Economics, Logistics and Environmental Impacts of Hybrid Electric Veh

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Hybrids are in Widespread Use

- **Honda**
  - **Insight**
  - **Civic**
- **Toyota**
  - **Prius**

Picture Source: Honda Motor Co.

New Models Are Coming

- Ford
  - Escape
- Dodge
  - Ram Truck
- GMC
  - Sierra SUV
  - Saturn VUE
- Lexus
  - RX330

Picture source: Toyota Motor Co.

Military Interest

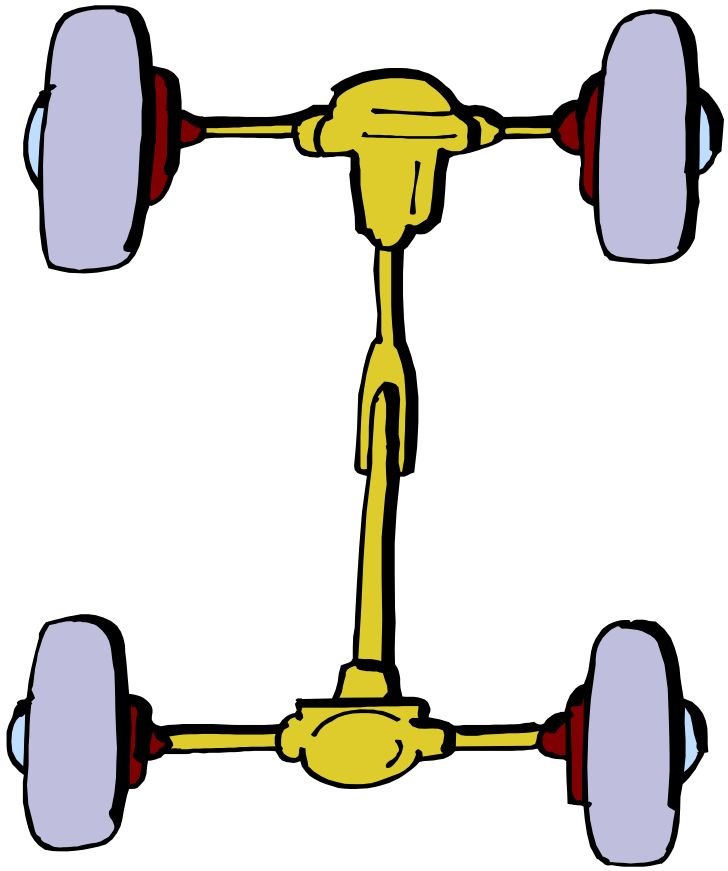
- Army
  - Humvee
  - COMBATT
  - FCS
- Marines
  - RSTV
- Air Force

Picture source: National Automotive Center

Topics To Be Covered Today

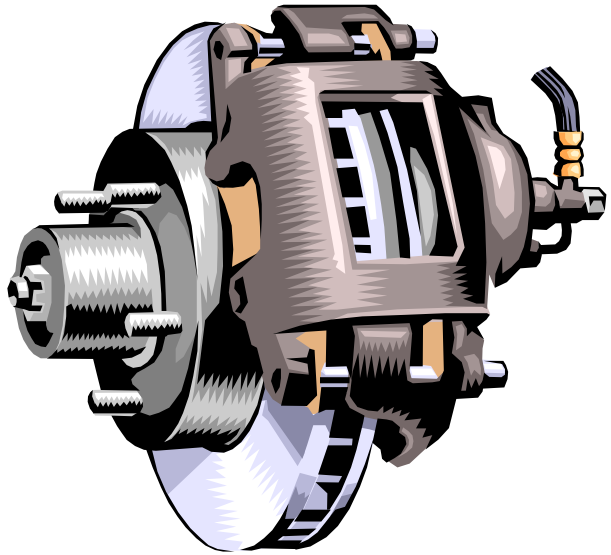
- Technology of hybrids
- Economics in military use
- Logistics
- Environmental impacts

