TARDEC Technologies

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Chuck Coutteau
Associate Director for Ground Vehicle Power and Mobility
Tank Automotive Research, Development & Engineering Center
September 30, 2008

DISTRIBUTION STATEMENT A:
Approved for public release; distribution is unlimited

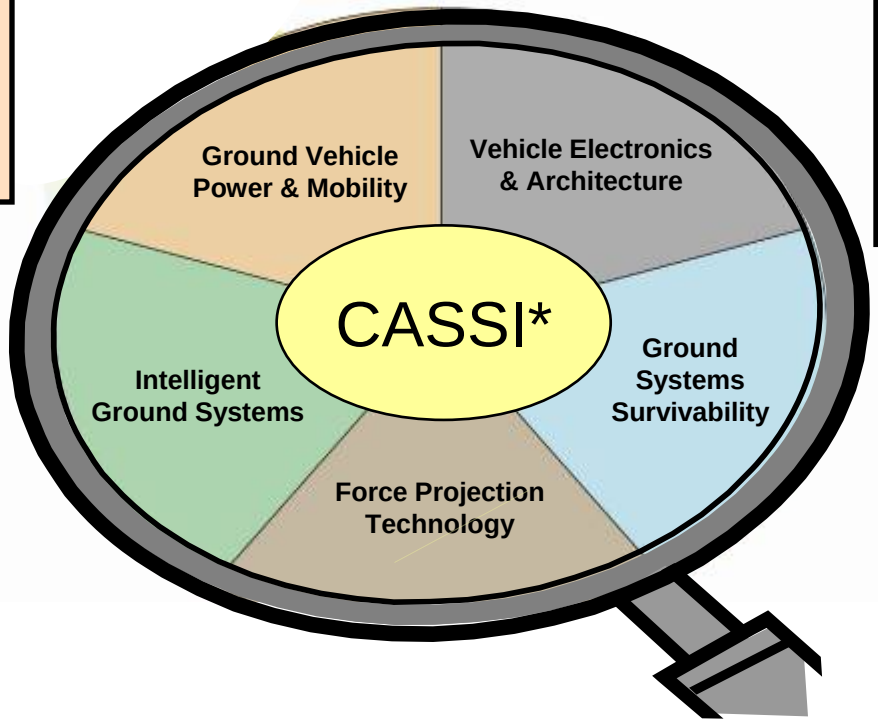
TARDEC Technology

Ground Vehicle Power & Mobility

- Hybrid Electric
- Pulse Power
- Engines
- Fuel Cells
- Suspension
- Tracks

Vehicle Electronics & Architecture

- Power Architecture/Management
- Electronics Integration
- Data Architecture
- Condition Based Maintenance (CBM)
- Diagnostics/Prognostics



Intelligent Ground Systems

- Robotic Systems Technology
- Human-Robot Interaction
- Crew Interface and Automation
- Robotic Follower ATD
- ARV Robotic Technologies Program

Ground System Survivability

- Active Defense
- Signature Management
- Laser Vision Protection
- Ballistic Protection
- Crew Survivability

Force Projection Technology

- Water Generation & Purification
- Petroleum, Oils & Lubricants
- Mechanical Countermine
- Combat Engineering/Bridging
- Gap Crossing
- Future Truck System

