

***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

## Emerging Technologies For the Future Fight

**Grace M. Bochenek, Ph.D.**

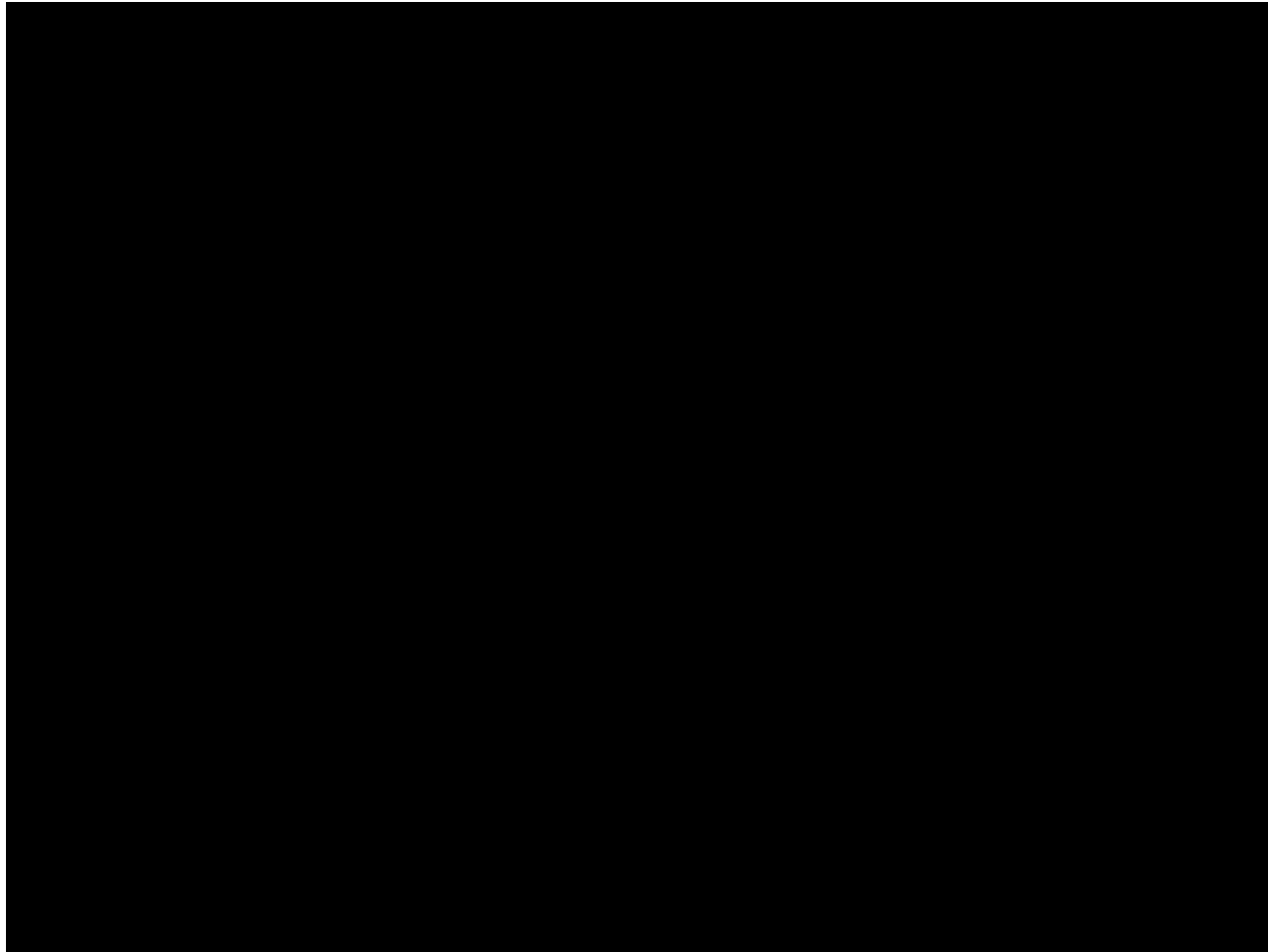
**Director, U.S. Army Tank Automotive Research, Development and Engineering Center**



