



U.S. Army Research, Development and Engineering Command

*Power & Energy  
from an Army Ground Vehicle  
Perspective*



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

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**2010 Department of Energy Annual Merit Review**

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# Agenda



- Army Ground Vehicles Introduction
- War Fighter Outcomes and Power/Energy Needs
- Army Ground Vehicle Challenges
- Engine Emissions Policy
- Networked Energy Concept
- Future Directions



# Army Ground Vehicles



- 300,000 + tactical and combat vehicles (150 – 1500 BHP)
- 240,000 + trucks – class 2 thru class 8 + (150 – 500 BHP)
- 40,000 + 2-stroke powered vehicles (200 – 500 BHP)



**MRAP - Mine Resistant Ambush Protected**



**PLS – Palletized Loading System**



**HEMTT – Heavy Expanded Mobility Tactical Truck**

\*FVPDS (Jan. 2000)  
Fielded Vehicle Performance Data Systems



# Army Ground Vehicles



## COMBAT VEHICLES

- **M1 Abrams (AGT-1500)**
- **M109/M110 Self Propelled Howitzer (8V71T)**
- **M2/M3 Bradley (VTA-903)**
- **M88 Medium Recovery Vehicle (TCM-1790)**
- **M578 – Light Armored Recovery Vehicle (LRC) – (8V71T)**
- **M60 family (TCM-1790)**
- **Chaparral Missile Launcher (6V53T)**
- **FAASV – Fast Assault Ammunition Supply Vehicle (8V71T)**
- **M551 Sheridan Assault Vehicle (6V53T)**
- **Stryker (3126/C7)**

## TACTICAL VEHICLES

- **HET Heavy Equipment Transporter (8V92TA)**
- **HEMTT Heavy Expanded Mobility Tactical Truck (8V92TA)**
- **PLS Palletized Loading System (8V92TA)**
- **2.5 Ton Truck (LD-465/LDT-465)**
- **M939 5 Ton Truck (NHC 250/6CTA8.3)**
- **M915/M916 Line Hauler (NTC400/S-60)**
- **M917, M918, M919 Tractor (NTC 400)**
- **HMMWV (GM 6.2/6.5 IDI)**
- **CUCV Commercial Utility Cargo Vehicle (GM 6.2/6.5 IDI)**
- **Family of Medium Tactical Vehicles (C7)**

LEGEND: **black:** four-stroke diesel   **red:** two-stroke diesel   **blue:** gas turbine

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# 10 Comprehensive Warfighter Outcomes



