



**U.S. Army Hybrid Propulsion System R&D Overview
ATA/Technology & Maintenance Council 2011 Fall Meeting
Hybrid Powertrain Task Force Session
19 Sep 2011 – Raleigh, NC**

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Transportation Energy Security Team**



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- U.S. Army National Automotive Center Overview
- The Energy Challenge for the U.S. Military
- Hybrid Propulsion System R&D Projects
- Departments of the Army, Defense & Energy Collaboration
- Q&A

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Chartered by the Secretary of the Army on 21 June 1993

Mission:

“The Center will serve as the Army focal point for the development of dual-use automotive technologies and their application to military ground vehicles. It will focus on facilitating joint efforts between industry, government and academia in basic research, collaboration, technology, industrial base development and professional development.”

“Leveraging Opportunities to Fill Technology Gaps.”

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National Automotive Center Command Chain



Army Materiel Command (AMC)



Research, Development & Engineering Command (RDECOM)



Tank-Automotive Research, Development & Engineering Center (TARDEC)

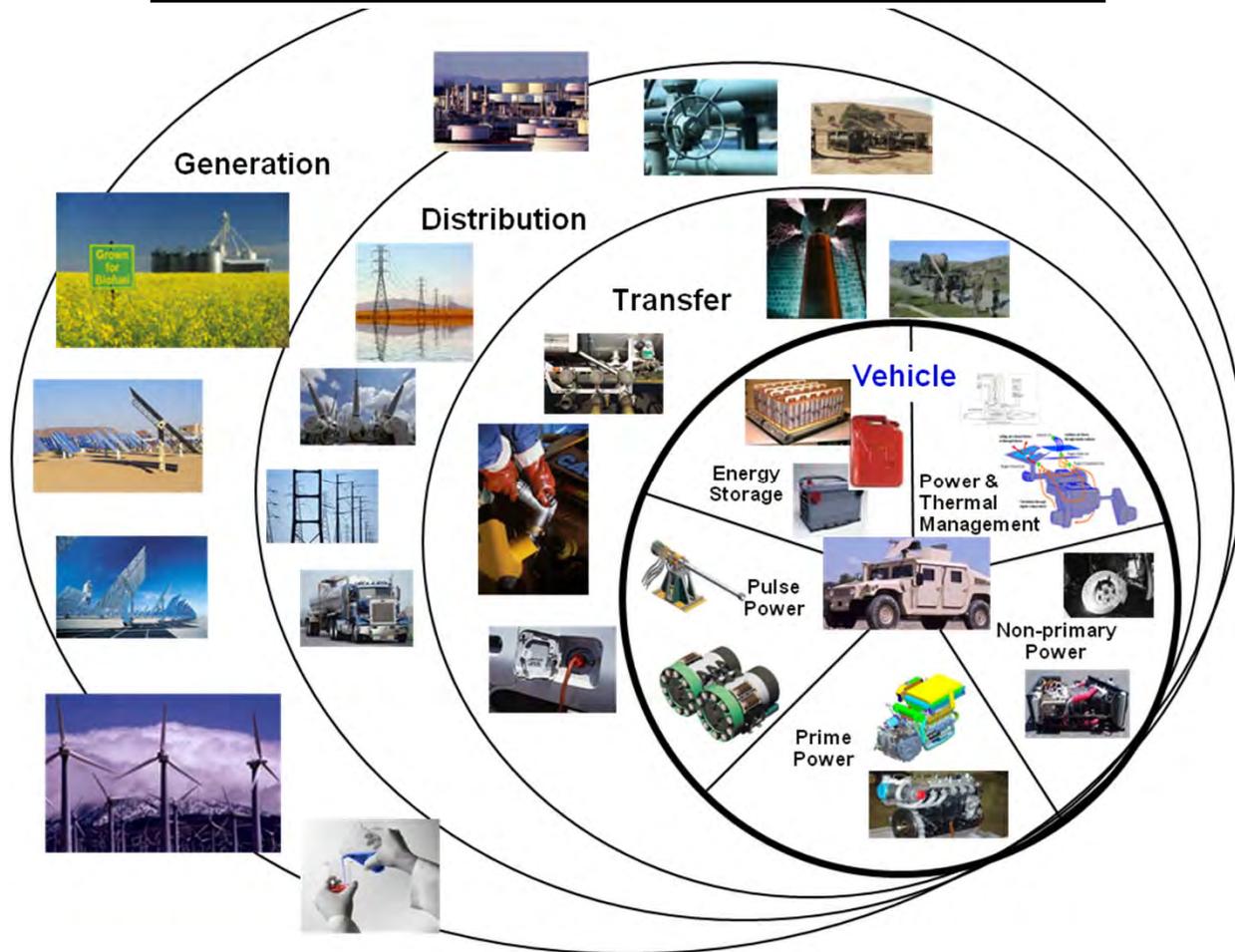


National Automotive Center (NAC) – Warren, MI

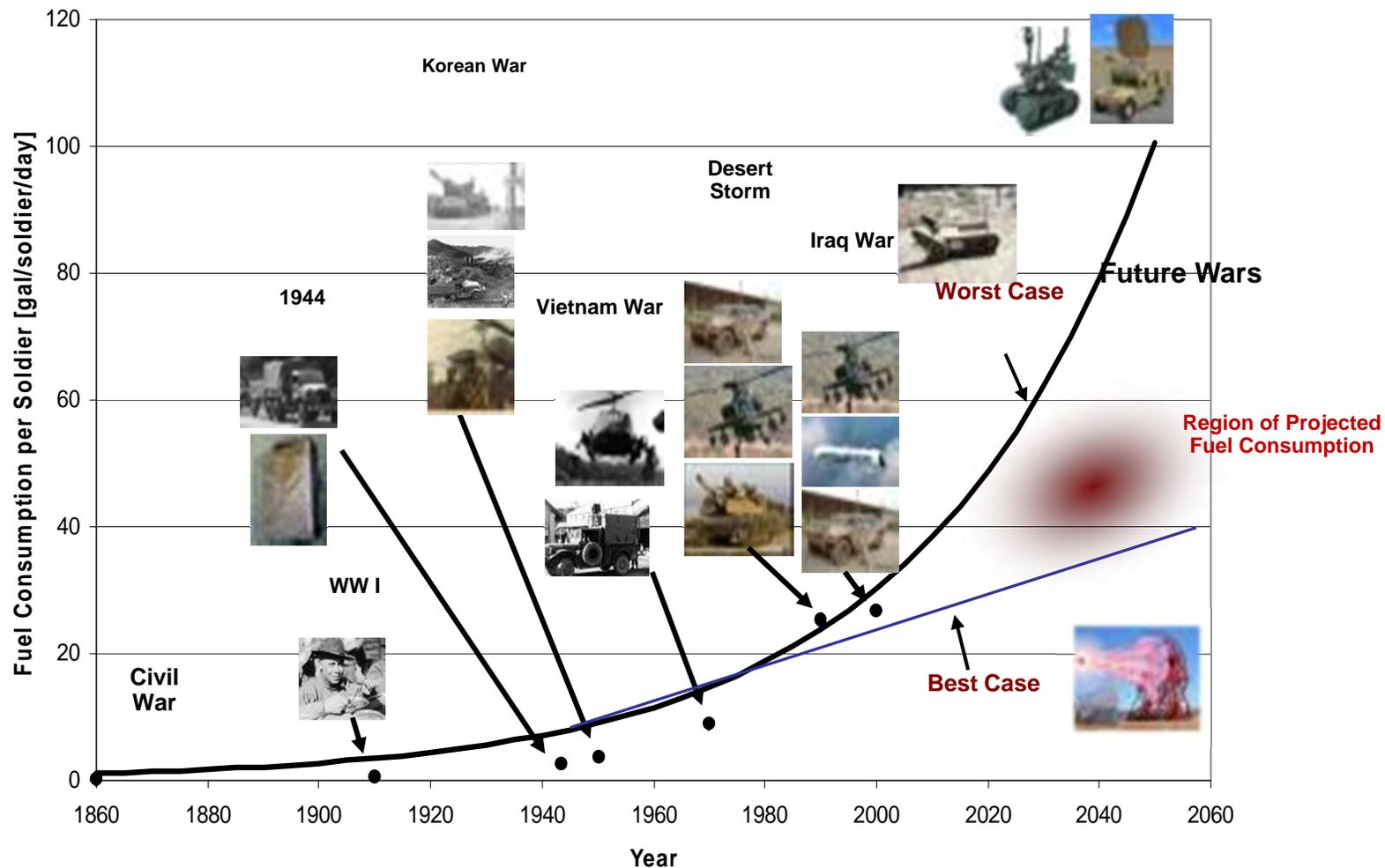
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**End-to-End Energy Business:
From Generation to Application**