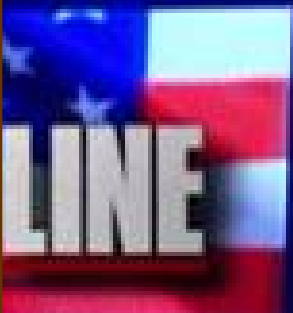


- The Current Fight
- Building for the Future Fight *NOW*
  - **Power & Energy**
  - **Robotics**
- Partnering with the Nation's Best
- Building the Future Workforce











- **Increase force protection**
  - Fewer fuel convoys means fewer people and systems in harm's way
- **Increase sustainability**
  - Operate for longer / go farther without resupply
  - Reduce O&S costs
  - Crude oil closed at \$96.37/Bbl on 11-7-07; DoD standard (refined) price is additional \$25/Bbl
  - Free up manpower and equipment
- **Reduce Dependency on foreign oil**
  - Reduce revenue flow to unfriendly / unstable nations



**“For too long our nation has been dependent on foreign oil...and the way forward is through technology.”**

*President George W. Bush, State of the Union Address, 23 January 2007*

**“We’ve also got to address the challenges of energy security and global climate change. We need to harness the power of technology”**

*President George W. Bush, Speech at the Asia-Pacific Economic Cooperation Business Summit, 7 August 2007*



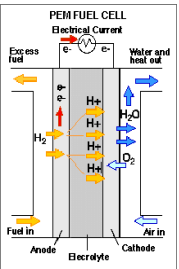
**“Reducing the military's dependence on fuel for power generation could reduce the number of road-bound convoys.”**

*U.S. Marine Corps Maj. Gen. Richard Zilmer, Defense News, August 2006*



## Supply Security

## Demand Reduction



### Supply

- Conventional fossil fuels
- Synthetic fuels (e.g. coal, natural gas derived fuels)
- Other alternative fuels (e.g. renewable jet and diesel, biomass, alcohols, hydrogen, etc.)
- Renewables (e.g. solar, geothermal, wind, wave/ocean)
- Novel supply (e.g. fuel cells)
- Nuclear
- Exotics (e.g. isomers)
- Local electrical grid

### Demand

- Conservation Initiatives
- Fixed base
- Tactical base
- Platforms
- Efficiency
- Life-Cycle Cost



- Direct oil / fossil fuel costs
- Policy, processes and risk assessment
- Refining capacity
- Energy availability
- Doctrine

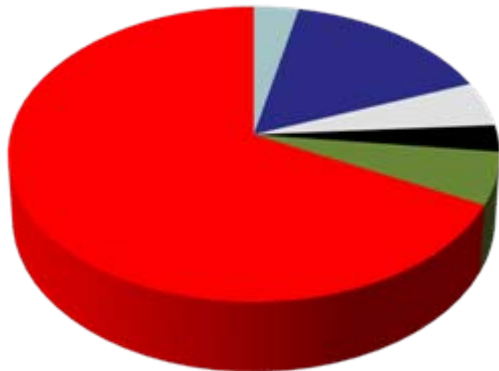
## Assured Distribution

## Convergence for Energy Security



## Peacetime Consumption (DSB Report)

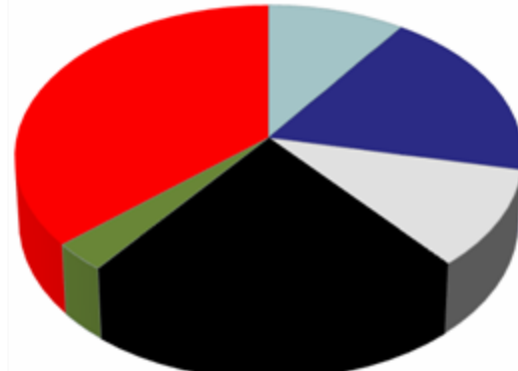
**112.4 Trillion Btu**



- Combat Vehicles (3%)
- Combat Aircraft (16%)
- Tactical Vehicles (5%)
- Generators (3%)
- Non-Tactical Vehicles (6%)
- Facilities (67%)

