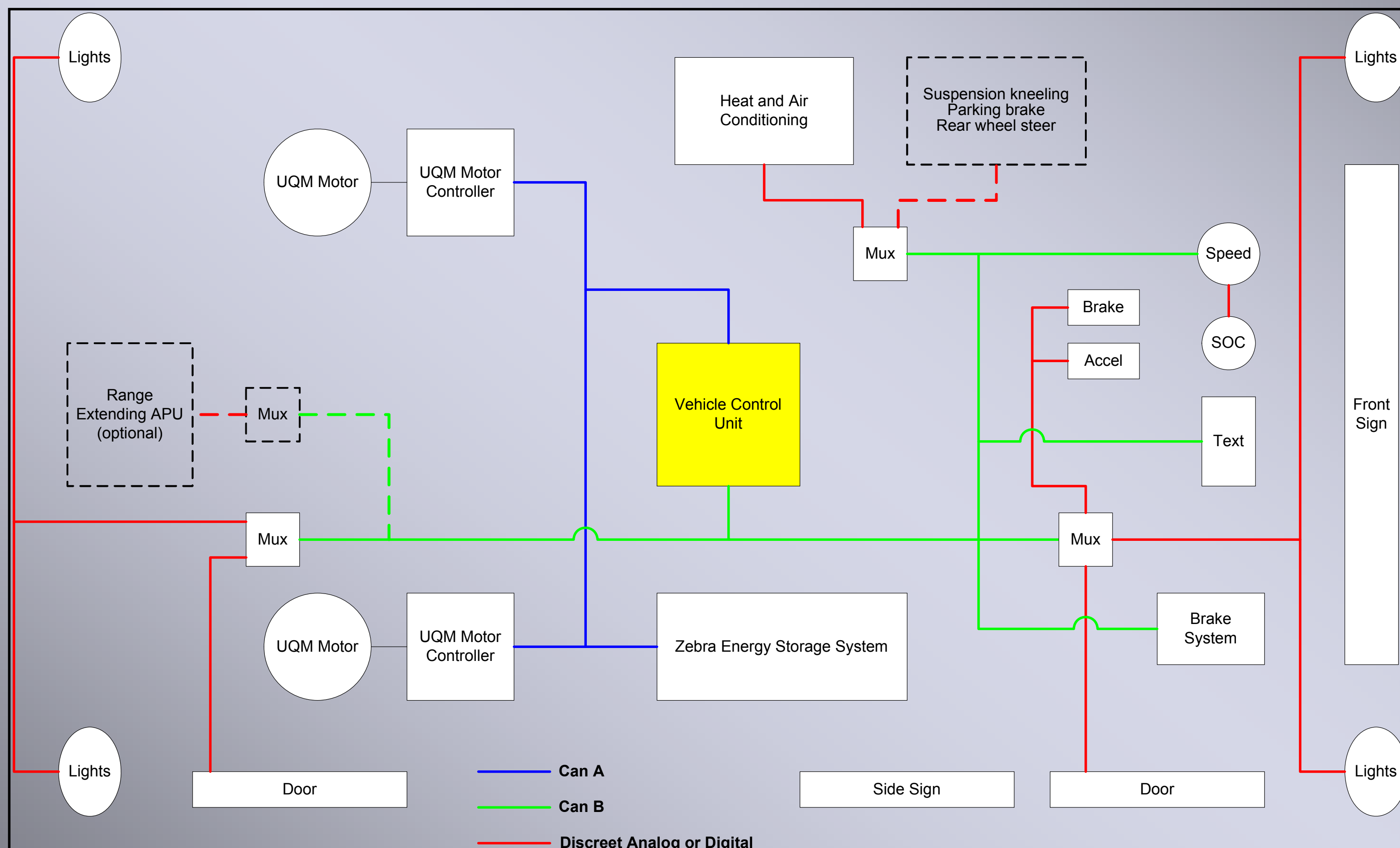
Installation in Rear Engine
Compartment with Fuel Tank