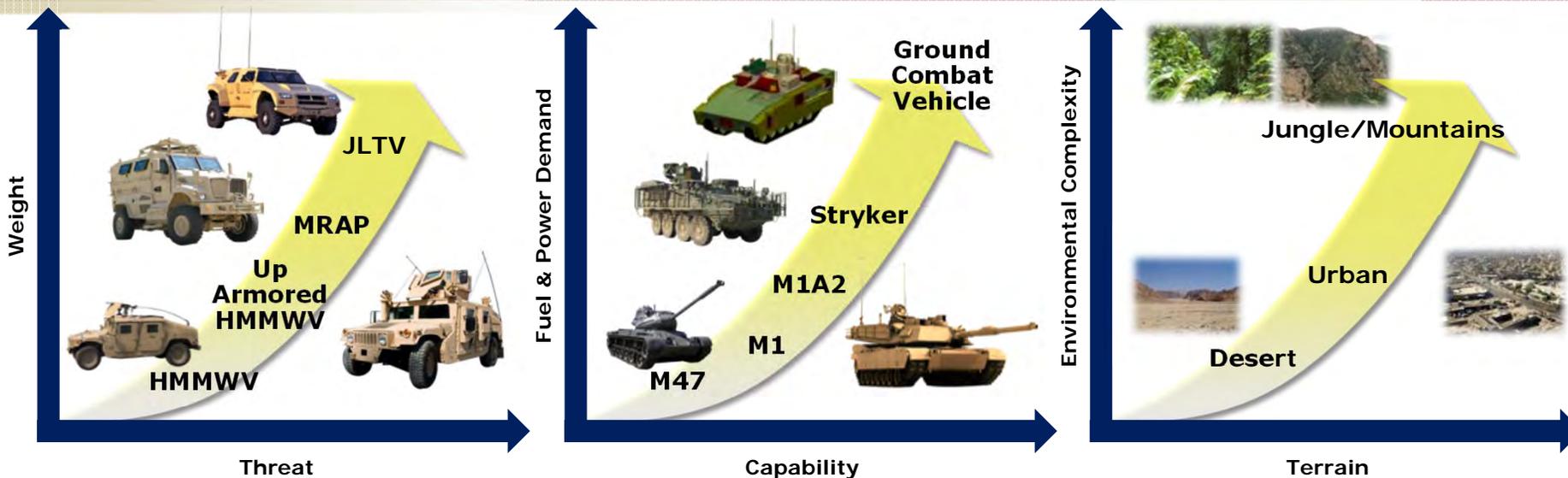


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Increasing Demands and Operational Flexibility
Require Strategic Investments in Key Areas



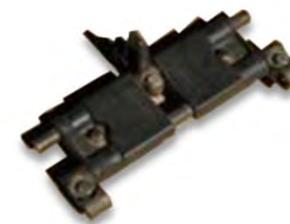
Energy Storage



Power Generation
& Control



Thermal Management



Track & Suspension

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2007 Kuwait / OIF / OEF Fuel to FOB (M Gal)

431



Number Convoys Resulting in 1 Casualty

24

Number Convoys Per Day

2.5

Days Between Casualties

10

IMPACTS of Saving 1% Fuel

\$5-82B

Fewer Dollars Spent on
Fuel

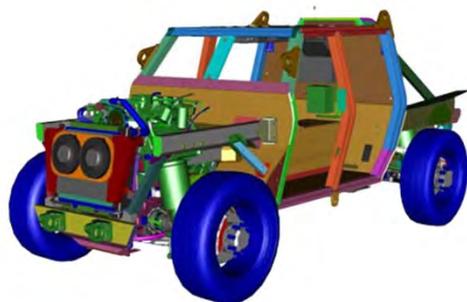
6,444

Fewer Soldier Trips

37

Fewer Casualties

**Modeling and Simulation:
Optimize the System**



Research and Testing



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**Demonstrate Systems
and Technologies**



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The Energy Challenge for the U.S. Military – Vehicle Fleet



▶ Tactical Vehicles

Vehicle	Description	Units
Light Tactical Vehicles (LTV)	HMMWV vehicle variants made up of 1 ¼ ton payload class	163,661