## Wartime Consumption (DSB Report)

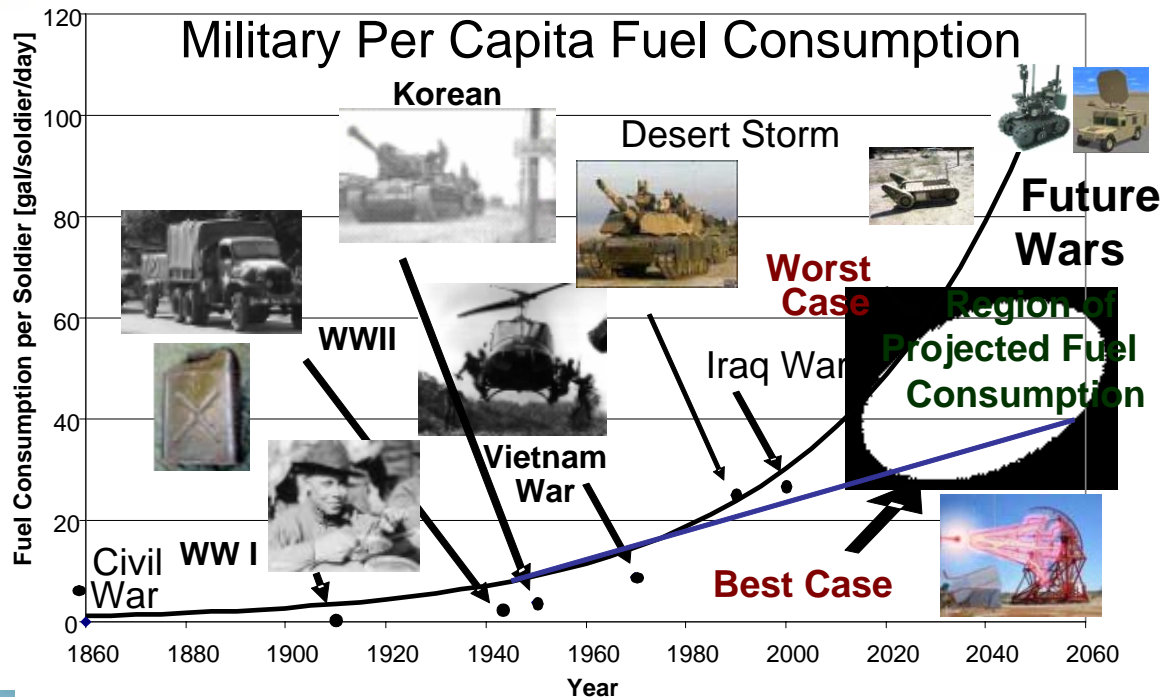
**206.6 Trillion Btu**



- Combat Vehicles (10%)
- Combat Aircraft (19%)
- Tactical Vehicles (11%)
- Generators (22%)
- Non-Tactical Vehicles (3%)
- Facilities (35%)