Hybrid Electric Veh Tech

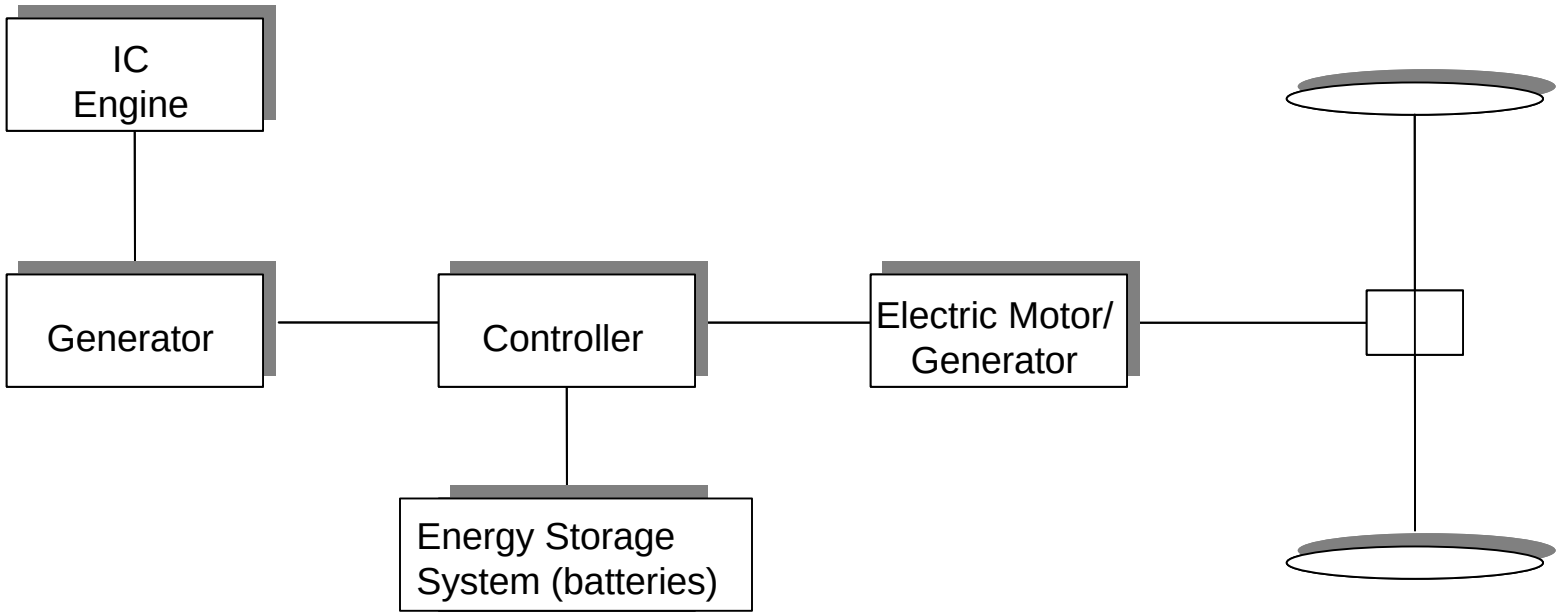


Features of HEVs

- Combine 2 sources of power; electric motor and internal combustion engine
- Regenerative braking