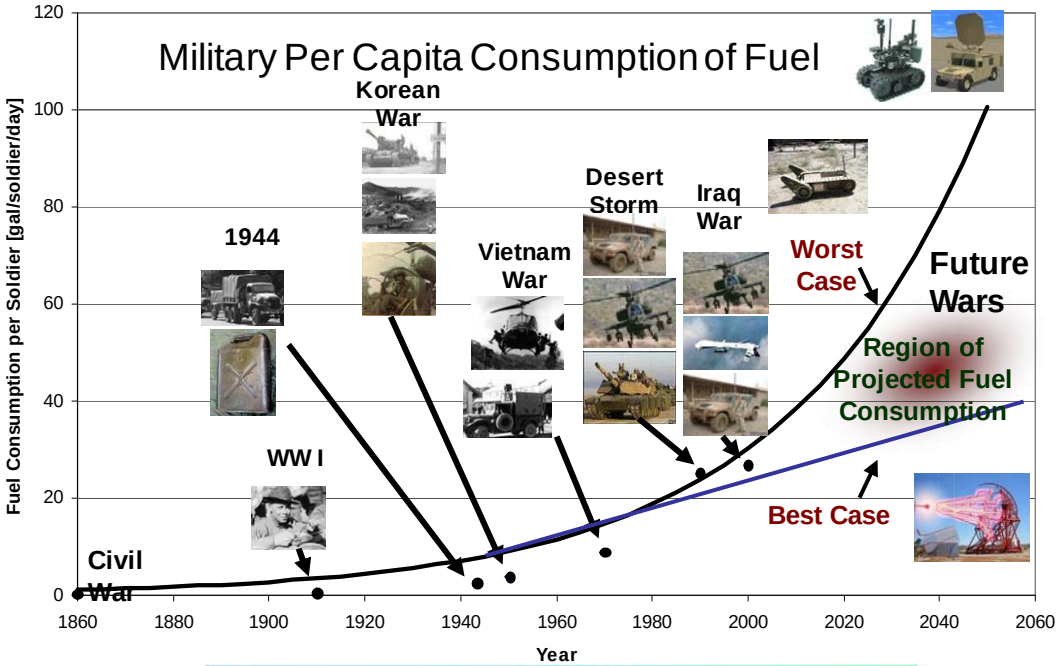
* Concepting, Analysis, System Simulation & Integration

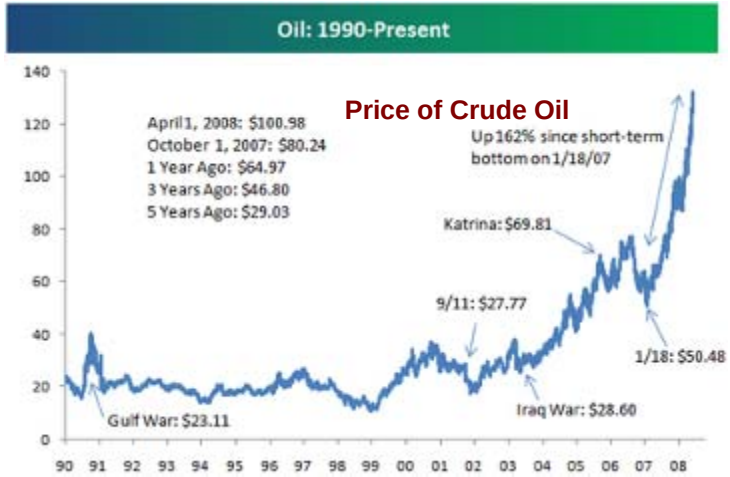
- Requirements Capture, Concept Development, Program Formulation
- Dynamic/Structural Performance, Mathematical Modeling, Data Analysis
- Physical Validation, Systems-Level Validation
- High Power Computing, Advanced Collaborative Environments
- Integrated System-Level Demonstrators

UNCLAS: Dist. A. Approved for public release

The Challenges

- **Battlefield consumption of energy increasing**
  - New C4ISR technologies
  - IED Defeat Systems
  - New weapons (EM guns, lasers)
- **Energy security problematic**
  - Cost of fuel skyrocketing
  - Alternative sources sought – wind, solar, bio-mass, waste to energy
- **Operational issues**
  - Battery usage & limitations – energy & power density
  - Demand for auxiliary power on-board vehicles
  - Emphasis on silent ("quiet") watch
  - Unmanned vehicles (air/ground)
  - Unattended sensors
  - Inefficient management/ distribution of power
  - Demand for soldier-wearable power
- **Increased emphasis on system power metrics and energy efficiency** (KPPs, low consumption components)