Medium Tactical Vehicles (MTV)	14 variants in 2.5 and 5 ton payload class	43,143
Heavy Tactical Vehicles (HTV)	Heavy-duty trucks, 10 ton and up, used for cargo, moving heavy equipment, tractors, tankers, wreckers, fire fighting trucks, dump trucks and others	55,236
Mine Resistant Ambush Protected (MRAP)	A family of armored fighting vehicles designed to survive IED attacks and ambushes	10,902 (*16238 required)
Total		272,942

▶ Non-Tactical Vehicles

Vehicle	Description	Units
Passenger Vehicles	Sedans, station wagons, passenger vans, SUVs	86,138
Light Trucks	Vans, pickup trucks	42,665
Medium Trucks	Miscellaneous cargo, flatbed, boxvan, others	43,762
Trucks	Heavy-duty trucks	17,598
Other	Ambulances, buses and support vehicles	6,633
Total		196,796

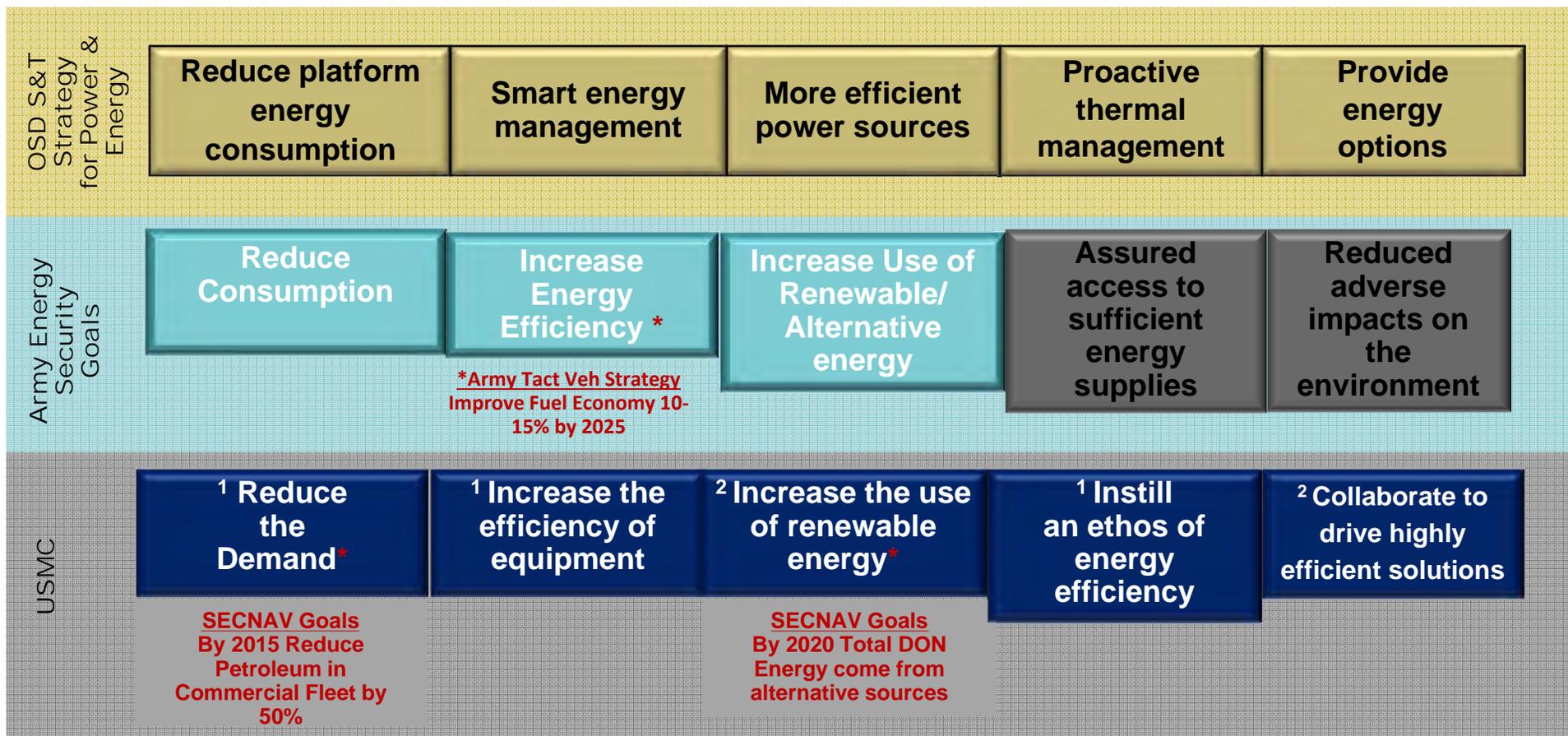
- ▶ All tactical vehicles are considered medium or heavy-duty by commercial standards (they are above 10,000 GVW, and all use JP8)
- ▶ About 30 percent of non-tactical vehicles are also medium or heavy-duty
- ▶ In total, about 72% of the total DoD fleet is medium or heavy-duty vehicles