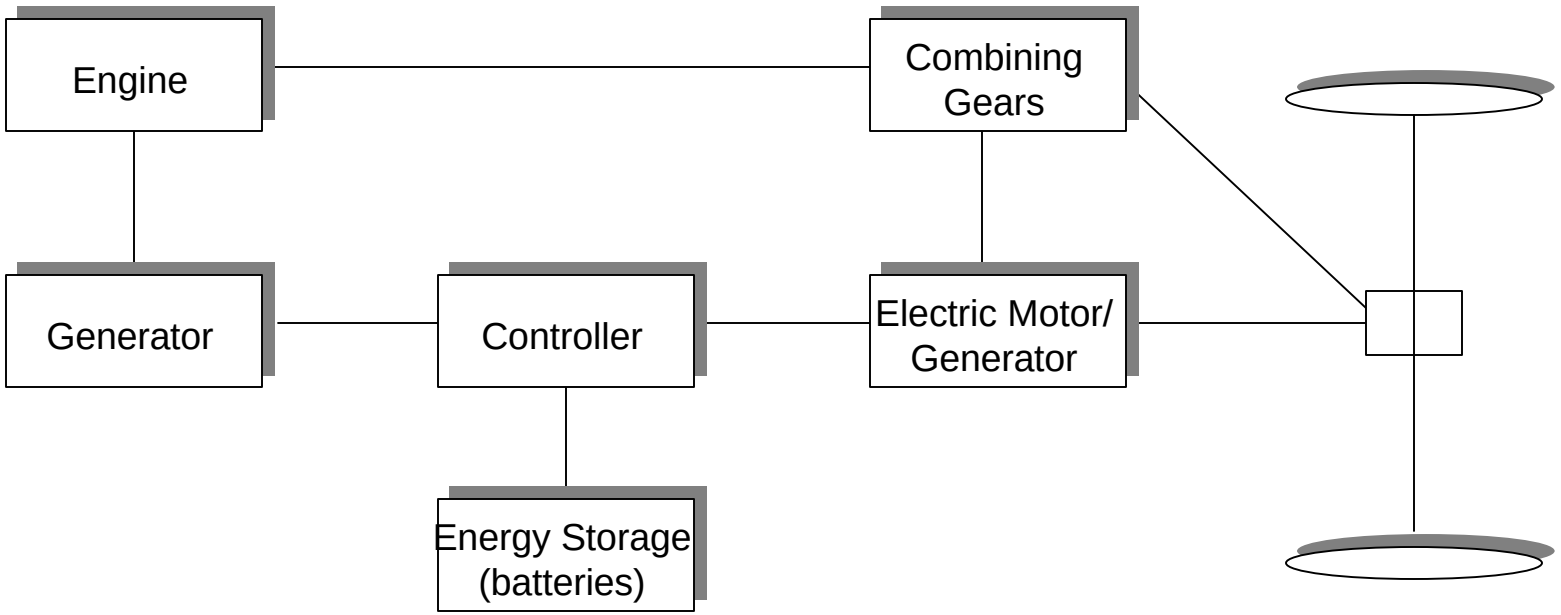
Series Hybrid



Properties of Series Hybrids

- 10-15% gain in fuel efficiency
- Flexibility with regard to engine location
- Can be configured for onboard power generation
- Proven technology – used in train engines, diesel submarines
- Most hybrid trucks use series design