UNCLAS: Dist. A. Approved for public release

Ground Vehicle Solutions

Current Systems

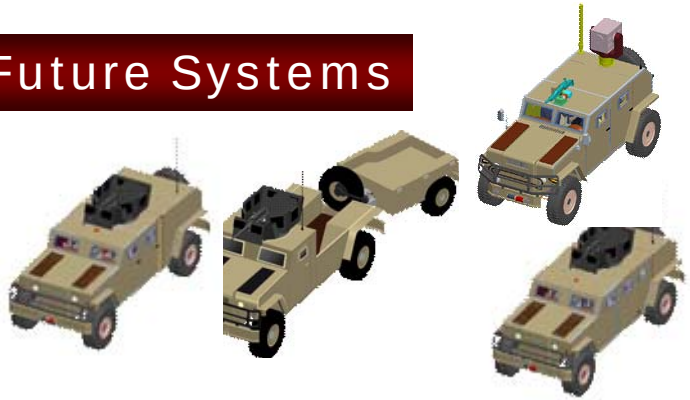
HBCT

M1114

Parallel Hybrid MSV

2 Parallel hybrid UVs

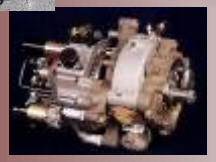
Future Systems



FCS MGV

Supporting Science and Technology Investments

Rotary Engine APU

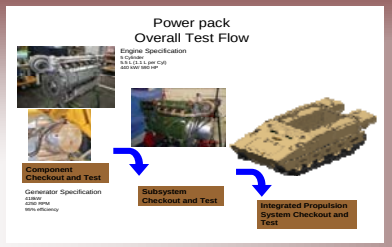


Advanced Track

Fuel Efficient ground vehicle Demonstrator (FED)

Energy Storage & Safety

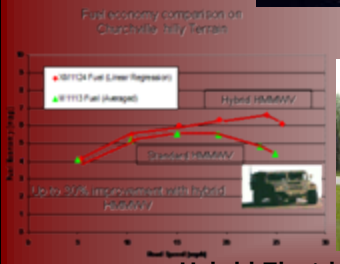
EGTL/P&E SIL



JP-8 Reformer

Si/SiC dc-dc converter

AAEF



Hybrid Electric Evaluation and Assessment (HEVEA)