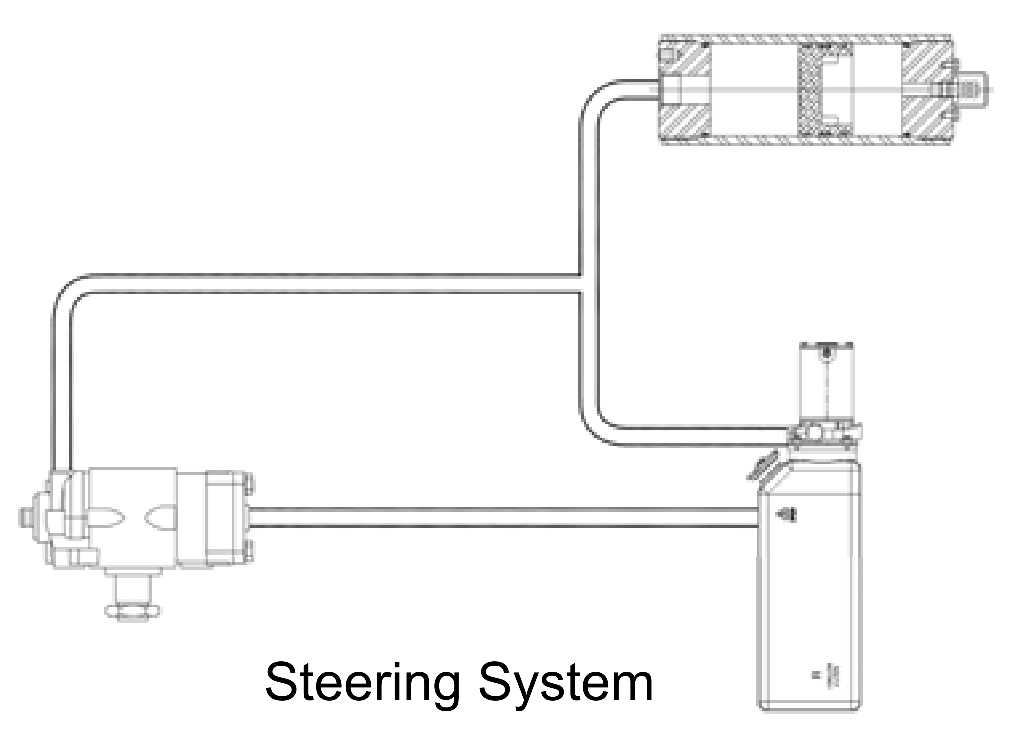
DESIGN OF DIESEL GENERATOR UNIT

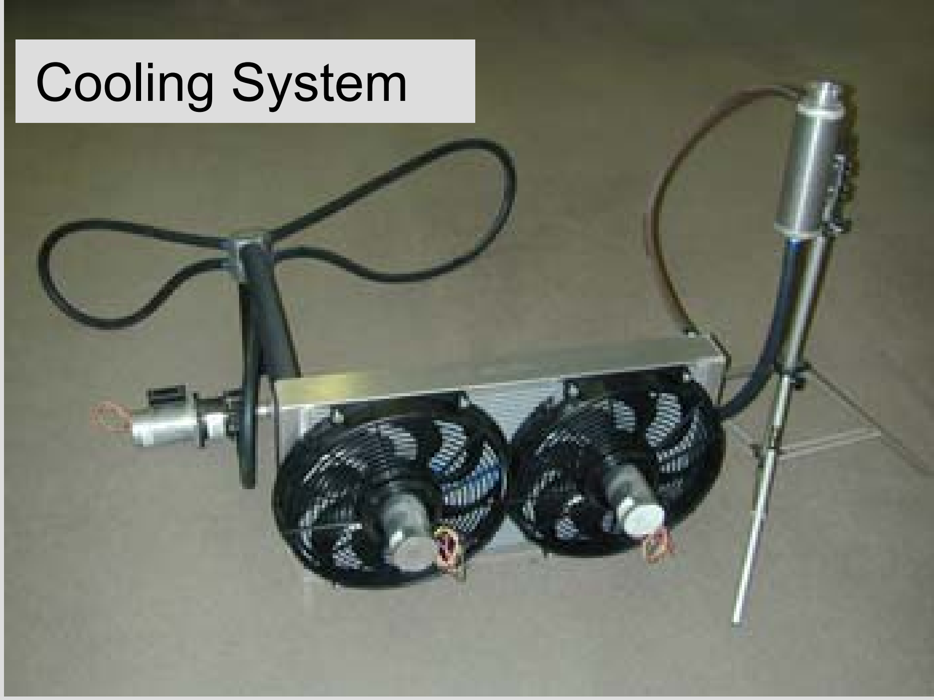
VEHICLE CONTROLLER

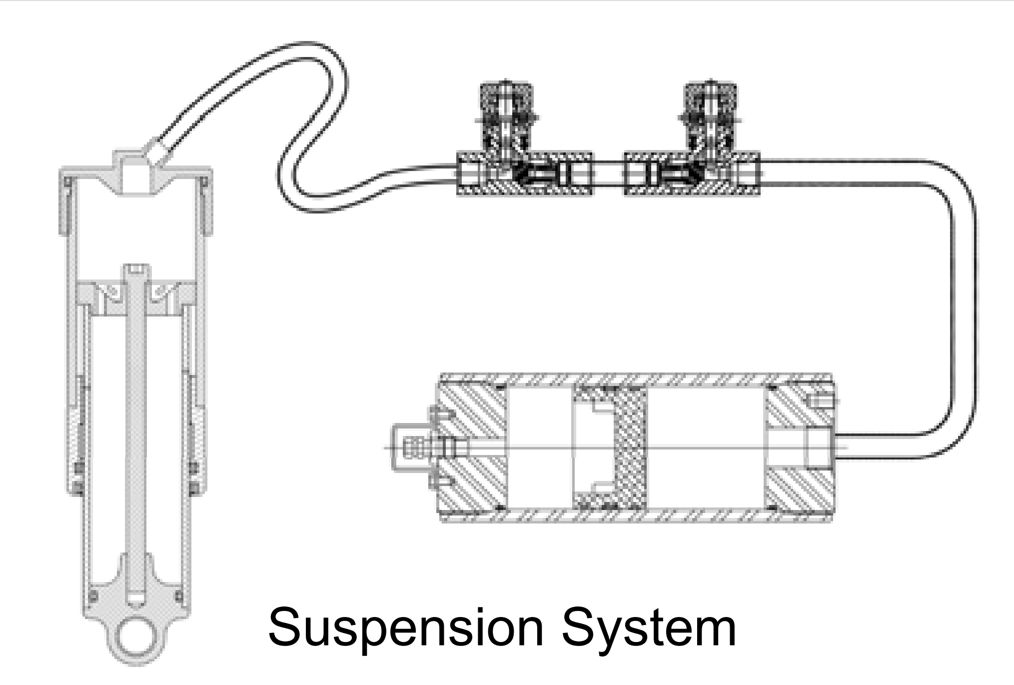
IQAN Vehicle Controller from Parker-Hannifin was selected due to its versatility and ease of programming. (shown with UQM traction motor controller)