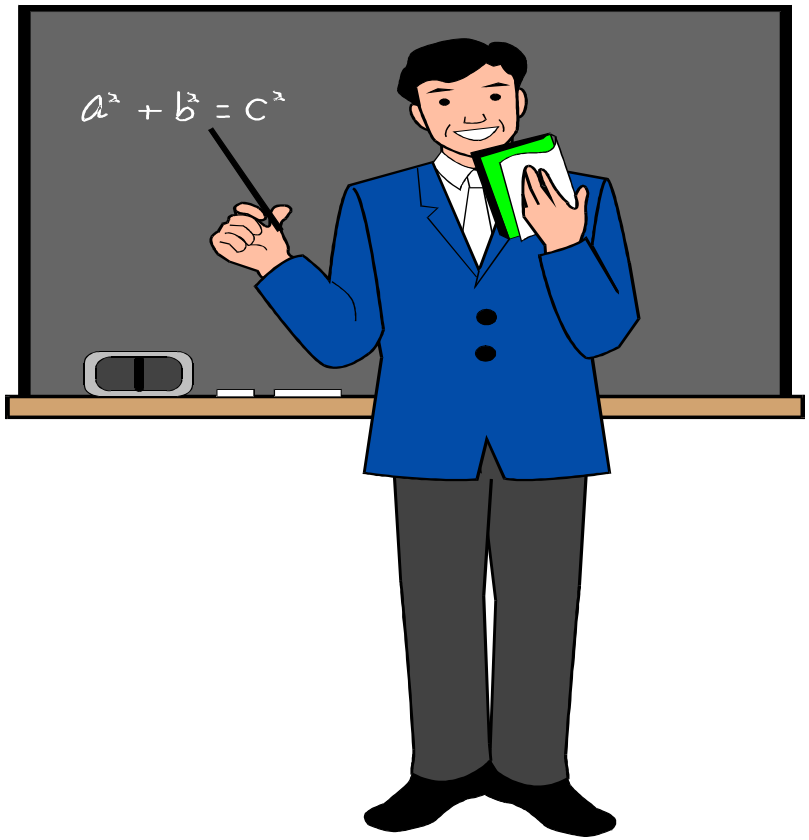
Parallel Hybrid



Properties of Parallel Hybrids

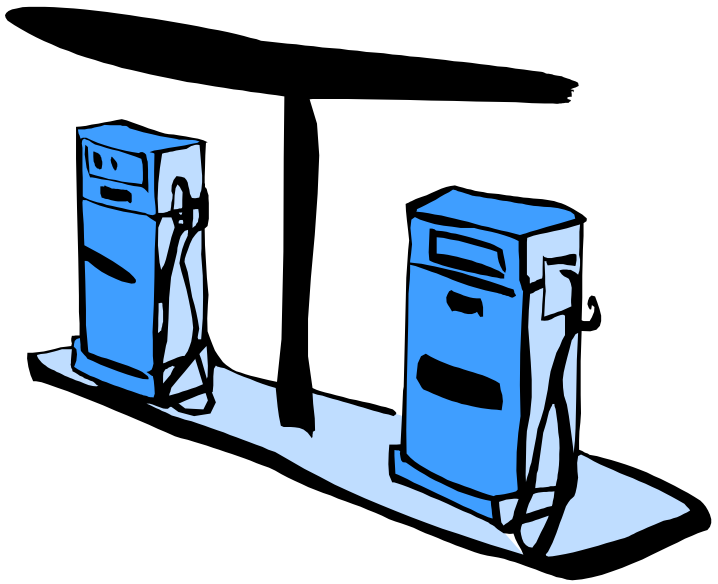
- Motor, engine work together
- Significant gains in fuel efficiency
- Used in Toyota Prius, Honda Civic
- Being tried in trucks
- Can be configured for onboard power generation

Economics of Hybrids in Military Use



Potential Savings

- **Reduced fuel consumption**
- **Reduced brake maintenance**
- **Reduced need for standalone generators**



Incremental Costs

- **Higher initial cost (addition of electric motor, batteries)**
- **Periodic battery replacement**

Economics of th Humvee: Meth

- Comparison to Conventionally Powered Humvee
- Net present value analysis (20 year life)