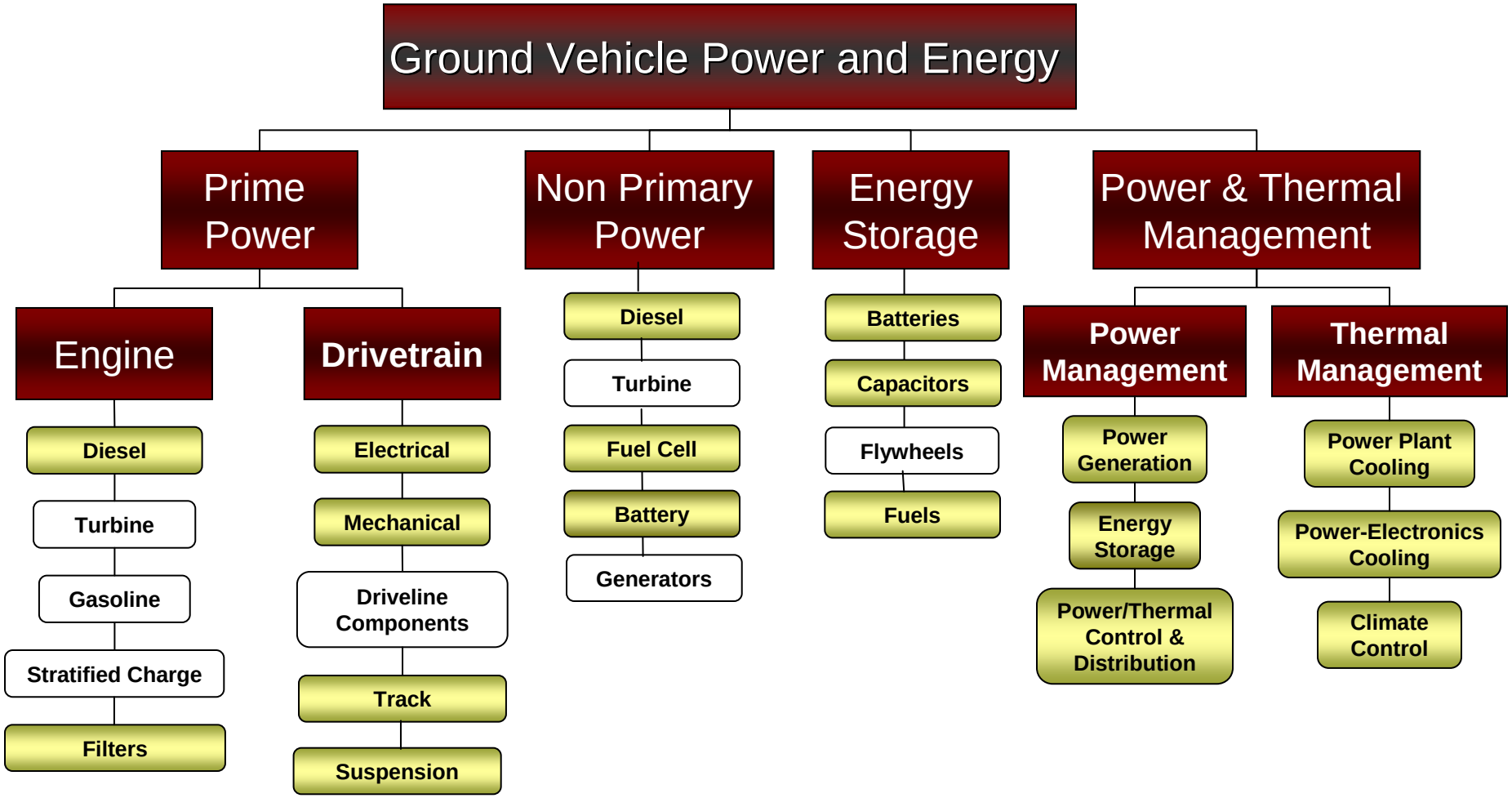
OBVP

Phase change, graphite foam, & nanotechnology thermal solutions

"Smart", networked switches, robust operation & reduced size

UNCLAS: Dist. A. Approved for public release

GVPM Technologies



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
UNCLAS: Dist. A. Approved for public release

Prime Power

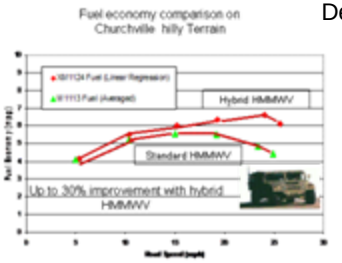
Current Systems

M88 Repower

Tactical Vehicle Engine Dev and Optimization

AAEF

Advanced Track



Hybrid Electric Evaluation and Assessment (HEVEA)

Hybrid Hydraulic Vehicle Development

Bradley Transmission Testing

Si/SiC DC-DC Converter

Elastomer Research

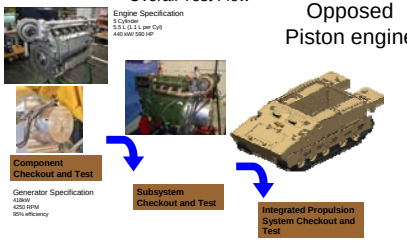
Future Systems

Power and Energy SIL

Diesel Engine research

Diesel Engine

EGTL/P&E SIL



Opposed Piston engine

Pulse Power Supply for High Energy Lasers

Efforts Supporting Current Force

- HMMWV Engine Optimization
- M88 Repower technical and testing support
- Turbine Engine Durability
- LMTV Full Load Cooling Evaluations
- Hybrid Electric Vehicle Evaluation and Analysis
- Vehicle Driving Cycle Development
- TWV engines and emissions challenges
- Bradley and Abrams improved track