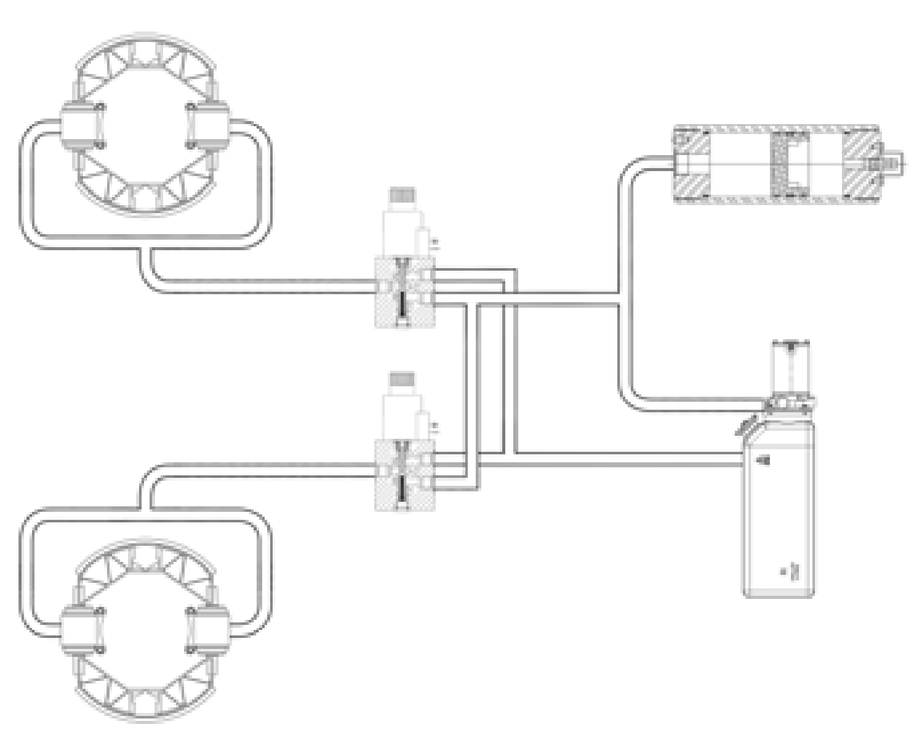
Block Diagram of Vehicle Electronics



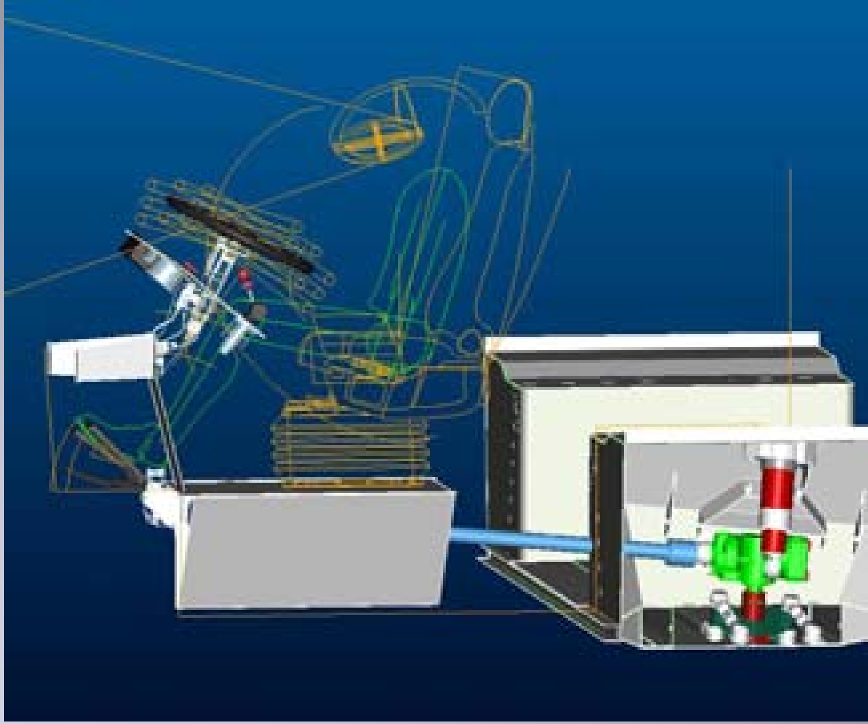








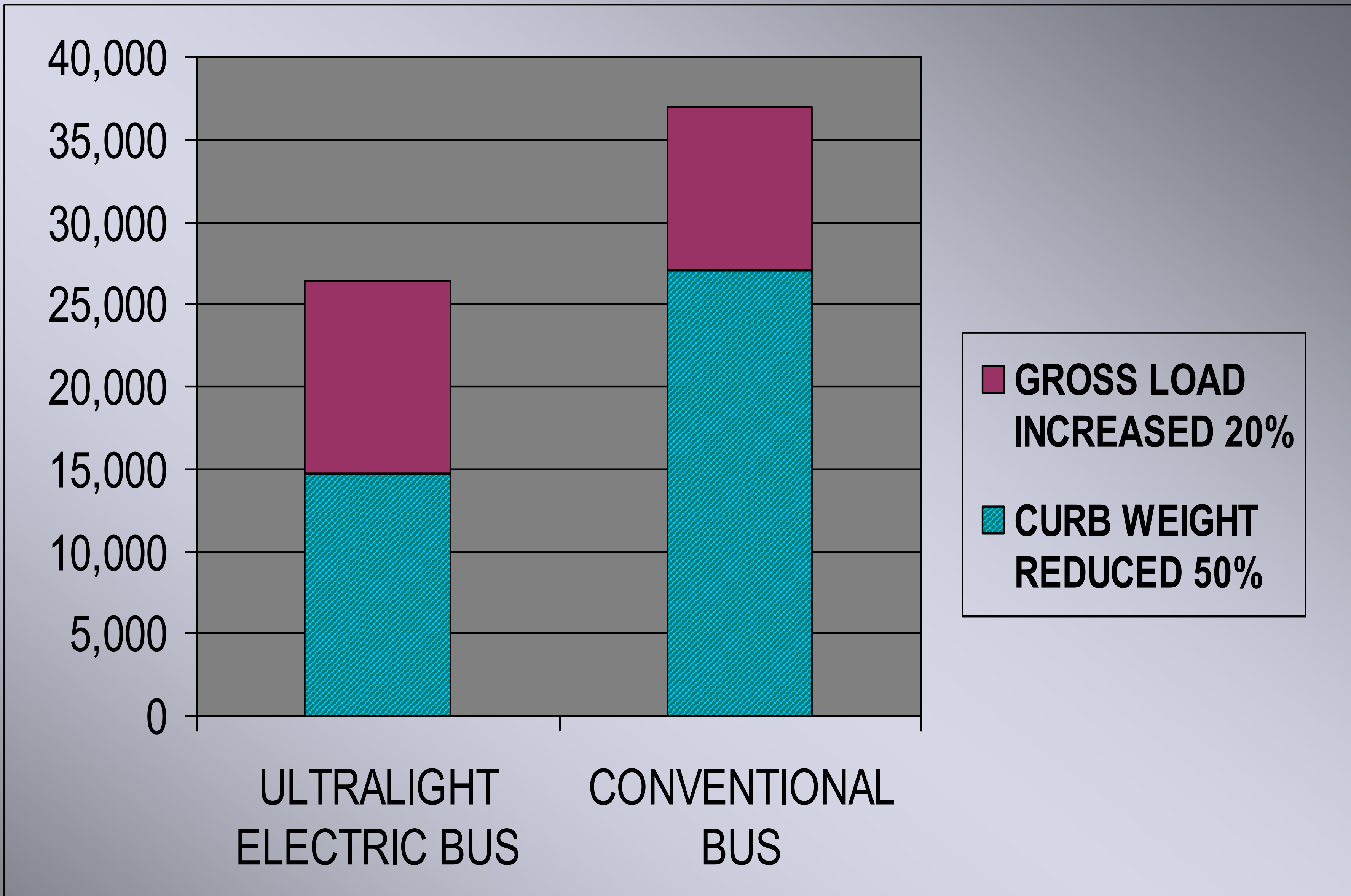
COOLING AND HYDRAULIC SUBSYSTEMS




CAD MODEL AND PROTOTYPE OF DRIVER’S STATION

EXPECTED RESULTS

- 14,700 LB CURB WEIGHT
  WITH 10 ZEBRA BATTERIES
- 50% REDUCTION IN CURB WEIGHT
- 20% INCREASE IN PAYLOAD CAPACITY
- 300% INCREASE IN FUEL ECONOMY
- 32% COST REDUCTION (STRUCTURE)



THIS CHART SHOWS A 50% REDUCTION IN CURB WEIGHT OF THE BATTERY-ELECTRIC VERSION OF THE AUTOKINETICS BUS COMPARED TO A CONVENTIONAL DIESEL BUS