## The Challenges

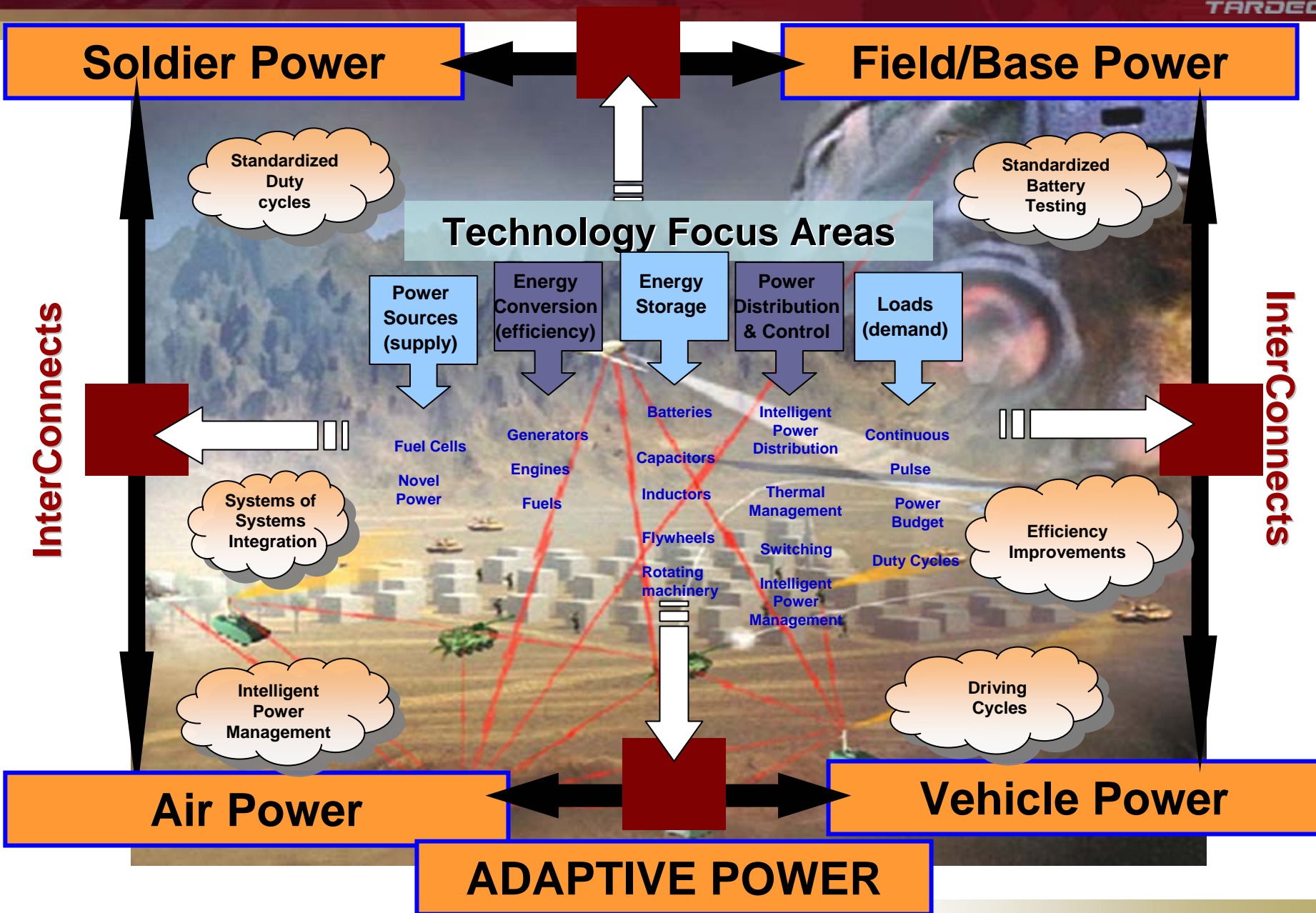
- Battlefield consumption of energy increasing
- Energy security problematic
- Operational issues
- Increased emphasis on system power metrics