Efforts Supporting Future Force

- FCS Engine Generator testing in the EGTL
- FCS propulsion testing in the PE SIL
- Hybrid Electric Vehicle Evaluation and Analysis
- FCS segmented band track
- Vehicle Driving Cycle Development
- High Speed Diesel Engine R&D
- High operating temperature power electronics (SiC)
- Demonstration of exportable power to Battalion TOC in AAEF
- Compact integrated hybrid power systems for future combat and wheeled vehicles

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

UNCLAS: Dist. A. Approved for public release

Hybrid Electric Vehicle Evaluation and Assessment (HEVEA)

- *Problem:*
- No holistic approach to define, evaluate, and substantiate TWV mobility requirements and specifications.
- No standard Hybrid Electric Vehicle Test Methodology for TWV.
- TWV duty cycles not well defined/understood; Increasing difficulty in assessing advantages and disadvantages of hybrid propulsion systems.

- *Challenges:*
- Accepted industry practices (SAE) for testing are not developed to be replicated in traditional military settings.
- No industry standard advancing propulsion systems, specifications including requirements.

- *Key Goals:*
- Data and analyses to support PEO CS/CSS information requirements for JLTV MS B
- Develop Hybrid Electric Vehicle (HEV) Fuel Economy and performance **Test Operating Procedures (TOP)**
- Determine the fuel economy benefits of HEV using quantifiable test data
- Develop and validate TARDEC M&S models
  - **M&S capability to provide a tool to predict hybrid electric drive cycle performance and fuel economy.**
  - **VPSET**

- *Key Efforts:*
- Vehicle Testing: ATC, PM JCSS, PM LTV, PM MTV, PM HTV, ONR, BAE, SS/AH, AM GEN, OSHKOSH, LM, IMG
- GVSL Execution of Experiments/Support - DCS
- Electrical Power Architecture SIL Upgrade/Support and
- Thermal Management: DCS, UofM Dearborn
- M&S vehicle propulsion systems analysis and tool: SwRI, SAIC, ONR

9 conventional and 7 hybrid electric vehicles are being tested

A. Conventional:
2 - HMMWVs,
2 -2 1/2T LMTVs
1 - 5T MTV
1 – FMTV CVT
2 – HEMTTS
1 – AM GEN UV

B. Hybrid Electric
1 – HMMWV
1 – RSTV
1 - IMG UV
1 – LM UV
1 – AH/SS MSV
1 – BAE FMTV
1 – OSHKOSH HEMTT A3

- *Customer:*
- PM JCSS, PM JLTV. PM-LTV

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

UNCLAS: Dist. A. Approved for public release

Non-Primary Power

Current Systems → Future Systems

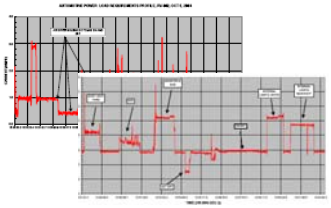
400A Alternator
(M1114 Kit)

280A Alternator
(RG-31 Kit)

10kW Rotary JP-8
Auxiliary Power Unit

3.5kW Auxiliary Power Unit to support
Asymmetric Threat Defeat JUONS

APU Testing and Analysis



Non-propulsion Load Analysis

Fuel Cell Ground Support
Equipment

OPOC Engine APU

JP-8 Reformer

SOFC APU

Efforts Supporting Current Force

- On Board Power Kits for M1114 and RG-31
- APU Upgrades for M-939 and RG-31.
- Non-primary Power for PEO GCS Combat Vehicles testing and development
- Non-primary power load profiles