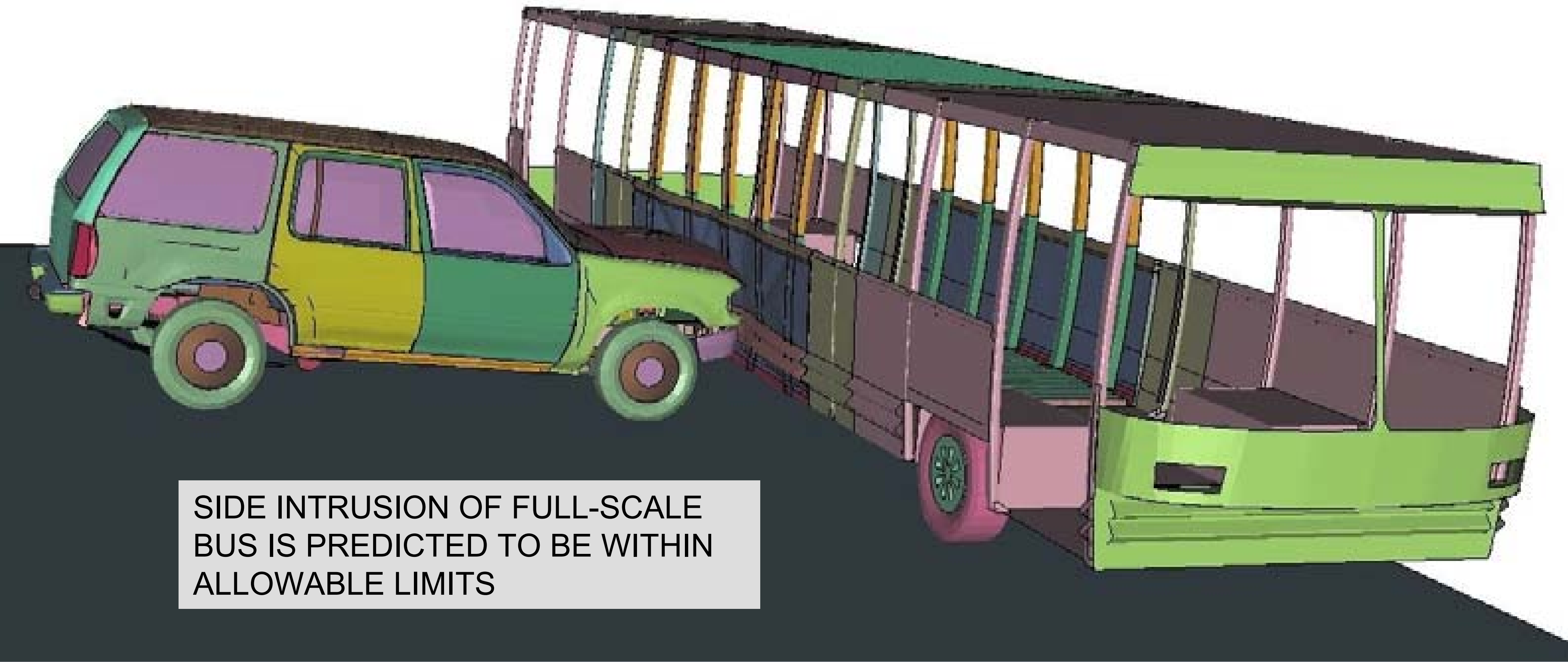
Technology Transfer / Collaboration

A large number of partners, suppliers, and technical advisors have contributed to this program. We gratefully acknowledge their help and guidance.

- NovaBus – Early stage technical advisor
- Terradyne Inc. – Potential bus manufacturer and technical advisor
- Ebus – Potential bus manufacturer