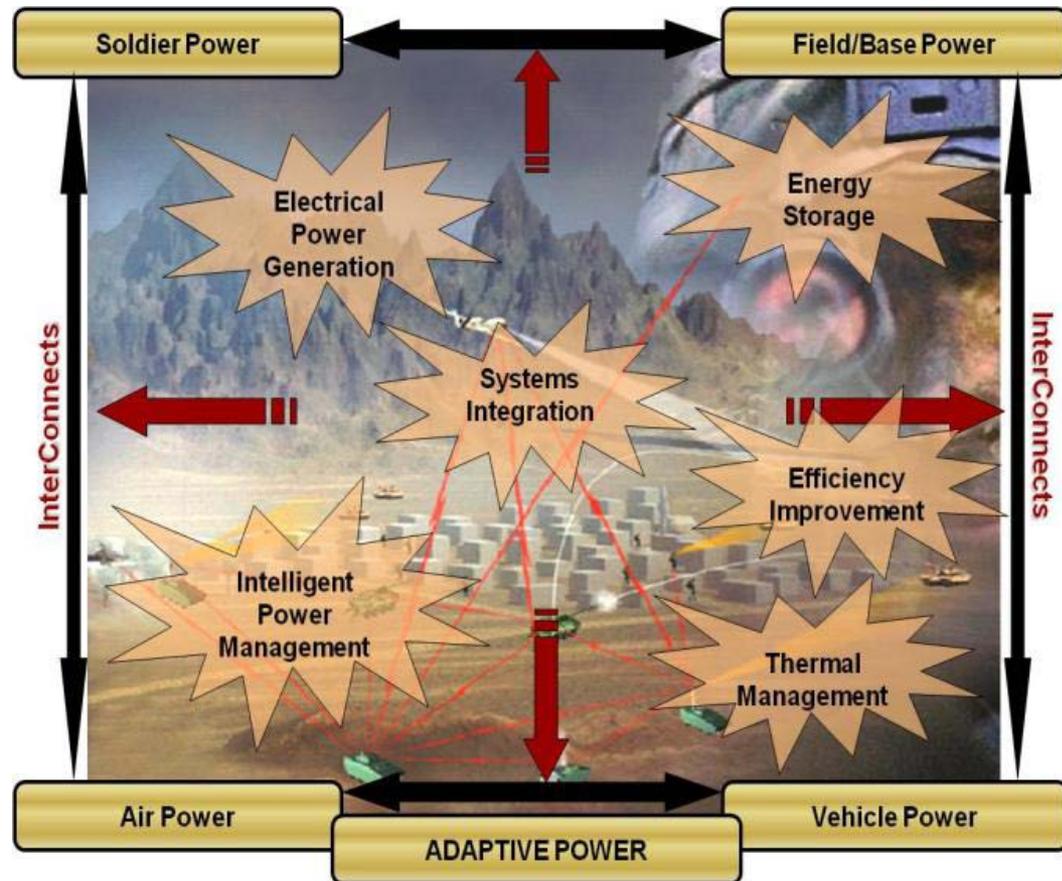
- Battle Command Network
- Counter IED and Mine
- **Power and Energy**
- Human Dimension
- Training
- Force Protection
- Battlespace Awareness
- Force Application
- Logistics
- Unmanned Systems Operations



ASA (ALT)



# Power and Energy Warfighter Outcome



- Provide enhanced ability to operate worldwide by reducing by **half, the weight and volume of fuel** associated with powering the force.
- Combat platforms require up to 30 MJ of pulsed power for lethality and **20 percent increase in continuous power** to enable superior tactical mobility, speed and an excess capacity for on/off board electrical power use while **increasing fuel economy by 40 percent**.
- Emerging electrical components and systems require dismounted **Soldiers to possess a fourfold increase of available power**, above current 12.3 Watts-Hr, at half the tactical weight.

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**



# Fuel Economy Economic Driver

U.S. ARMY

**RDECOM**

**\$10 per barrel  
increase in oil  
increases  
DoD costs by  
~\$1.3B per  
year**



**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**



# Force Structure and Force Protection Driver



## Tactical Fuel Logistics & Protection

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



# On Board Electrical Power



- Growing need for countermeasures, protection, sensors, ad hoc HVAC, etc.
- Silent watch need; minimal noise
  - In-line starter generators
  - Auxiliary power units
  - Hybrid propulsion architecture
  - Fuel cells
  - Batteries
- Can't impede mobility
  - Dash speed, top speed on grade, high tractive effort to weight cooling
- One solution does not fit all vehicle applications



# Army Ground Vehicle Propulsion Challenges



1. Cooling
2. Cooling
3. Cooling
4. Fuel Effects
5. Filtration



The Army vehicle cooling point is high tractive effort to weight under desert-like operating conditions (ex. 5 ton wheeled vehicle ~0.6 while 15 ton tracked vehicle ~0.7 both at 120 F ambient)