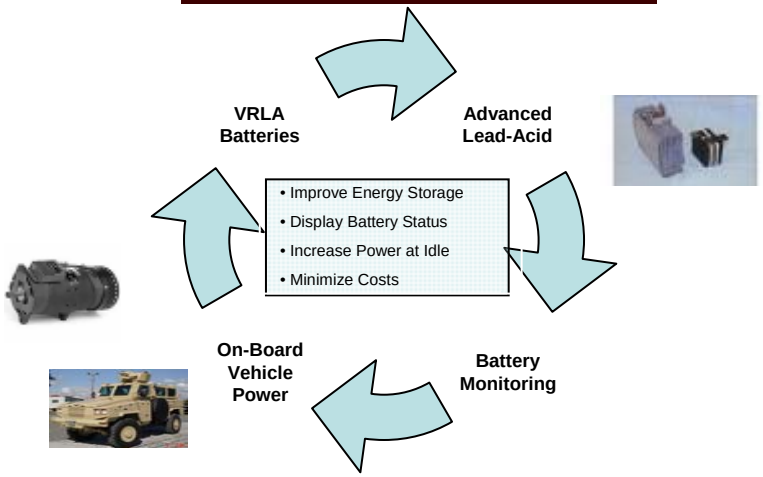
Efforts Supporting Future Force

- Non- Primary Power load profiles
- Energy Storage systems
- JP-8 Reformation for future fuel cell APUs
- Alternative Power sources

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
UNCLAS: Dist. A. Approved for public release

Energy Storage

Current Systems

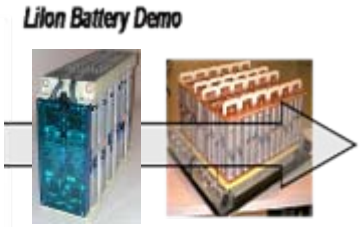


Testing & Safety Evaluations and improvements

Capacitors for EMA

Future Systems

L-i-Ion Battery Manufacturing Technology Objective



L-i-Ion Battery Module (50V)

NiZn Cell

LFP cathode

Li-Ion Prismatic Cell

Li-Ion/Ultracap Hybrid Energy Storage

Efforts Supporting Current Force

- Battery Monitoring Technology development and testing
- Advanced Lead acid battery testing and qualification
- Advanced Lead Acid Battery Technology Enhancement
- Ballistic Impact Test and Evaluation for Batteries
- Integration, Testing, & Evaluation of Battery Packs in vehicle demos

Efforts Supporting Future Force

- High Power, High Energy Li-Ion Battery Manufacturing
- Large format Li-Ion prismatic cells with integrated liquid cooling
- development
- Lithium-Iron Phosphate (LFP) Battery Safety Improvements
- Ultra High Power Li-Ion Cells for Pulse Power
- Advanced Battery Architecture
- Ballistic Impact Test and Evaluation for Batteries
- Thermal Runaway Studies for safety improvements
- Integration, Testing, & Evaluation of Battery Packs in vehicle demos
- Nickel Zinc Battery Development

UNCLAS: Dist. A. Approved for public release

Power and Thermal Management

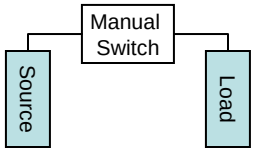
Current Systems → Future Systems

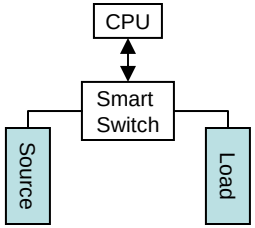
Basic Power and Thermal Mgmt
- Crew Intensive
- Manual Load Control
- Limited Monitoring
- Limited Fault Detection and Diagnostics
- No Thermal Management

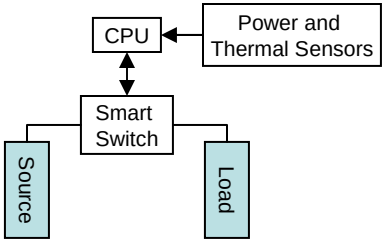
Intelligent Power and Thermal Mgmt
- Reduced Crew Burden
- Semi-Automatic Load Control
- Energy Storage/Generation Monitoring
- Improved Fault Management and Diagnostics
- Limited Thermal Management