**Discarded Batteries  
(90% Still Usable)**



**The HMMWV has progressed from a 85 amp alternator to a 400 amp alternator**





## Generation



## Distribution

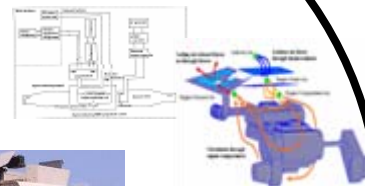


## Transfer



## Vehicle

### Power & Thermal Management



### Energy Storage

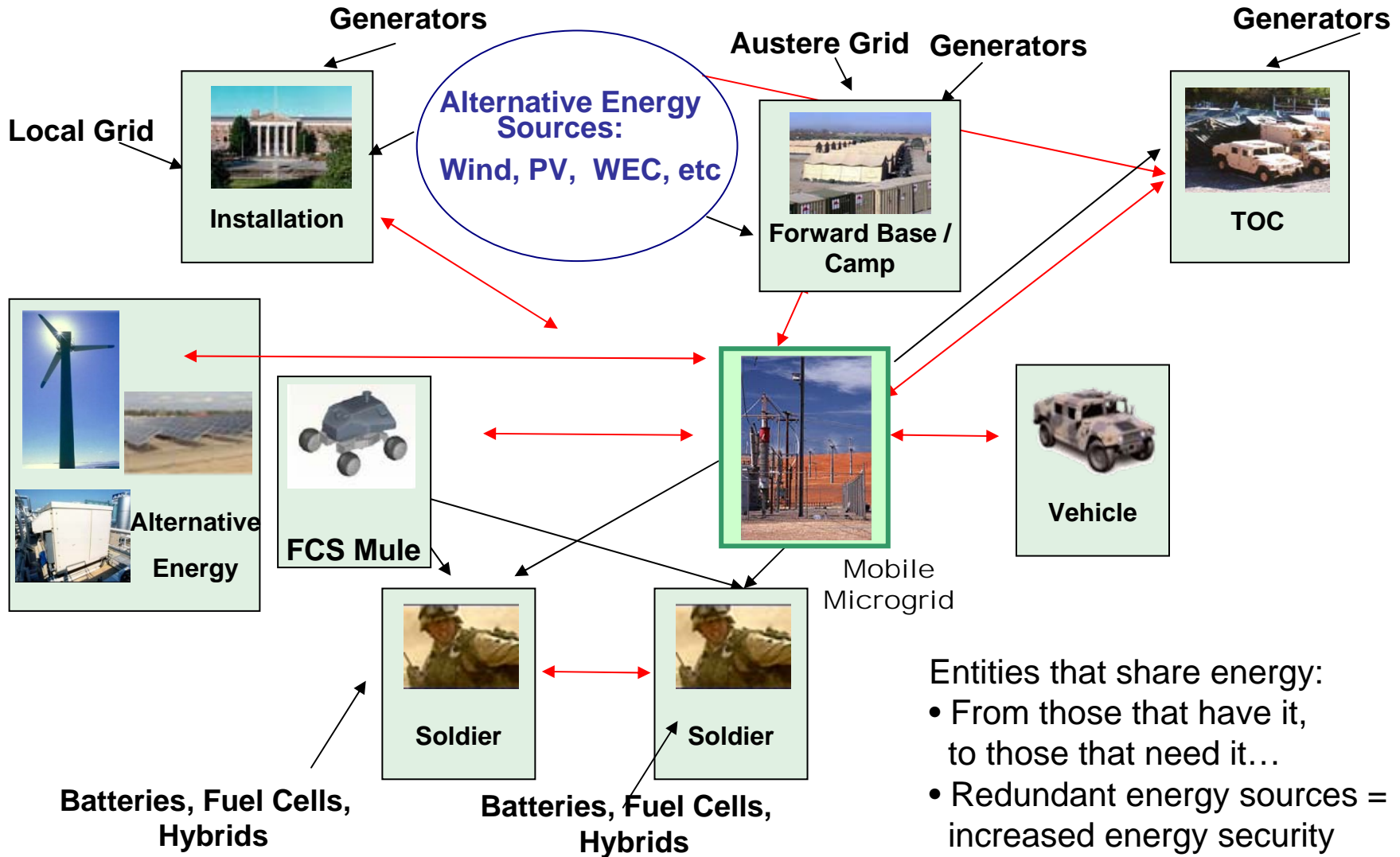


### Non-primary Power



### Prime Power





Improving *energy* capability through holistic power sharing - you're in the fight...!