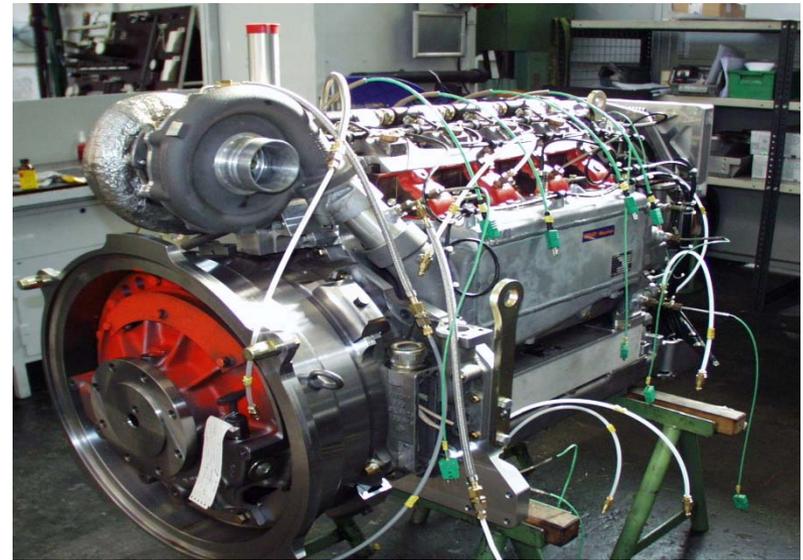


# High Power Density Propulsion Systems – Combat Vehicles



- Army definition of Propulsion System **Power Density (PD)**:
  - $PD = \text{sprocket (wheel) power} / \text{total propulsion system volume [bhp/ft}^3\text{]}$
  - Air filtration requirements, thermal management system, transmission, engine (fuel), ducting requirements

Ex. Bradley FIV:  $PD = 3$   
FCS MGV target:  $PD = 6$   
Research target:  $PD > 8-10$