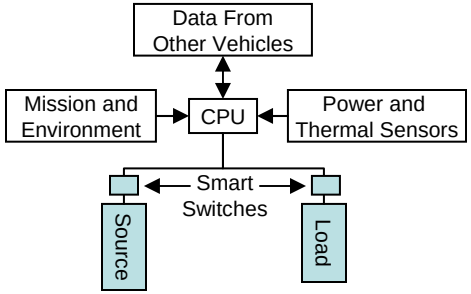
Cognitive Power and Thermal Mgmt
- Minimum Crew Burden
- Adaptive Load/Source Control
- Mobility, Survivability, Lethality Sensor Monitoring
- Full Diagnostics, Fault Management, Prognostics
- Integrated Thermal Management Strategies

Collaborative Power and Thermal Mgmt
- System of Systems Application
- Network Aware
- Optimized Power Utilization Across Multiple Vehicles
- Shared Learning Among Vehicles
- Increase Situational Awareness for Army Leaders









ILAV AC Test

LMTV Full Load Cooling Test

HERCULES Full Load Cooling Test

Software Standard

Flexible cables

Integrated Power and Thermal Systems

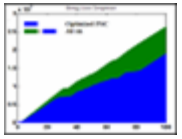
Graphite foam Heat Exchangers

Stryker Interior Temperature Test

Electrical Power Architecture Lab

Advanced Inverter Cooling Demo

Reduced Size "Smart", Networked Switches


Power Optimization

High Temperature Electronics using SiC

Phase Change Technology

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
UNCLAS: Dist. A. Approved for public release

Capabilities and Facilities

- **Propulsion Test Laboratory**
  - **10 Test Cells which include:**
    - **6 “engine” test cells used for performance, endurance, APU, transmission or drive train testing**
    - **3 vehicle test cells designed for steady-state tests to 44000 ft-lbs per side as well as transient tests and a Power & Inertia Simulator (PAISI)**
    - **Most contain portable dynamometers with absorption capability of 100-3000 horsepower**
    - **Test Cell #9 can simulate desert heat, wind and solar conditions at full load**
    - **Ambient temperature control to 160° F**
    - **Wind speeds up to 20mph in eight possible directions**
    - **Two 2500 Hp dynamometers**
    - **Test Cell #10 can test batteries, power electronics and motors to 6000rpm**

Powerpack Testing

- **Air Flow/Cooling Lab has air cleaner and radiator testing capability**
- **Power and Energy System Integration Laboratory (SIL)**
- **Track and Suspension Laboratory**
- **Motion Based Simulation Laboratory**
- **Power Management System Integration Laboratory (SIL)**
- **Modeling and Simulation**