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The Energy Challenge for the U.S. Military - Goals



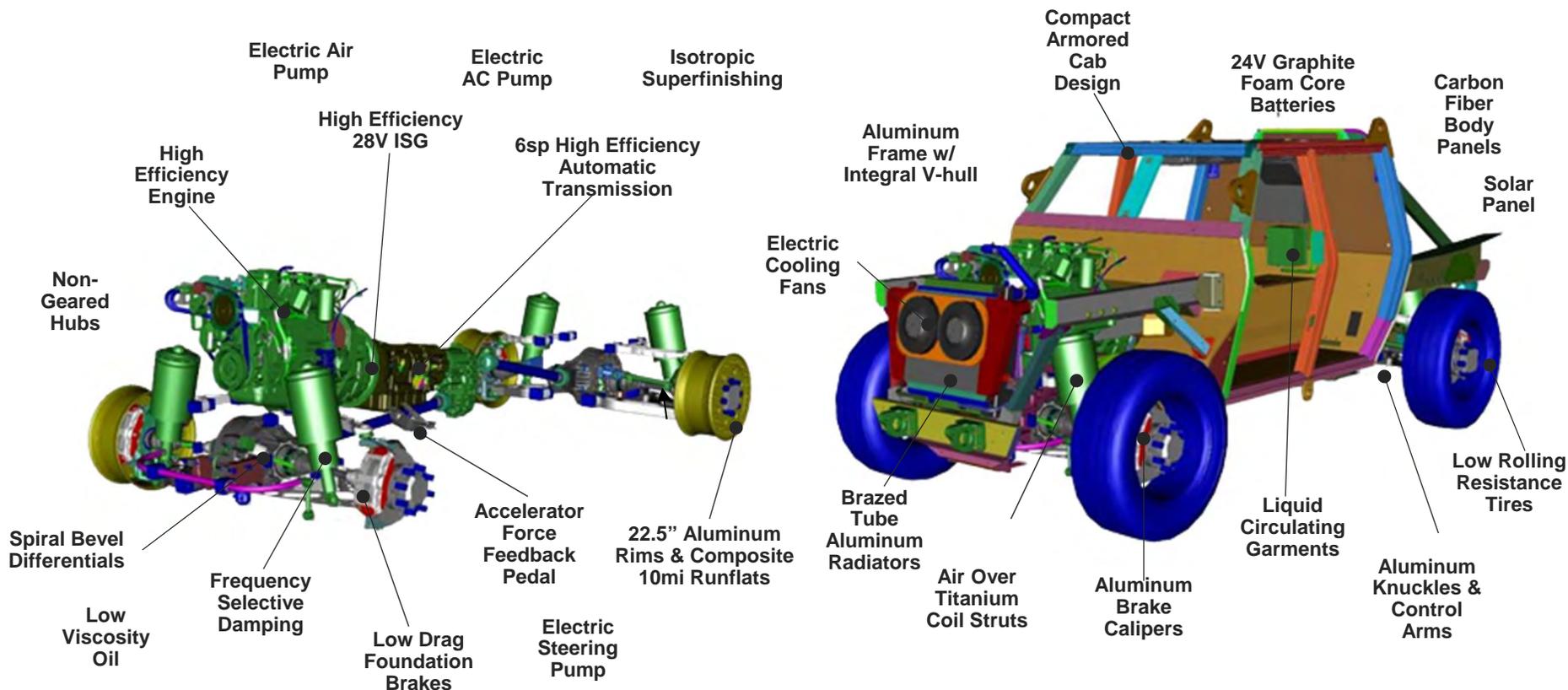
¹ 2010 USMC Commandant Planning Guidance