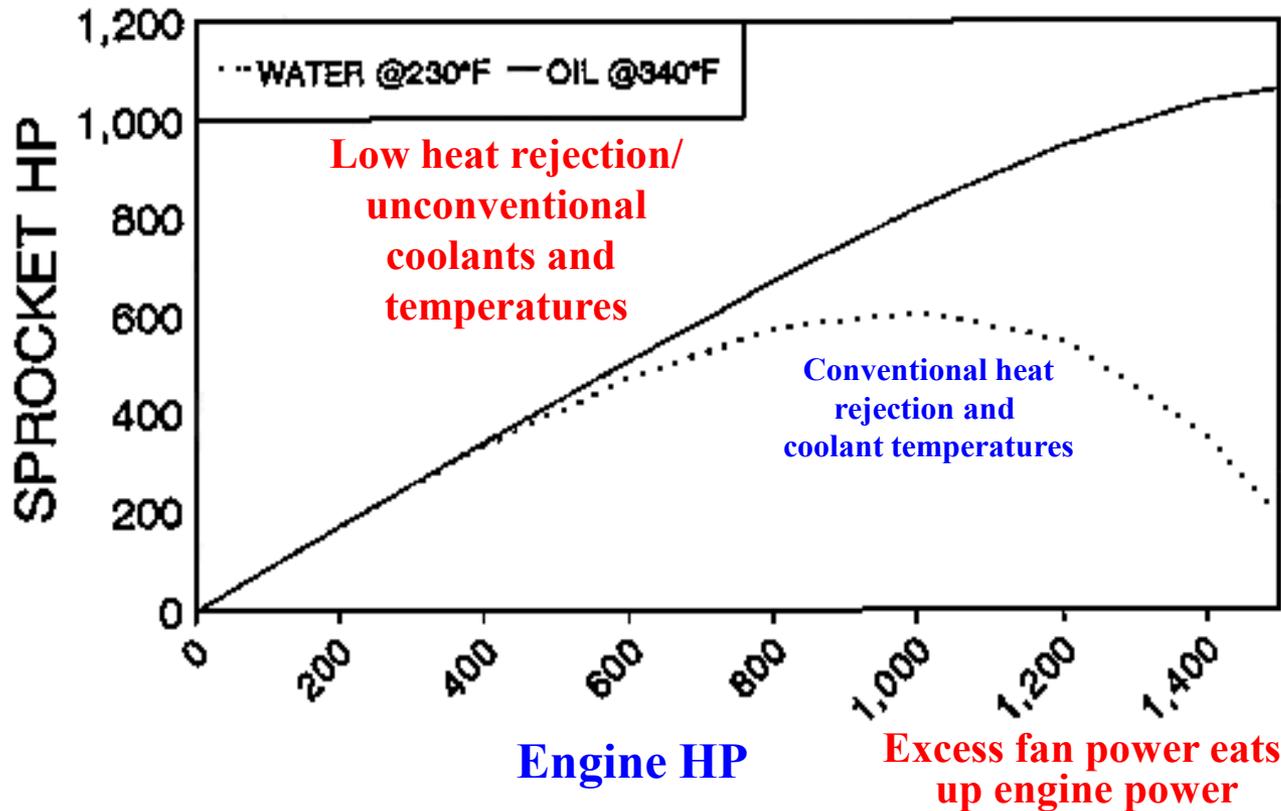




# Propulsion System Power Density – Combat Vehicle



## Sprocket Hp vs