Engine Testing

Power Management SIL

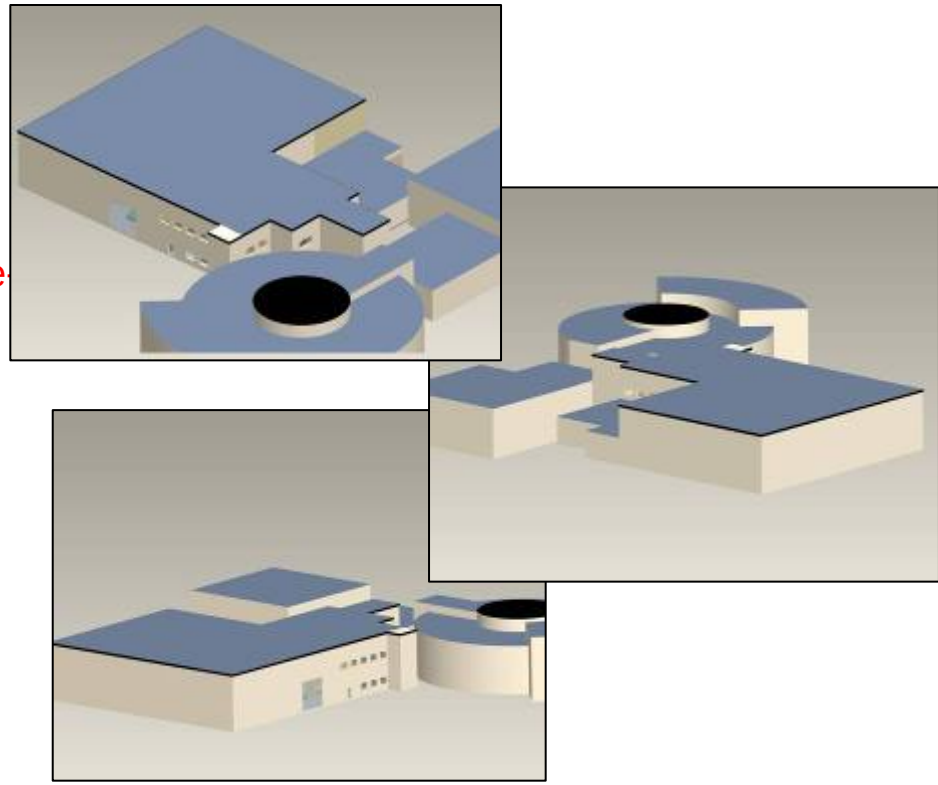
Power and Energy SIL

Vehicle Testing

Ground Systems Power & Energy Lab (GSPEL)

Timeframe:

- COE RFP Released 5 Aug 08
- Projected 31 Oct 08 Contract Award
- Break Ground Spring FY09
- Operational Fall FY11



Project Summary:

This project provides the Army with a much needed state-of-the-art research and development (R&D) laboratory space and equipment to conduct the experimentation, modeling, simulation, and testing of all military ground vehicles from sub-system components to systems of systems.

It provides a centralized facility with the capability to effectively test, optimize and integrate all current and alternative vehicle power generation and energy storage systems as well as power management and control into current and emerging classes of vehicles, wheeled and tracked, manned and unmanned.

The Power & Energy Laboratory is a key component of the strategic plan required to develop, support and sustain the Army's current and future combat and tactical ground vehicle systems.

UNCLAS: Dist. A. Approved for public release

GSPEL Capabilities

New Energy Systems Laboratory

- Upgraded Electrical Components Lab with 350 kW AC dyno and load bank to include SiC/Silicon power electronics testing capability
- New hydrogen/JP-8 reformation Fuel Cell Lab for battlefield fuel reformation and 10-60 kW silent watch fuel cell RDT&E
- New capability to test and integrate high voltage/frequency chargers, high energy density capacitors, high current solid state switches and dc-dc converters into Pulse Forming Networks for vehicle application
- Relocated and upgraded SIL capability for efficient electrical power distribution and control strategy and architecture development, characterization, integration and test
- Relocated and upgraded Electrochemical (Battery) Power Lab to safely test/evaluate 10-60 kW advanced chemistry battery packs

New Airflow and Thermal Fluids Laboratory

- Relocated and 8X Upgraded flow rate Air Filtration Lab for all vehicles, fully automated, to include self-cleaning scavenge systems
- Relocated and 3X Upgraded flow rate radiator testing capability
- New calorimeter and Thermal Fluids Lab for all vehicle thermal management (cooling) systems including power electronics

New P&E Vehicle Environmental Laboratory (PEVEL)

New Vehicle Environmental Laboratory

- 10 AC Dynamometers (2 for BFVS class combat vehicle and 8 for all tactical/wheeled vehicle torque/speed ratings)
- Environmental capability from -60ºF to +160ºF with variable wind, solar (desert) and humidity (global) control
- Transient cycle (mission profile) test capability for repeatable/controlled condition performance characterization, field failure root cause analysis and modeling and simulation validation data
- New Electrical Integration Laboratory for subsystem/system level components integration, performance characterization and transient test/evaluation
- New Laboratory for network and system level integration of Pulse Power and Direct Energy high voltage/frequency/density/current components performance characterization and transient condition test and evaluation

UNCLAS: Dist. A. Approved for public release