² USMC Energy Assessment 2011

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Systems Engineering Driven Solutions



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Hybrid Propulsion System R&D Fuel Efficient Ground Vehicle Demonstrator (FED)



- Alternative Materials
 - Aluminum Space Frame Technology
 - Underhood Composite Components for Powertrain
 - Advanced Lightweight Materials
 - Dropside / Tailgate Panels
 - BRADLY HIROUA
 - Bulk Sub-Micron/Nano Grain Metals / Light Alloys
 - Flash Processing Bainetic Steel
 - SI Composite / Polymeric Dash Board and Interior Trim
 - Adhesives-Mech. Attach-Glass Bubbles
 - Friction Stir welding of light weight structures
 - Composite Seat Frame
- Auxiliary Power & Electrical
 - Parallel Magnetic Circuits
 - Free Piston Linear Generator for Hybrid Vehicle
 - Aluminum Wiring
 - Thermoelectric sound canceling muffler
 - LED lighting
 - Stirling Engine Based APU/NPS
 - High Temperature Thermoelectric Materials
 - Auxiliary Power Generation System (APGS)
 - Spek Gauges and Controller
 - Thermoelectrics
 - Power Management, Control, & Integration
 - Non-Thermal Plasma JP8 reformer & SOFC system
 - Lithium-Iron Phosphate Battery Technology
 - Lithium Ion Battery & energy storage systems
 - Miniature IC Engine / Generator for Auxiliary Power
 - Common Modular Power System
 - Wind Turbine
 - Linear Generator Engine
 - Lithium Ion High Power Batteries
- Propulsion
 - Fuel efficient diesel engine
 - SI High BMEP Engine
 - Smart Diesel Engine for the 21st Century Concept
 - Fast Heat Release System
 - Variator Transmission, IVT
 - Cylinder de-activation for 6.5L engine
 - Cooling Oil Optimization
 - Light weight, high power density diesel engine
 - Binary Logic Transmissions
 - FEAD Optimization
 - Turbo Compound
 - Turbo Compounding
 - L-33 MM Hybrid Propulsion Systems
 - Turbocharger
 - Ground Gearing to AGMA 11 and 12
 - Needle Roller Bearing Clutches
 - FE Bearing Applications
 - ISG (Integrated Starter Generator)
 - Hybrid electric drive system
 - Dynamic Neural Nets and BSFC for fuel economy
 - Dual Mode Two Engine Drive Train Architecture
 - Hybrid powertrain systems
 - Sonex Controlled Auto Ignition (SCAI)
 - PHEV drivetrains, control algorithms, and CVTS
 - HHO Technology
 - Start-Stop & Idle Stop Accessories
 - Pulse Jet Air Cleaner Ultra
 - Hybrid Energy Module (HEM) for Electric and Hybrid
 - Waste Heat Recovery
 - Hydraulic Hybrid Transmissions
 - Series Hydraulic Hybrid
- Fuels & Lubes
 - CerMet – ceramic coating nanotechnology
 - Advanced Engine Oil Lubricant
 - Infrared-Excitation for Increased Fuel Combustion
 - Isotropic Finishes and Coatings to improve Efficiency
 - Lubricant System Design for Fuel Efficiency
 - Advanced Drive Axle and Transmission Lubricant
 - FQS On Board Fuel Quality Sensor
 - Advanced Lubrication for low friction
 - MicroBlueÅ
 - Ovonic Solid Hydrogen System
 - Thermal Management
 - Systems Integration
 - Aerodynamics
 - Island EVT
 - Improved Packaging for Battery Cells
 - Underbody Hull Design
 - Flat V
 - HIP Model V
 - Inverted V
 - Standard V Hull
 - Chassis & Suspension
 - Electric Power Assist Steering (EPAS)
 - Airless Wheel for Improved Fuel Efficiency
 - Electronically Controlled Active Suspension
 - Magneto-Rheological Active Dampers
 - Enhanced Suspension System
 - * TARDEC tech-base programs relating to technologies

Over 100 Technologies Reviewed

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Fuel Economy:

- 7.5 mpg Composite
 - 12.6 mpg Convoy Escort
 - 7.1 mpg Urban Assault
 - 4.8 mpg Cross Country
 - 0.51 gpm Idle



Survivability:

- Integral V-hull
- Blast protected seating
- Upgradeable B-kit

Weight:

- 12,500 lbs VCW (w/ B-kit)
- 2900 lbs Payload
- 15,400 lbs GVW

Mobility:

- 18" Step Climb
- 60% Grade

Performance:

- 50 mph Speed on 5% Grade
- 30kW Onboard Power

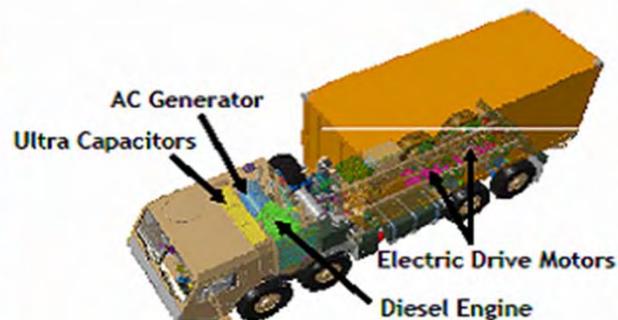
**FED concept meets or exceeds
M1114 HMMWV capabilities with
70+% better fuel efficiency**