Engine Hp Ambient Air 120°F

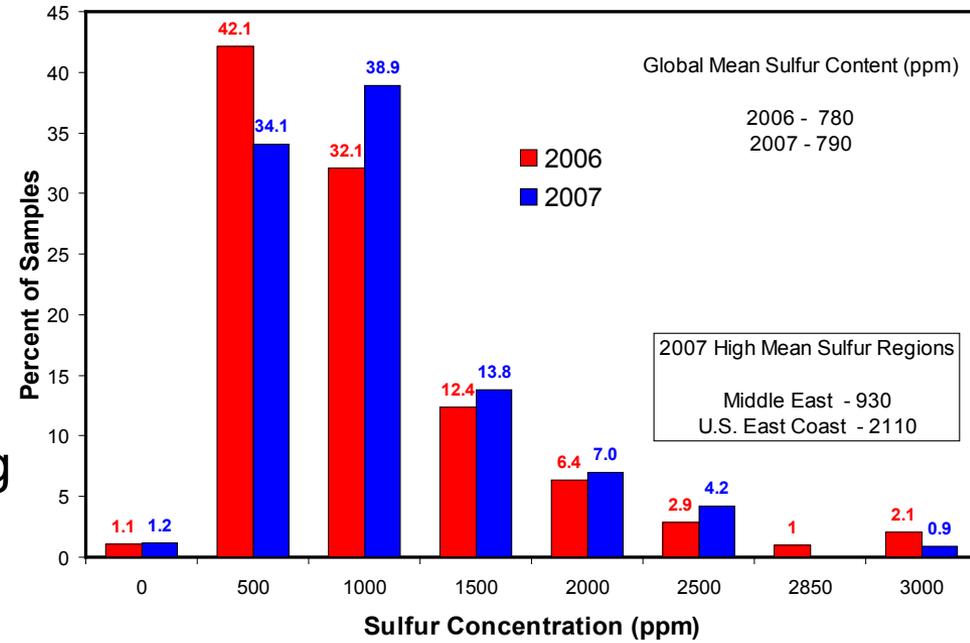
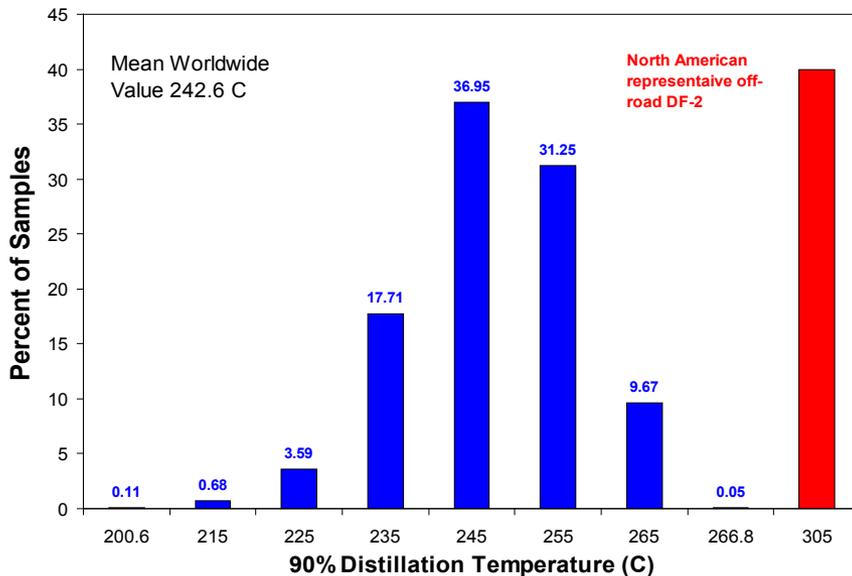




