



A NAVISTAR COMPANY

# 2010 DOE Vehicle Technologies Program Review Presentation

*Plug IN Hybrid Vehicle Bus: Project ID: VSS023*

*Principal Investigator Eric Sailor*

*Navistar*

*June 7, 2010*

This presentation does not contain any proprietary, confidential, or otherwise restricted information



## Schedule

- 10/01/2009 – 2/13/2013
  - 1st Period to 02/28/2011
  - 30% Complete

## Budget

- Total \$19,800,696
  - \$9,877,413 GOV
  - \$9,923,283 Share
- 1st period Total \$8,013,958
  - \$4,006,979 GOV
  - \$4,006,979 Share

## Barriers

- Engine-Off, Electric Transportation – Target 30 miles on a charge
- Commercialization
  - Availability
  - Affordability
  - Reliability
  - Integration



# Objectives



A NAVISTAR COMPANY

- The goal of this project is to develop an PHEV school bus that satisfies a majority of customers and accelerates market introduction.
  - Develop a plug-in hybrid electric school bus capable of 30 miles of engine-off operation from 0-45 MPH.
  - Reliable and easy operation for operators and school districts
  - Affordable and cost effective
- First period 10/2009-2/2011
  - Capture stakeholder requirements and vehicle integration requirements
  - Develop both parallel and series constructions.
  - Implement these designs with at least two battery types.
  - Optimize prototypes for period 2 fuel economy and emissions testing & customer evaluation

# Milestones



A NAVISTAR COMPANY

Tasks	Date	Description	%
Task 1	10/09-1/10	<b>Vehicle Requirements</b> Contained in program requirements document	100
Task 2	12/09-03/10	<b>System Design</b> Key powertrain systems and components nearly complete. Secondary systems (i.e., HVAC) are behind	40
Task 3	01/10-06/10	<b>Electric Accessory Component Development</b> Requirements will be compared and assessed	60
Task 4	01/10-06/10	<b>Hybrid-Electric Component Development</b> Some suppliers have products underdevelopment, not yet released	20
Task 5	05/10-09/10	<b>Software Development</b> Module approach to enable rapid changes & adjustments	20
Task 6	06/10-12/10	<b>Concept Vehicles Build and Delivery</b> New smaller engines have been installed on two buses	10
Task 7	11/10 – 2/11	Initial Track Testing	0



## Technology Solutions must exceed customer's alternatives

- The desired fuel and emissions saving can only be accomplished if these school buses are purchased and used; therefore technical challenges must be solved with customer acceptable commercial solutions. Top-down driven requirements.
- Identified, specified and will develop the functionality, reliability and performance of both parallel and series systems to stakeholders.
- Challenging team members to demonstrate or explain how their ideas and proposals meet the program requirements.

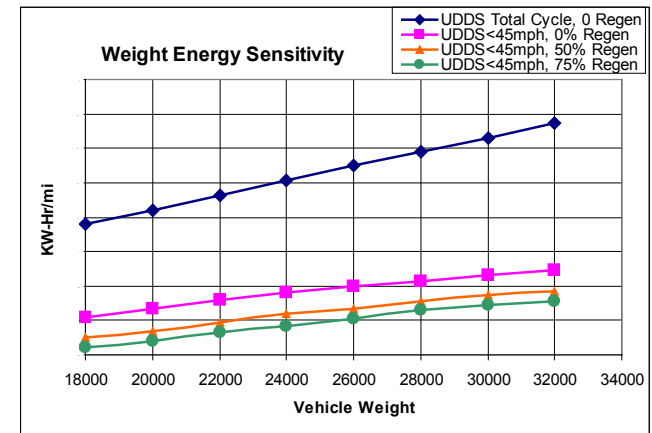
# Approach/Strategy



A NAVISTAR COMPANY

## Strategy/ Construction

- Provide 30 miles of electric propulsion to meet the average school route of 30 miles. 50% of routes could potentially use 100% electric propulsion.
- Electric Propulsion 0-45 mph has been selected to enable urban operation and reduce the electric storage. This EP limit also enables the engine to operate predominantly in efficient regions which also increases fuel economy.
- The parallel system shall use a post-transmission system to meet states specification for an automatic transmission.
- The decoupled driveline series systems shall use a smaller, more fuel efficient engine for the average power of school bus routes.