- Picture Source: IDT PEI

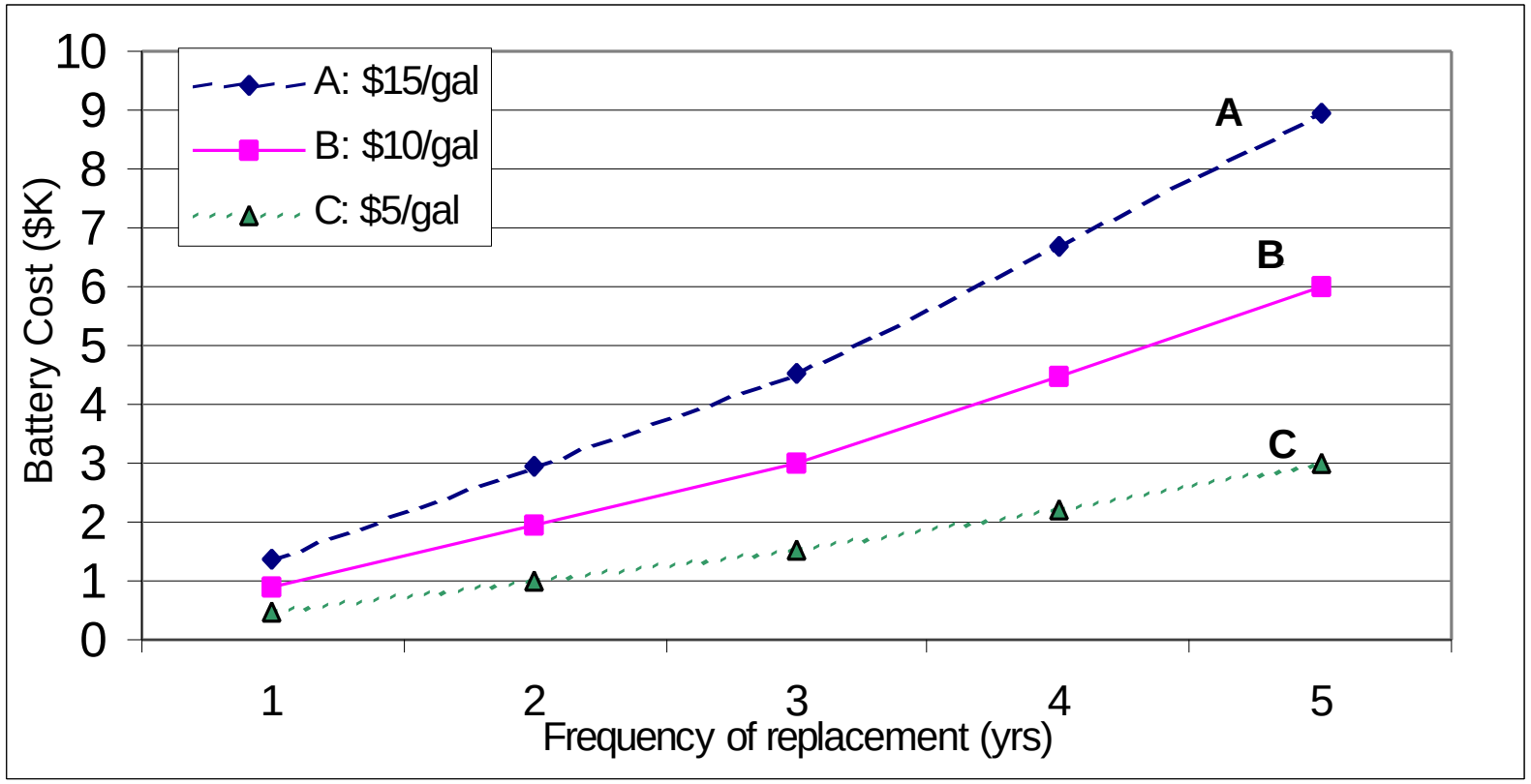
Economics of the Hybrid Humvee: Key Assumptions

- Value of onboard power generation = incremental cost of vehicle
- Cost of fuel reflects underlying logistics network (estimated at $10/gal.)
- Conventional Humvee gets 9 mpg, driven 3500 miles per year
- Hybrid provides 30% efficiency gain
- 3 year battery life; $3000 replacement cost

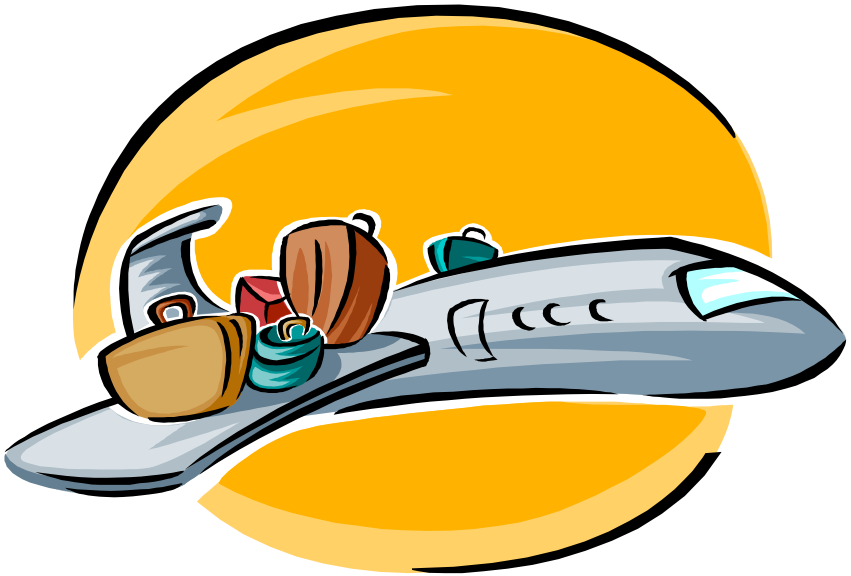
NPV of Hybrid Humvee Relative to Conventionally Powered