## COMPONENTS

### Component Elements



DC/DC Converters



Batteries

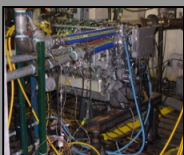


Motors

### Subsystem Elements



Engines



Engine Generator

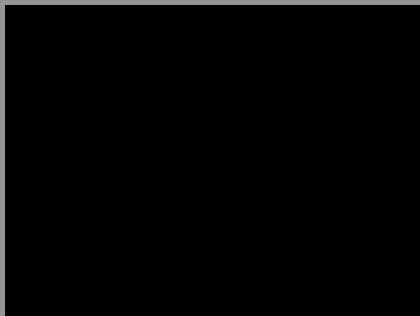
### High Temperature Electronics



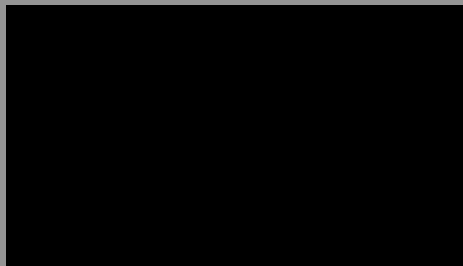
High Temperature Power Electronics

## SYSTEM INTEGRATION

Engine Generator Test Lab (EGTL)  
Warren, MI



Power & Energy SIL  
Santa Clara, CA



## FCS NLOS-C

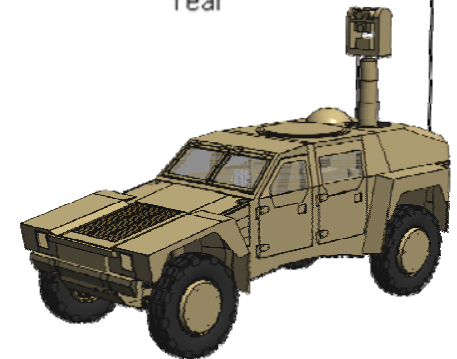
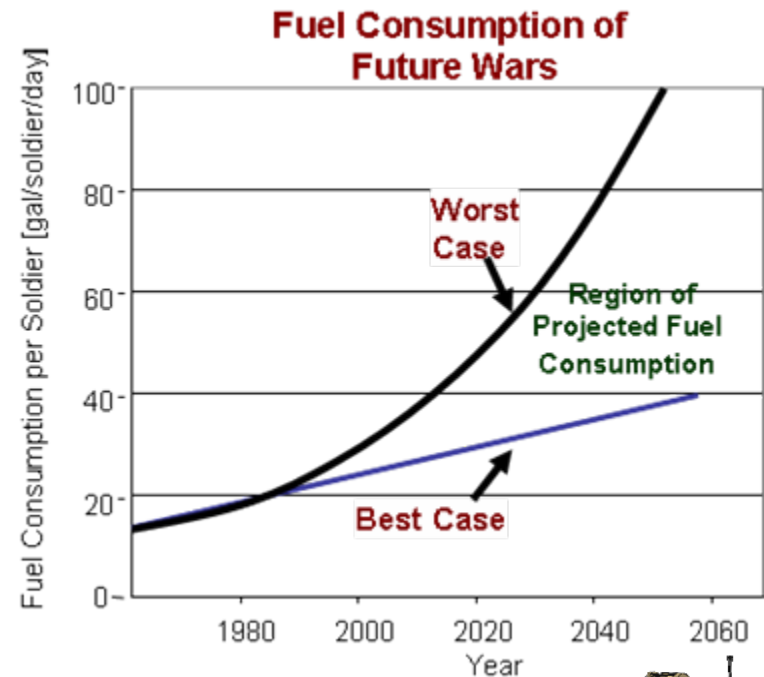
### Design Benefits

- No Mechanical Link
- No Drive Shaft
- Design Flexibility
- Improved Maintainability
- Lower Silhouette





- **Silent Watch/Mobility**
- **Improved energy efficiency**
- **Fuel economy and emissions reduction**
  - Reduced logistics burdens
  - Regenerative braking / energy recovery
- **Enhance functionality, flexibility, power quality, and management of on-board power**
  - Net-centric warfare and C4ISR
  - Extra power to handle peak electronic loads
  - Pulse power and directed energy weapons
- **Improved export-power capabilities**



## Current Systems



## Future Systems

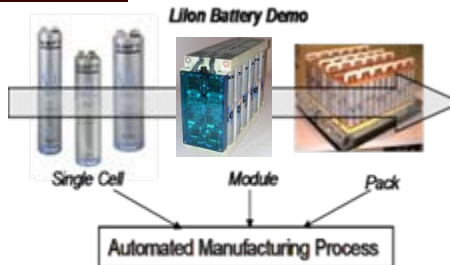
### Current Technology



Advanced Lead-Acid



Capacitors for EMA



### Testing



### Improvements



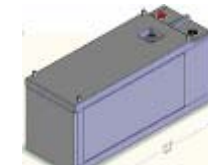
Li-Ion Prismatic Cell



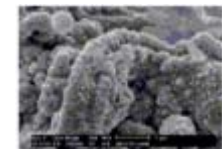
L-i-Ion Battery Module (50V)