# JP-8 Property Specifications

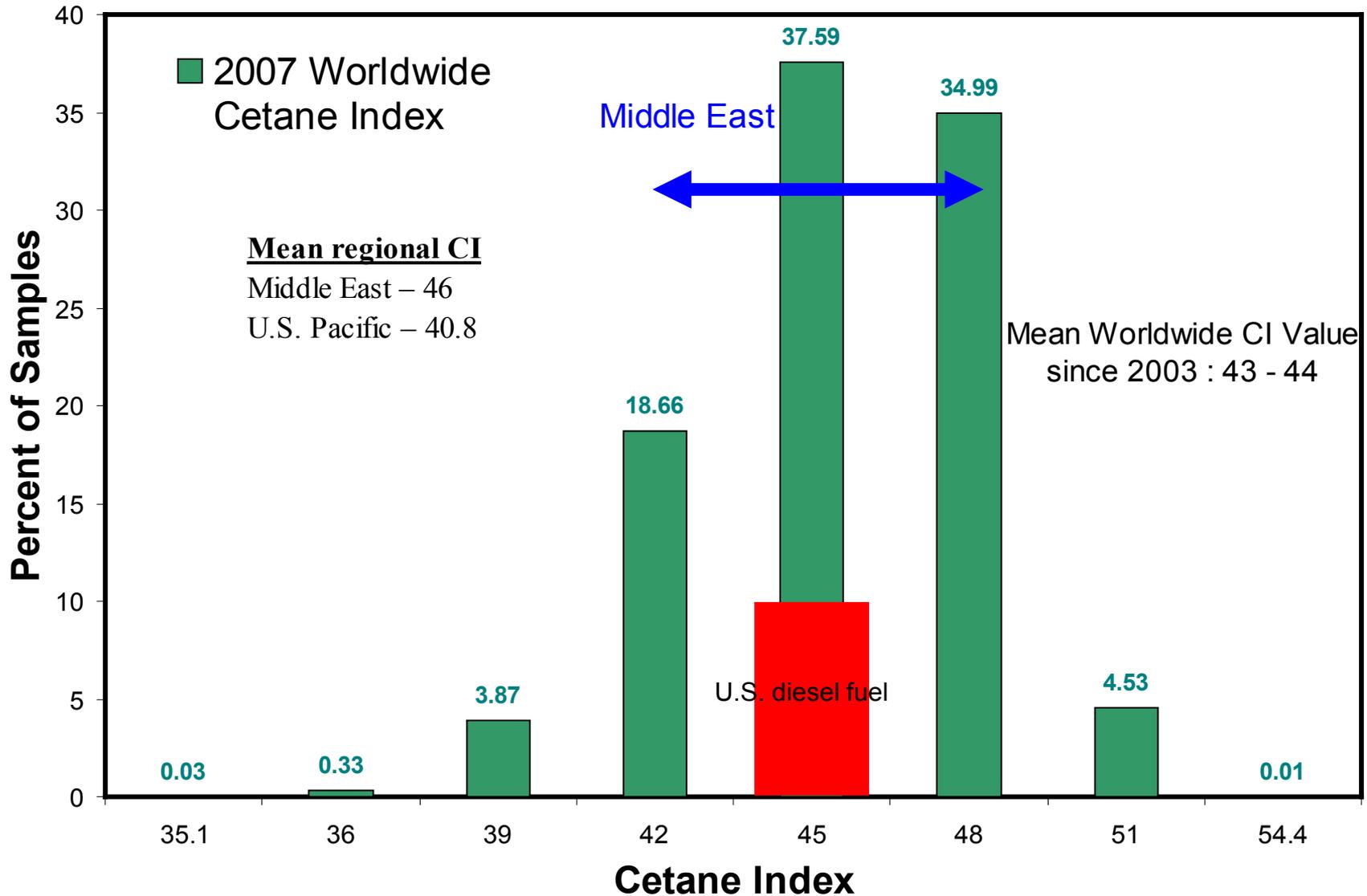


- **Sulfur content: max. 3000 ppm**
- Aromatics: max. 25%
- Specific gravity: 0.775 – 0.84
- Evaporation Characteristics:
  - 10% recov.: max. 205 C
  - End point: max. 300 C
- Net Heating Value: min. 42.8 MJ/kg
- **Cetane Index: none**





# JP-8 Cetane Index Worldwide Trend in 2007





# Engine Emissions Policy



- The Army can not buy 2007 or Tier IV (> 75 bhp) compliant COTS engines and directly integrate into current and new heavy-duty vehicles.
- Combat vehicle: permanent armor/attached weapon system – National Security Exemption (NSE) via **40 CFR, 89.908**
- ‘Tactical Vehicles’
  - ✓ Without ARMOR – NSE from 2004 and 2007 standards (i.e. meet 1998) and Tier IV
  - ✓ With ARMOR – NSE from ALL standards