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Diesel-Electric HEMTT A3

- Technologically advanced HEMTT M1120
- 8" shorter and 4,000 lbs lighter than production HEMTT
- Enhanced LHS loads/unloads 13-Tons of Flatrack cargo from C-130
- Diesel-electric (ProPulse®) powered, Series hybrid drivetrain
- 20% improvement in fuel economy (mpg)
- Exports 100kw of military grade A/C electrical power
- Ready for user operational evaluations and LRIP this spring



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**Diesel-Electric Hybrid High Mobility
Multipurpose Wheeled Vehicle (HMMWV) in
Exportable Power Demonstration at Ft Bliss,
TX during the 2010 Renewable
Energy Rodeo & Symposium**

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Retains all capabilities of standard HMMWV

- **High Vehicle Performance**
 - **Top speed of 80 mph**
 - **Acceleration from 0 to 50 mph in 7 sec**
 - **Low thermal signature**
 - **Low audible noise**
- **90 A, 24 V electrical system**
- **Source of mobile electric power**
 - **24 kWh storage**
 - **55 kW continuous power**
 - **250 kW peak power**
- **No exhaust plume in electric mode**
- **Ultra-low smoke in hybrid mode**
- **Regenerative electrical and mechanical disc braking**
- **Electric powered steering and braking**



Diesel-Electric Series Hybrid Advanced Ground Mobility Multipurpose Vehicle (AGMV) in Display/Ride/Drive at Ft Bliss, TX during the 2010 Renewable Energy Rodeo & Symposium

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The objective of the Clandestine Extended Range Vehicle (CERV) program is to develop a second-generation high-performance light-duty off-road diesel-electric series-hybrid vehicle to assess mission suitability, supportability, and performance.

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The project objective is government and industry to jointly develop a military grade all terrain Electric Hybrid vehicle that meets and exceeds Internal Transportable Vehicles (ITV) and Light Mobility Vehicles (LMV) specifications to enable military forces with a means to complete their missions effectively and safely. Proven technology and design principles from the sports of off-road racing and extreme rock crawling are combined with high level systems engineering from the aerospace and automotive industries.

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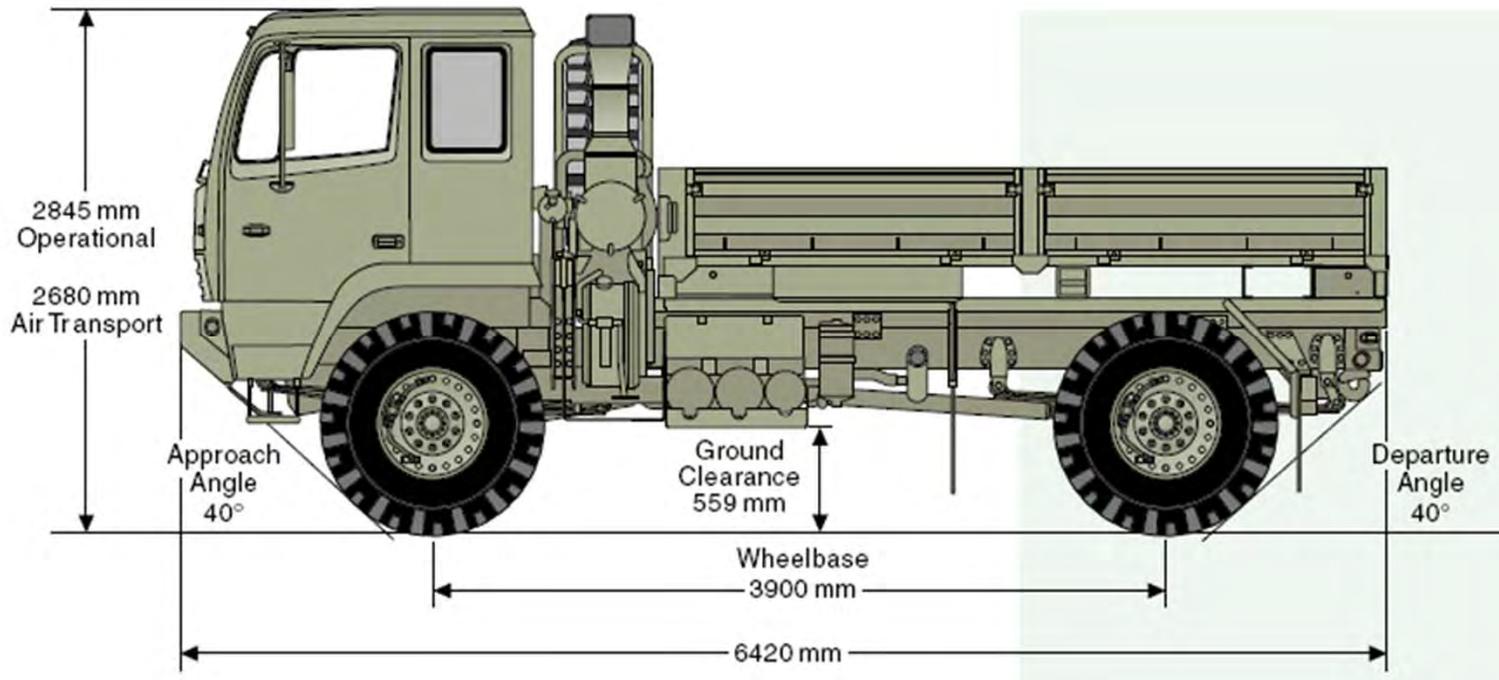
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Unmanned Ground Vehicle (UGV) - Multifunction Utility/Logistics and Equipment (MULE) on display at the Association of the United States Army's Institute of Land Warfare Winter Symposium and Exposition in Fort Lauderdale Fla.