Base Case	$15/gal	4-year battery repl.	$2000/ battery repl.	50% mpg gain	5,000 miles/ year	7% v. 6% ROI
$90	$5,237	$2,312	$3,491	$4665	$4502	$121

Humvee Breakeven Battery Cost vs. Life at Different Fuel Costs



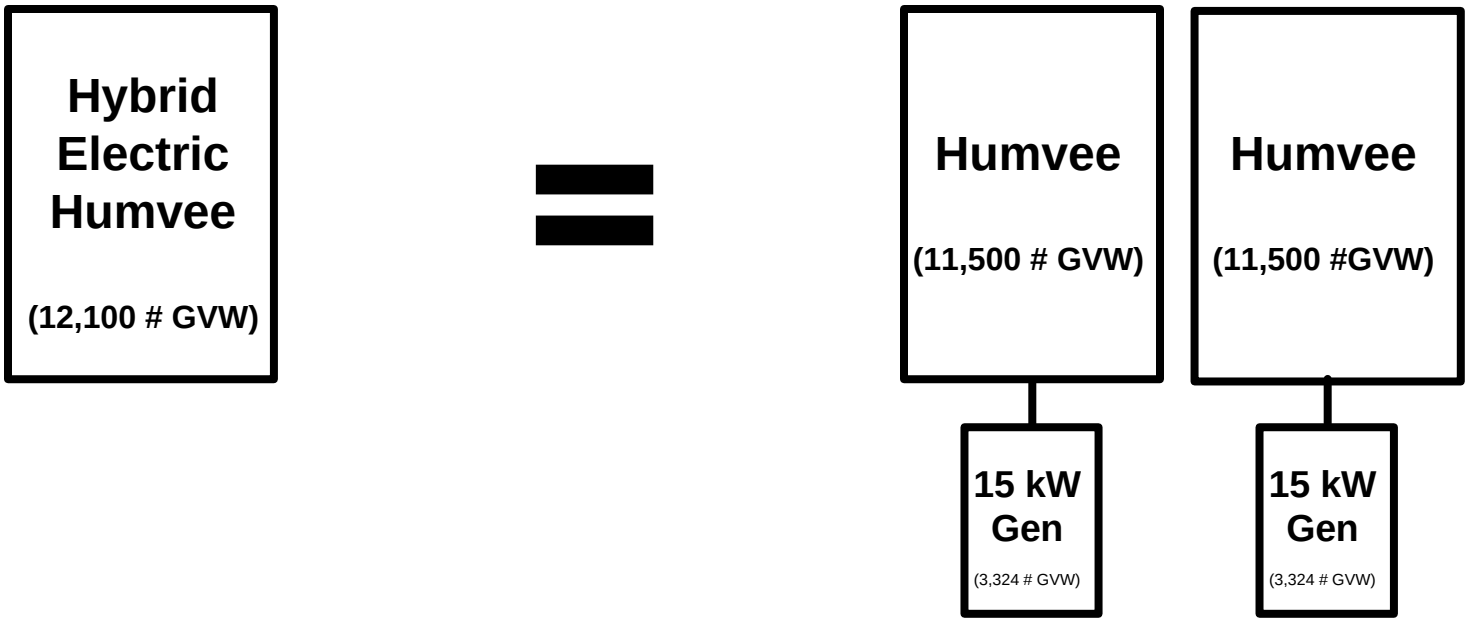
HEV Logistics Gains



Logistics Footprint: What Does Onboard Power Generation Imply for Fuel and Weight Savings?