# Engine Emissions Solution Pathways

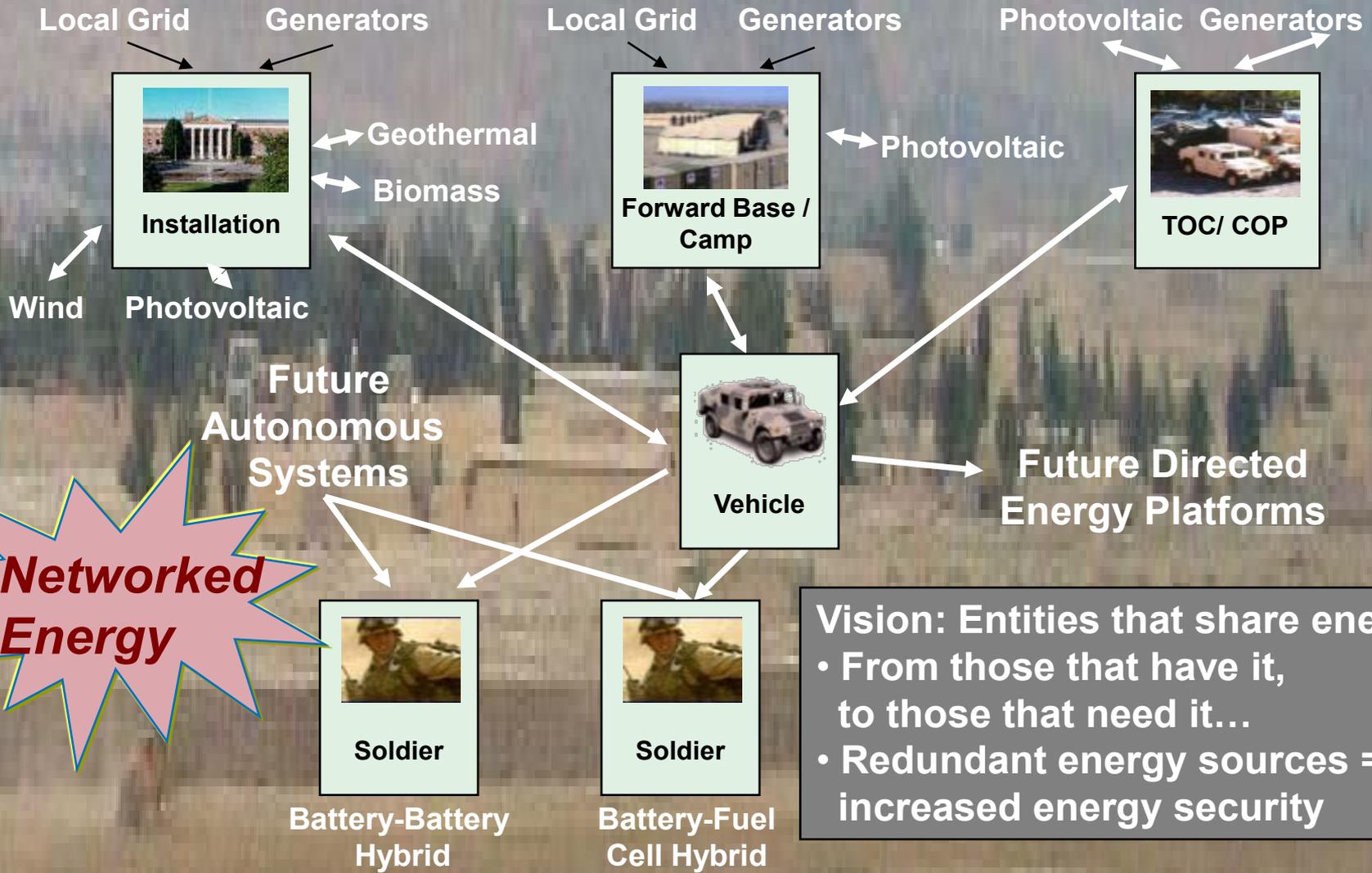


- Near term
  - Modified on-road COTS minus cooled EGR and exhaust aftertreatment
  - TIER II or TIER III engines
- Mid term
  - Modified on-road COTS and TIER IV minus cooled EGR and exhaust aftertreatment
  - Tier II or TIER III engines
- Long term
  - unknown





# Concept for Networked Energy





# Ground Vehicle Power and Energy Future Directions



- Advanced Propulsion System
  - Low heat rejection and high power to weight ratio engines; propulsion materials
  - Heavy-fuel flexible and more efficient engines
  - More efficient transmissions
    - Longitudinal and cross-drive; wider ratio
  - Hybrid propulsion for mission specific applications
  - Energy Recovery Systems
- On-Board Electrical Power
  - In-line starter generators, auxiliary power units, fuel cells
  - High energy and power density batteries



**THANK YOU!**



# BACK UPS



# Power and Energy Strategy for Future Directions



## RDECOM Strategic Directions in Power and Energy

Higher Energy Power Sources for  
Soldiers and Sensors

Unmanned Air and Ground Platforms

Intelligent Energy Management with  
Alternative Energy Sources

Ground Platforms Auxiliary Power and  
Quiet Watch Capabilities

High Energy Weapons

## DDR&E Energy and Power Areas of Opportunity

Tactical Energy Independence

Autonomous Platform Power

Grid Power Distribution & Control

Platform Efficiency & Environmental  
Impact

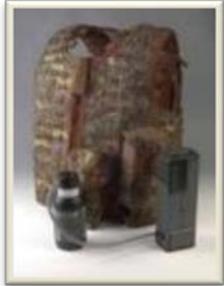
Electric Weapons & High Power Sensors



# Strategy for Future Directions



**Higher Energy Power Sources for Soldiers and Sensors**



Rucksack Portable Power System



**Unmanned Air and Ground Platforms**



**Intelligent Energy Management Coupled with Alternative Energy Sources for Reduced Logistical Burden (Combat Outposts)**



Reformed Methanol Hybrid Fuel Cell

**Ground Combat & Tactical Vehicles  
Vehicle Auxiliary Power and Quiet Watch Capabilities**



Trojan Vehicle Fitted with Rolls-Royce APU

**High Energy Weapons**



# Power & Energy Technology Gaps



## C4ISR & Soldier

High Density Storage for Soldiers and Platforms

Logistic Fuel Conversion for Auxiliary Power Sources

Efficient, High Density Alternative Energy Capture and Conversion

## Ground

Power Sources and Conversion for Small Autonomous Systems

On Board Power-Higher Density, Higher Power Mechanical To Electrical Conversion

Intelligent, Scalable Power Management & Distribution

Integrated Power Management on Platforms

## Air & Effects

Reliable Extended Shelf Life Power Sources for Munitions

High Temperature Power Electronics for Platforms