- National Fuel Cell Bus Technology Initiative – Proposed joint program
- Southern Fuel Cell Coalition – Proposed joint program
- Michigan State University – Diesel generator development
- NREL and ANL – Vehicle performance simulation
- ORNL – Side impact crash simulation

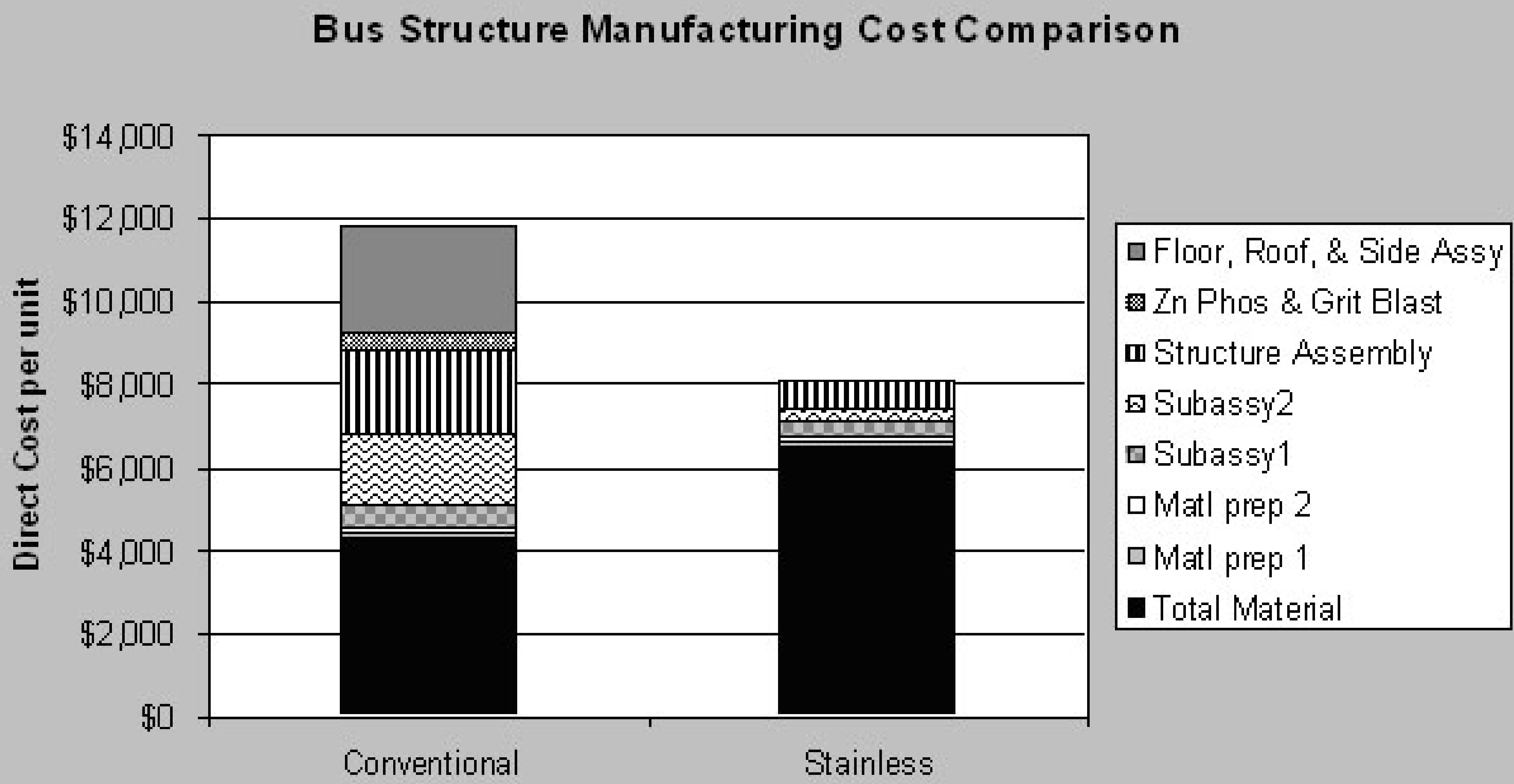
Technology Transfer / Collaboration (cont.)