# Approach/Strategy



A NAVISTAR COMPANY

## FCVT programs contributions





- Simulation tools (i.e., Advisor, PSAT)  
- This program will benefit from the DOE supported commercial development of Li-ion cells, modules and battery management systems.
  - Environments significantly more severe; underbody & frame rails.
  - Peak power duration significantly longer (40-60s, not 10s), rapid cell heating.
  - Packaging size are different; we have no trunk, center rails construction.
- High Temperature Electronics & Thermal Management techniques  
- Published cost targets based upon extensive analysis acts as a competitive force in the marketplace.
- This program supports FCVT education and outreach goal to increase awareness of the benefits of energy-efficient technologies. Introducing students and their parents to Plug-In school buses expands the customer base to these technologies; immediately and for the next generation of drivers.

Table 2.2-7. Processed APEEM Targets for Advanced Hybrid and Fuel Cell Vehicles

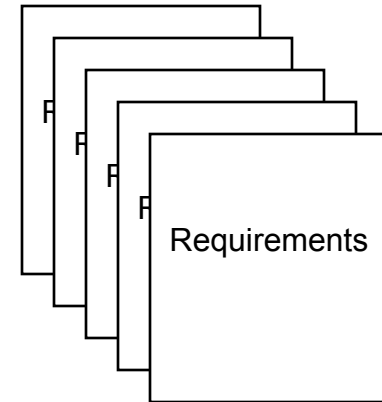
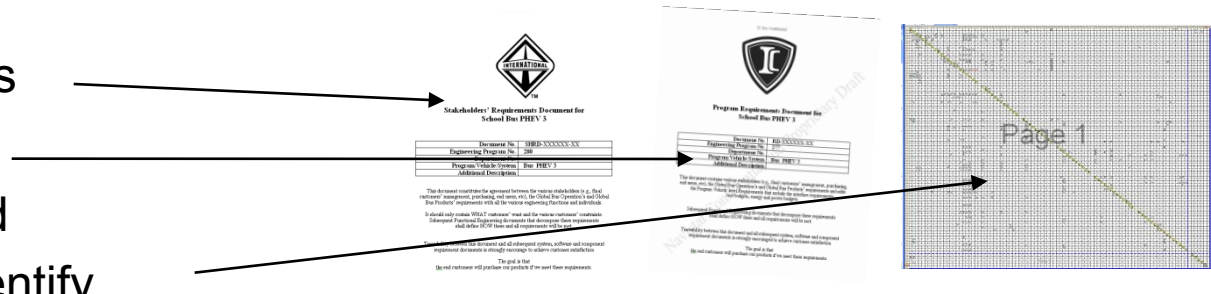
Parameter	2010 Target	2015 Target	2020 Target
<b>Integrated Electric Propulsion System</b>			
<i>Electric Motor and Green Electronics (Inverter/Controller)</i>			
Power Level, peak/continuous, kW	55/90	55/90	55/90
Specific Power at Peak Load, kW/kg	<=1.06	<=1.2	<=1.4
Voltage Power Density, kW/L	<=2.50	<=2.5	<=3.0
Cost, \$/kW	<=19	<=12	<=8
Efficiency 10% to 100% speed, 20% rated torque	>=81	>=81	>=84
Coolant Temperature, °C	90	100	100
<b>OCDC Converter (applies e-Hybrid and Transmission)</b>			
Specific Power at Peak Load, kW/kg	0.8	<=1.0	<=1.2
Voltage Power Density, kW/L	1.8	<=2.0	<=2.0
Cost, \$/kW	15	<=8	<=5
Efficiency 10% to 100% speed, FTP drive cycle	85	88	90
Coolant Temperature, °C	90	100	100