- Assume onboard generating capability = 30KW of power
- Assume otherwise need two 15KW portable generators and vehicles to pull each
- Assume hybrid Humvee in power generation mode uses same fuel as two 15KW generators

Assumed Equivalency of Hybrid Onboard Power Generation With Standalone Generators



Source: Army Program Office, Light Tactical Vehicles

Best Case Results

- 1 fewer conventional Humvee tow vehicle
- 2 fewer standalone generators
- Weight savings:
  - 1 Humvee (11,500 lbs)
  - 2 15KW generators (3324 lbs each)
  + 1 hybrid weight increment (600 lbs)
  = Net reduction of 17,548 lbs

- Fuel savings of 1 less vehicle plus 30% fuel efficiency gain for the other

Alternative Case Result

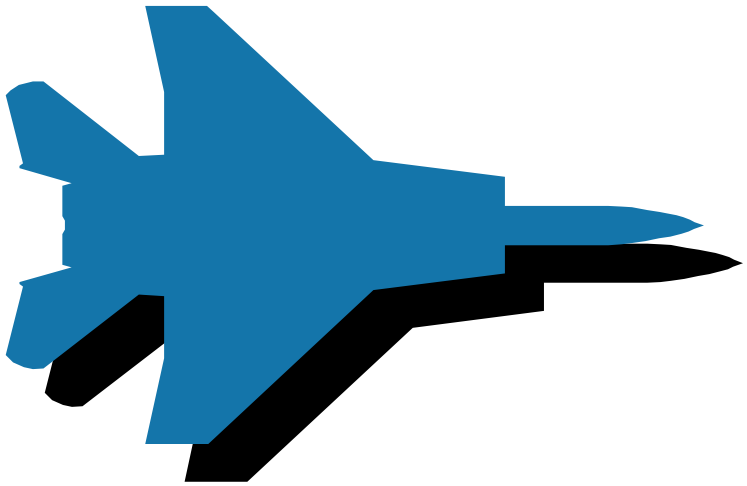
(Assume 15KW Onboard Generator)

- -1 fewer standalone generator (-3324 lbs)
- +1 hybrid weight increment (+600 lbs)
- = Net reduction of 2724 lbs

- 30% gain in fuel efficiency

Potential Logistics Savings for Weapons Systems

- THAAD
- SHORAD



THAAD –30 KW Hybrid Humvee Could Provide Power to Two Shelters

- **Eliminate 2 15 KW towed generators + towing vehicle**
- **25-30% reduction in fuel use**

Source: Army Program Office, Light Tactical Vehicles

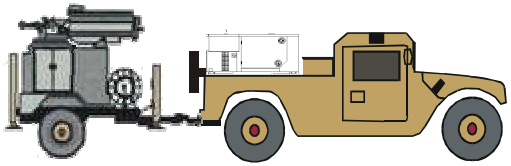
Plus Fewer Required Airlift Sorties

Picture source: National Automotive Center

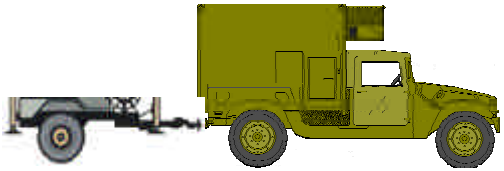
Potential Logistics Savings for SHORAD System