NiZn Cell



Li-Ion / Ultracap Hybrid Energy Storage



LFP cathode

### Efforts Supporting Current Force

- Battery Monitoring Technology development & testing
- Advanced Lead acid battery testing & qualification
- Advanced Lead Acid Battery Technology Enhancement
- *Battery Ballistic Impact Test & Evaluation*
- Battery Pack Integration, Testing & Evaluation

### 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 Battery Safety Improvements
- Ultra High Power Li-Ion Cells for *Pulse Power Thermal Runaway Studies*
- Battery Pack Integration, Testing & Evaluation
- Nickel Zinc Battery Development

**Advanced Batteries are the foundation for hybrid vehicles and technologies**

## Alternative Fuels Program



### Fuel Evaluations

- Chemical composition
- Physical properties
- Fuel system impacts



### System Evaluations

- Fuel-system interactions
- System performance and durability
- Fuel specification inputs
- Suitability of fuel for use in Army equipment



### Engine Evaluations

- Fuel ignitability
- Fuel combustion
- Performance / durability

## Domestic Manufacturing Capability



## Dual use Applications



## Alternative Fuel Vehicles & Infrastructure



### SANGB Hydrogen Filling Station



## Advanced Mobile Microgrid



## Advanced automotive batteries - Enabler of alternative energy



Cells



Modules



Packs





***“The future of the auto is bright and increasingly electronic. Autonomous driving means that someday you could do your email, eat breakfast, do your makeup and watch a video while commuting to work”.***

Rick Wagoner, CEO GM, Consumer Electronics Show 2008 Keynote address stating that GM plans to test driverless cars by 2015 and have them in production by 2018.

## Technology Components

Academic Partnerships

## Demonstrators

Gladiator

Robotic Decontamination

RF Stryker

TAGS-CX

Integration

SME Defined Scenarios

## Military Relevant Test & Experimentation

Robotics Collaboration and RVCA ATO Experimentation

Convoy Active Safety Technologies (CAST)

Tech Transfer

## Transition and Requirements Development

Future Force SMI

FCS JTRS

FCS MULE

FCS ANS

Current Force Convoy Operations

Integration Technology Development  
Lessons Learned to Enable Early  
Technology Insertion

Tying in Commercial Automotive Safety Research



## Jointly Funded by OSD JGRE and JCR

### Program Goals:

- Provide low cost (\$10-20K) convoy automation (Leader/Follower) capability for current force Army vehicles
- Support Warfighter requirement for convoy automation and active safety
- Provide Robotics capability in CS/CSS community
- Leverage RF, RDECOM and other FCS Technologies

### Enhanced Soldier Protection

- Increased Situational Awareness
- Reduced Collisions
- Reduced Crew Driving Tasks
- Reduced Fatigue
- Increased Driver Cognition



**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**



- S&T Support to the RS-JPO
- Develops and Fosters external Relationships
- Matures technology for Insertion into ATO programs
- Robotics Outreach
- RS JPO Collaboration Cell Lead
- Support to IGS Capability Cells
- Robotics Academic Programs (Including Curriculum Development)



Government Partnerships	Industry Partnerships	Academia Partnerships	Community Outreach

## Robotics, Engineering and Technology (RET) Days

- Students gain insights into technology careers, math & science.
- Robotics is a multi-disciplinary field (electrical, mechanical & computer engineering).
- Supports Michigan's objective to be a technology based economy

## Michigan Robotics FIRST Support

- **3 Michigan Regional Competitions in 2008**
  - Provided VIP Speakers
  - Provided Technical Judges
- **TARDEC engineers serve as mentors to several metro-Detroit area high schools**
- **Future Activities:**
  - 2009 Michigan Regional Sponsorship
  - Assisting in building arenas for regional competitions
- **2009 – International Competition**