# Program Accomplishments

## Top-Down Driven Requirements.

- Stakeholders requirements
- Program requirements
- 88 new functions identified
- N square chart used to identify function interaction
- Partition and aggregation of functions
- Supplier scope requirement documents
  - Electricity to parallel mobility converter
  - Electricity to series mobility converter
  - Electric energy storage
  - Utility to dc electric converter
  - Fuel to electricity converter



- On two buses, the V-8 engines have been replaced with smaller I-4 engines

# Program Accomplishments- continue

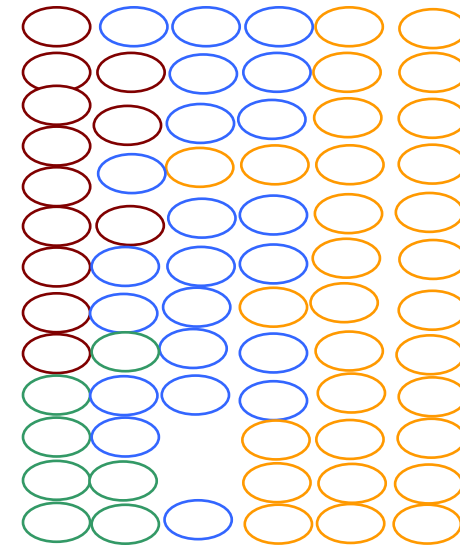


A NAVISTAR COMPANY

## Top-Down Driven Requirements.

### In Progress

- Supervisory Control requirements
- Electric Accessories
- Electric Sensor Requirements
- Integration
  - Physically on the vehicle
  - Material Flow
  - Energy Flow
  - Information Flow



Functions

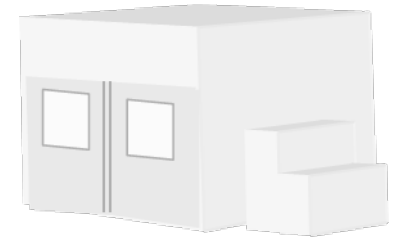


# Collaborations



- **Battery Pack Testing**

- Demonstrate packs meet requirements before Fuel Economy and Emission testing
- Potential Suppliers (received quotations)
  - NREL
  - SWRI®
- Tests: C-rates, Temperature Range, Thermal Mgmt, SOC accuracy, etc.



- **Fuel Economy and Emissions Testing – phase2**

- Potential Suppliers (received quotations)
  - WVU
  - NREL
  - SWRI®
- Tests: mpg, whr/mi, PM, CO, CO<sub>2</sub>, HC

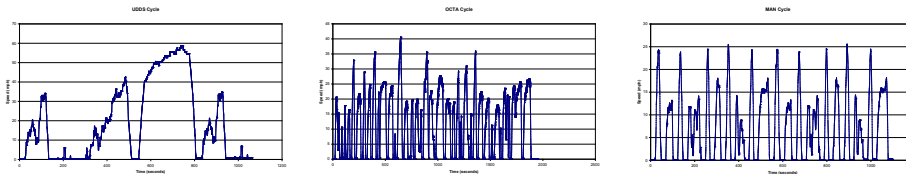
# Phase 2 Work 03/2011 - 11/2011



A NAVISTAR COMPANY

- **Fuel Economy and Emissions Testing**

- Two buses each construction
- Drive Cycles
  - UDDS
  - OCTA
  - MAN



- **Durability Testing**
- **Customer Ride and Drive Events**



## Commercialization Decision – which system?

# Summary



A NAVISTAR COMPANY

- It is estimated that each school bus deployed will displace 1400 gallons per annum of fuel with domestically produced electricity.
- These school buses are estimated to reduce CO<sub>2</sub> emissions by 28,000 lbs; eliminating emissions around school children – achieving a significant goal for many school districts.
- Successful commercialization of these technologies and their system integration is essential to realize these fuel and emission savings.

**End of Presentation**