Source: Army Program Office, Light Tactical Vehicles

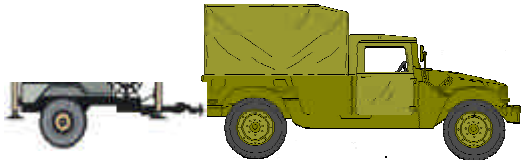
Current System



Stowed Sentinel Radar

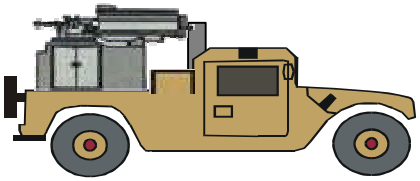


C2 Vehicle



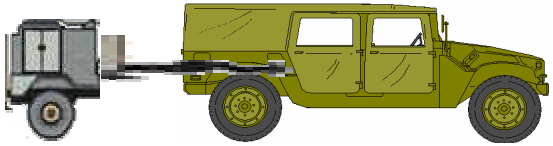
Crew / Maintenance Vehicle

Hybrid System



Stowed Sentinel Radar

On Hybrid Humvee



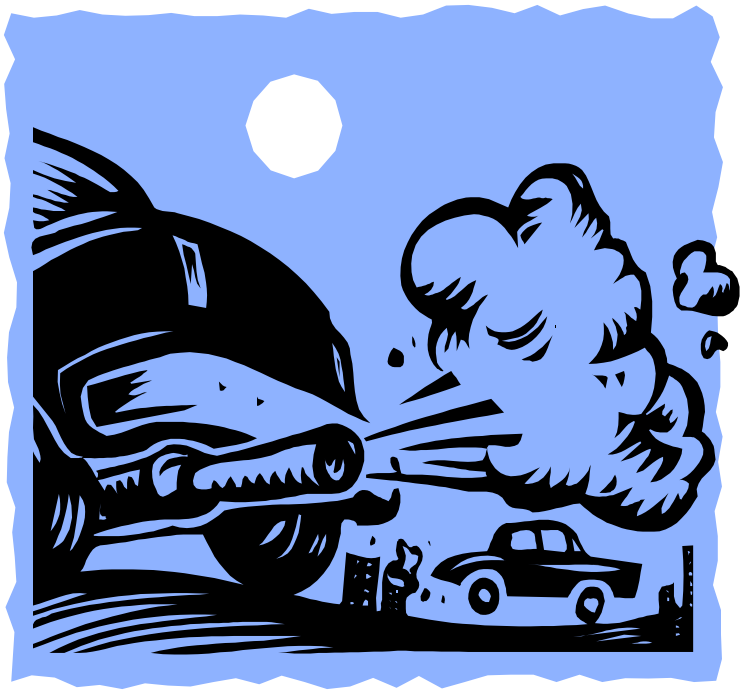
Combined C2/Crew Vehicle

Powered by Hybrid Humvee

Net SHORAD Savings

- 2 trailers
- 1 Humvee
- Up to 50% of fuel consumption
- Volume, mass reduction of 40-45%
- 1-2 men

Environmental Impacts



Potential Environmental Advantages

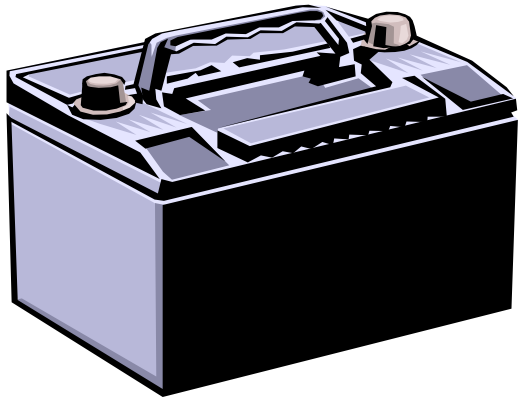
- Reduced fuel use
- Reduced air emissions
- Reduced equipment mass
- Reduced air sorties to deliver equipment

Reduced Air Emissions

(Tons/15 Year Service Life)

	Auto (gasoline)	LD Truck (diesel)	HD Truck (diesel)
HC	.091	.042	.129
NOx	.015	.073	.399
CO	.246	.095	.619
CO_2	19.818	26.160	78.000
PM	.003	.003	.046
SOx	.003	.004	.014

Potential Environmental Challenges



- **Battery disposal**
- **Increased mass of hybrid vehicle**
- **Parallel maintenance operations**

Conclusions

- Economics of hybrids look favorable for military
- Potentially important logistics savings
- Net environmental impacts probably positive:
  - Reductions in air emissions
  - Net reduction in material mass
- But operational, economic, environmental challenges exist:
  - Performance under operating conditions
  - Incremental cost
  - Battery disposal