- IBIS Associates and ORNL – Cost analysis
- AK Steel – Stainless steel materials and technical support
- Michelin – Prototype low rolling resistance tires
- Solutia and FoxFire – Energy efficient glass
- UQM – Traction motors and controllers
- Parker Hannifin – Vehicle controller and hydraulic subsystems
- MES-DEA – Zebra batteries and battery management system
- ZF and Pailton – Steering system
- D&N Bending – Roll-forming
- AristoCast – Stainless steel castings
- 3D Services – Laser cutting
- Ametek – Cooling system components



ORNL SIDE IMPACT STUDY

PERFORMED BY SRDJAN SIMUNOVIC
AND GUSTAVO A. ARAMAYO
OAK RIDGE NATIONAL LAB



COST ANALYSIS OF STAINLESS STEEL BODY

- INDEPENDENT STUDY FUNDED BY ORNL
- ANALYSIS PERFORMED BY IBIS ASSOCIATES USING TECHNICAL COST MODELING TECHNIQUES

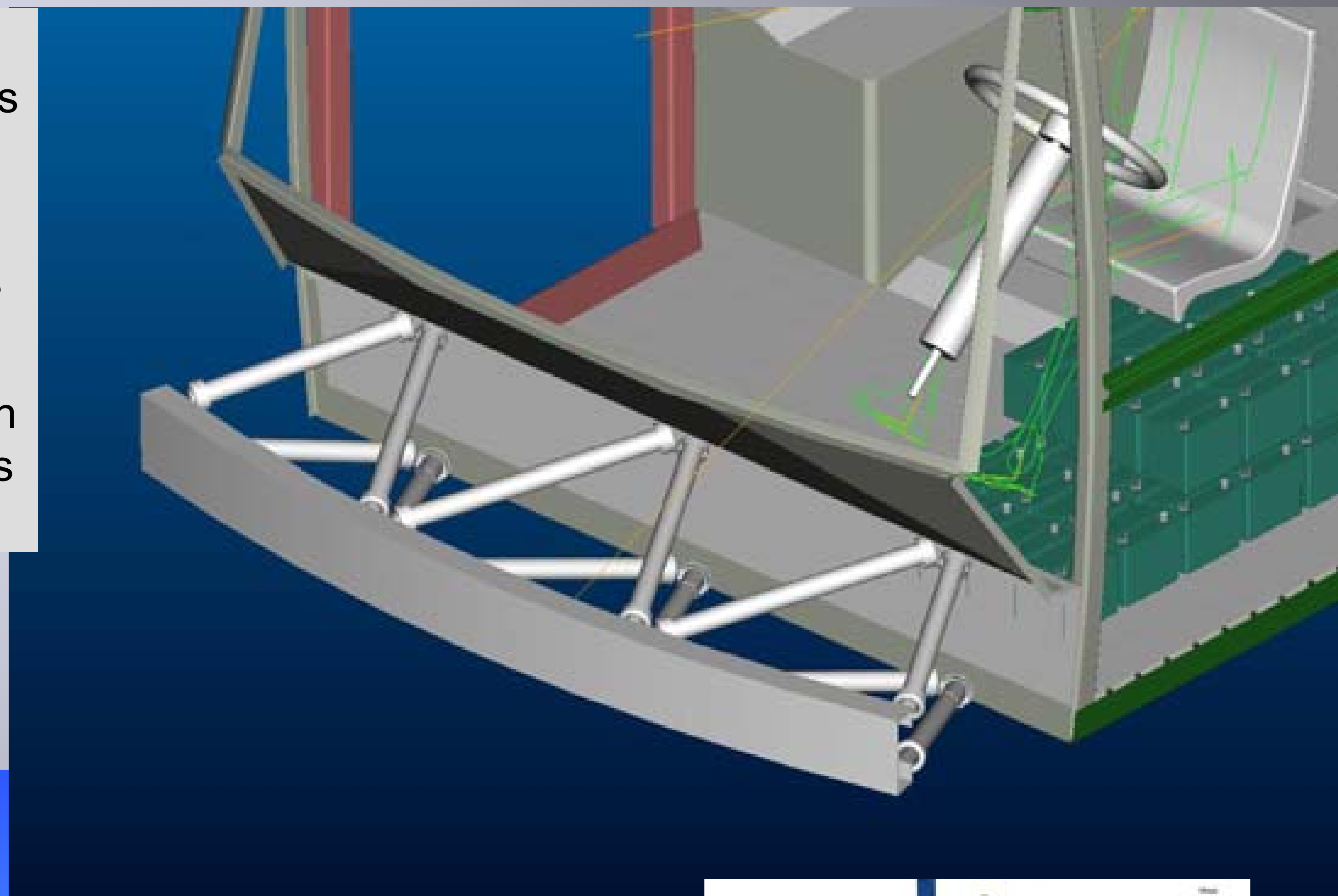
FUTURE WORK

TO BE COMPLETED BY 12-31-06

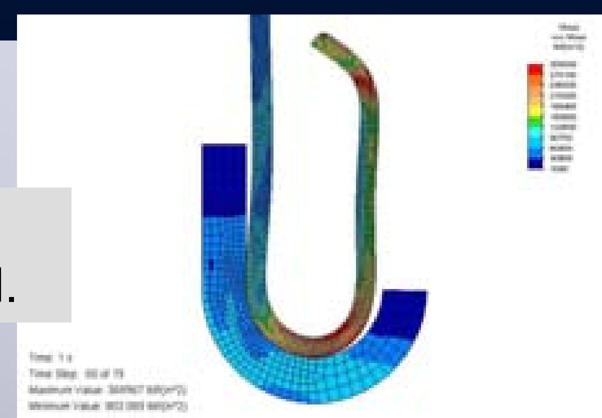
- Complete the installation, wiring and testing of the battery/electric propulsion system.
- Perform failure modes and effects analysis (FMEA) on the propulsion system
- Fabricate (or purchase) and install the following subsystems:
    - Crash system and facias
    - ADA compliance
    - Doors
    - Seats
    - HVAC
    - Lighting, wiring, and trim
- Perform initial road testing and development

CRASH SYSTEM DESIGN CONCEPT

- Bumper support system uses multiple round tubes in triangulated arrangement.
- Energy absorbing tubes collapse axially.
- Designed to protect both impacted vehicle and bus occupants.



Energy absorbing tube concept has been extensively analyzed and tested.



SUMMARY

- Project is on course to achieving at least a 3X improvement in fuel economy compared to current hybrid transit buses.
- No insurmountable technical obstacles are foreseen.
- Cost analysis of lightweight bus body indicates cost savings of 32%.
- Prototype completion anticipated to be December, 2006.
- Discussions underway with two potential bus manufacturers.