## Intelligent Ground Vehicle Competition (IGVC)

- **University Engineering education challenging students to design autonomous vehicles**
- **16 Competitions since 1993**
  - Thousand of Students
  - 332 Teams
  - 67 University
  - 4 Countries (Canada, India, Japan, and Mexico)

2nd Annual  
Robotics, Engineering and  
Technology (RET) Days

December 4 - 6, 2007



## Summer Hires:

- 20 Colleges, 53 Students
- 15 High Schools, 15 Students
- 2008 10% of Summer Hires converted to Co-op Program

## Projects:

- Survivability Material Processes & Ceramics Analysis
- Manipulator Arm Training for Walking Robot Prototypes
- Diesel Engine Simulations & Analysis

**47 Projects 68 Students**

## Co-Ops & Interns

- 2001-2006 more than 85% of TARDEC workforce recruited from co-op program
- 51 Co-Op Positions as of Sep 08
- 17 AMC Interns
- 95% Retention rate
- 18 Local University Memorandums of Understanding
- In 2007 126 TARDEC associates participating in higher education
  - 78% focused on emerging technology & global leadership curriculums



TARDEC's 2008 Summer Hire Expo



The Honorable Governor Jennifer Granholm &  
The Honorable Senator Carl Levin  
Touring the 2008 Summer Hire Exposition

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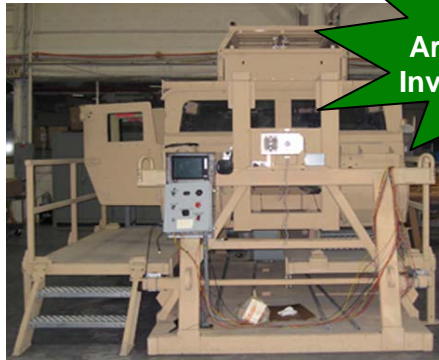


## Life-Saving Solutions

2007  
Army's Greatest  
Inventions Winner



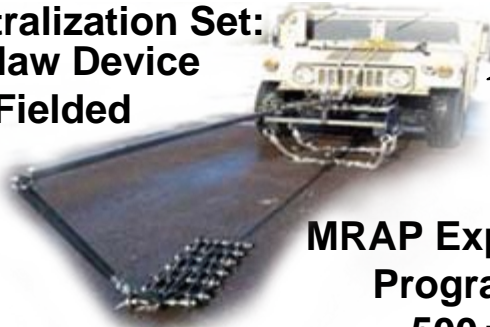
SPARK Mine Roller 360+ Fielded



2007  
Army's Greatest  
Inventions Winner

HMMWV Egress Assistance  
Trainer (HEAT)

Wire Neutralization Set:  
Wolf Claw Device  
10 Fielded



MRAP Expedient Armor  
Program (MEAP)  
500+ Fielded

2008  
ASA (ALT)  
Collaboration  
Award Winner

2008  
Army Acquisition  
Excellence Award  
Winner



### Additional Life-Saving Solutions

- Vehicle Expedient Armor
- M939 Crew Protection Kit (CPK)
- All Terrain Armored Cab
- Interim High Mobility Engineering Excavator (IHMEE) Advanced Crew Protection Kit
- Tactical Vehicle Add-on-Armor (AoA)
- Construction Vehicles AoA
- Fuel Tank Fire Protection
- HMMWV Automatic Fire Extinguishing System (AFES)
- M1114 HMMWV Motorized Turrets
- Omni-Directional Inspection System (ODIS)
- Weapon Systems Mapping Software (WSMS)
- Wolf Collar and Tail Wire Neutralization Set



DoD's Ground Vehicle Center of Excellence





## Tactical Fuel Logistics & Protection

Kuwait/OIF/OEF Fuel to FOB (Million gallons/yr).....	431
Fuel trucks needed.....	140,075
Convoys needed.....	9,332
Soldiers per convoy trip (Fuel trucks, protection, other support).....	120
Soldier Convoys.....	644,360
<b>Fewer Soldier Convoys.....</b>	<b>6,444</b>
<b>(Resulting from 1% Fuel Savings)</b>	