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The project objective is to integrate commercially available Hydraulic Hybrid drive system components into a Family of Medium Tactical Vehicles (FMTV) platform.

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**Road-Coupled Plug-in Parallel Hybrid Electric
Vehicle Developmental Prototype with Exportable
Auxiliary and Bi-Directional Electricity Power
Flow Capability (G2V & V2B/G)**

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**M915 Variant in Exportable Power
Demonstration at Ft Bliss, TX
during the 2010 Renewable
Energy Rodeo & Symposium**

Scope: Design, build, and deliver two military line haul semi tractors; one will meet the USAF specification (GU7) and the other one will meet the Army specification (M915).

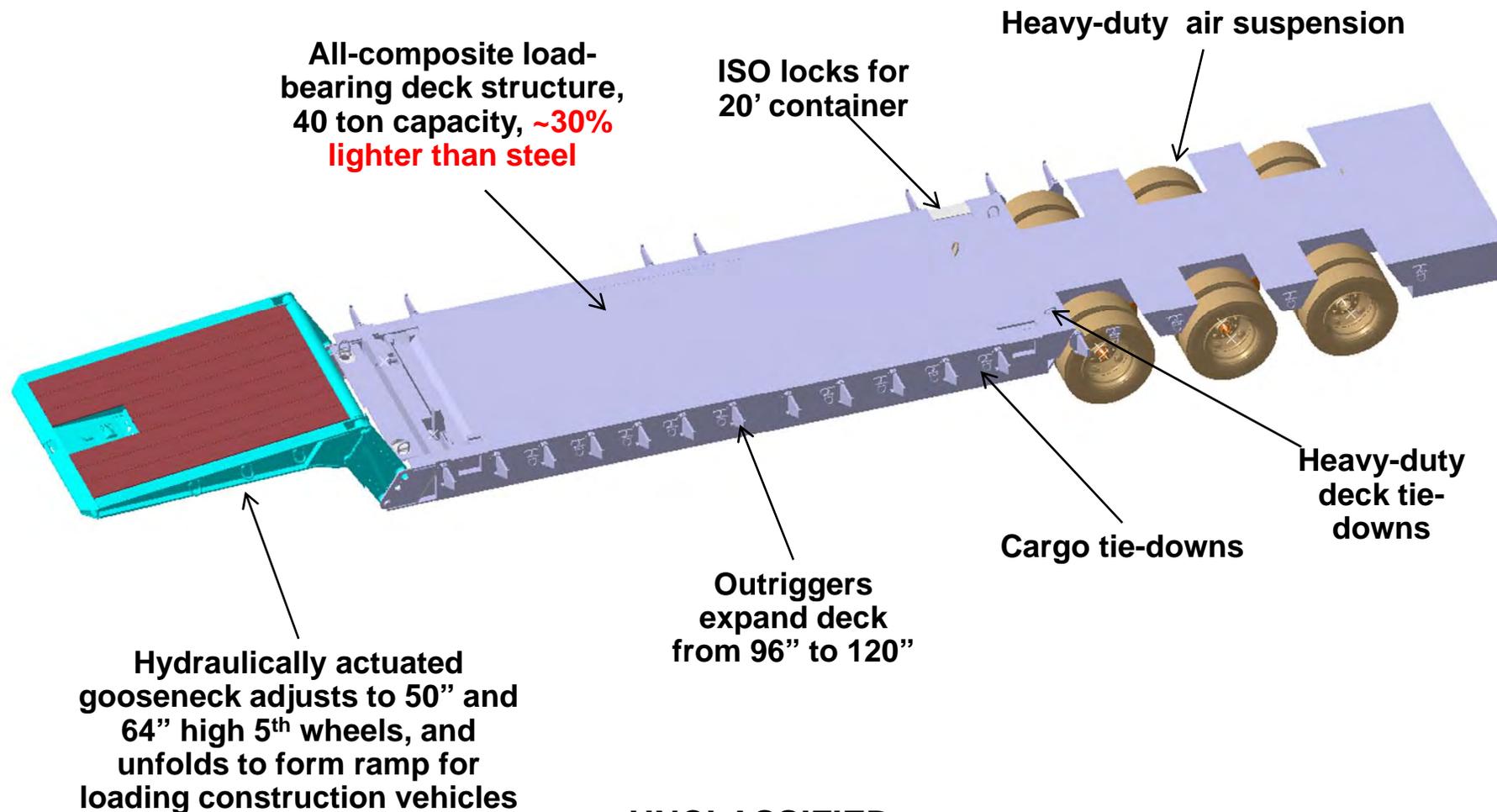
Technical specifications:

- 365 HP / 11 L diesel engine capable of operation on low sulfur (LS) diesel , B-20 biodiesel, and blended synthetic diesel fuel operation. The engine will meet 2010 EPA emission requirements
- Hybrid drive powertrain; a 160 Horsepower (Hp) electric machine used for propulsion and regeneration and includes a lithium ion battery energy storage
- Export power capabilities meeting mission requirements (5-50 kilowatt [kW])
- Air transportable via C-17 or C-5 aircraft
- Meets all highway driving requirements

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Lightweight Composite Multi-functional 40-ton Semi-trailer



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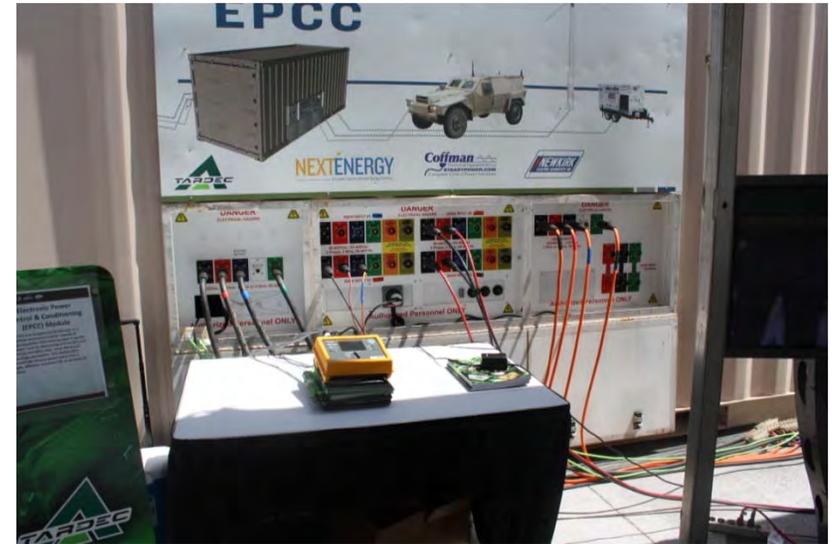
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The Hybrid Electric Reconfigurable Movable Integration Test bed (HERMIT) is a platform that includes the packaging and integration of components, providing engineers with an understanding of how the system will function within a military vehicle's spatial constraints. The platform can be reconfigured to meet the requirements of several Army ground vehicle systems, including tactical wheeled or tracked vehicles.

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**Electric Power Conditioning & Control (EPCC) Module
Power Demonstration at Ft Bliss, TX during the 2010 Renewable
Energy Rodeo & Symposium**

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**Army Ground System Power & Energy
Laboratory (GSPEL)
at Detroit Arsenal (Warren, MI)
Dedication and Grand Opening
Spring 2012**

- The Lab provides a full mission profile testing capability for tracked vehicles or up to 5-axled wheeled vehicles in any environmental condition
 - 10 wheeled vehicle dynamometers, lateral adjustment for different wheel spacing and translates in and out for different vehicle widths
 - 800 kW Power supply/sink and safety measures for utilizing hydrogen in chamber
 - Large environmental chamber - temperatures from -60 to 160 deg-F, 95% RH, wind speeds of 60 mph, solar simulation
- Expands development of Hybrid-Electric powertrain and Hybrid-Electric components
- Expands JP-8 reformation technology and fuel cell evaluation
- Thermal Management Lab for evaluation of vehicle heat exchange systems and power packs

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Hybrid Propulsion System R&D DA/DOD/DOE Collaboration



Within the past fourteen months the Departments of the Army (DA), Defense (DOD) and Energy (DOE) have entered into two significant technology development collaboration agreements:

July 2010 – DOD/DOE Memorandum of Understanding (MOU)

The purpose of the MOU is to identify a framework for cooperation and partnership between DOE and DOD to strengthen coordination of efforts to enhance national energy security, and demonstrate Federal Government leadership in transitioning America to a low carbon economy.

July 2011 – DA/DOE Advanced Vehicle Power Technology Alliance (AVPTA) Charter

The AVPTA will be a partnership between DA and DOE in accordance with the DOD/DOE MOU for the establishment of a joint technology research in the area of ground vehicle power technology research, development and transition. The Alliance will also leverage industrial research and development involving commercial automotive and defense ground vehicle manufacturers to transition technologies and increase precompetitive research and development.

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Hybrid Propulsion System R&D DA/DOE AVPTA Workshop



Work Groups Convened in Six Technology Focus Areas Identified for initial Joint Activity

Technology Focus Areas	Primary Interest	
	Army	DOE
1) Advanced Combustion Engines & Transmissions	High density, energy efficient powertrain	Extreme gains in engine efficiency
2) Lightweight Structures & Materials	Reduce weight to improve performance	Cost reduction for consumer market
3) Energy Recovery & Thermal Management	Improved efficiency, manage heat generation	Efficiency gains through waste heat recovery
4) Alternative Fuels & Lubricants	Standardization & security	Efficiency gains for the legacy fleet
5) Hybrid Propulsion Systems & Energy Storage	Efficiency improvements	Efficiency improvements
6) Analytical Tools	Assessment/Design Trades	Assessment/Design Trades

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**Thank You
for
Your Attention

Questions?**

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