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Maneuver Science and Technology Programs in Fuel Efficiency and Battlefield Power

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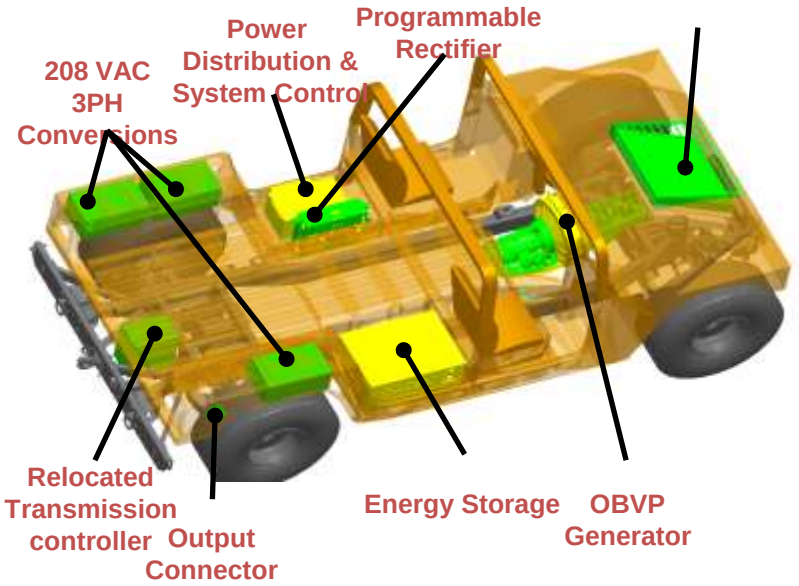
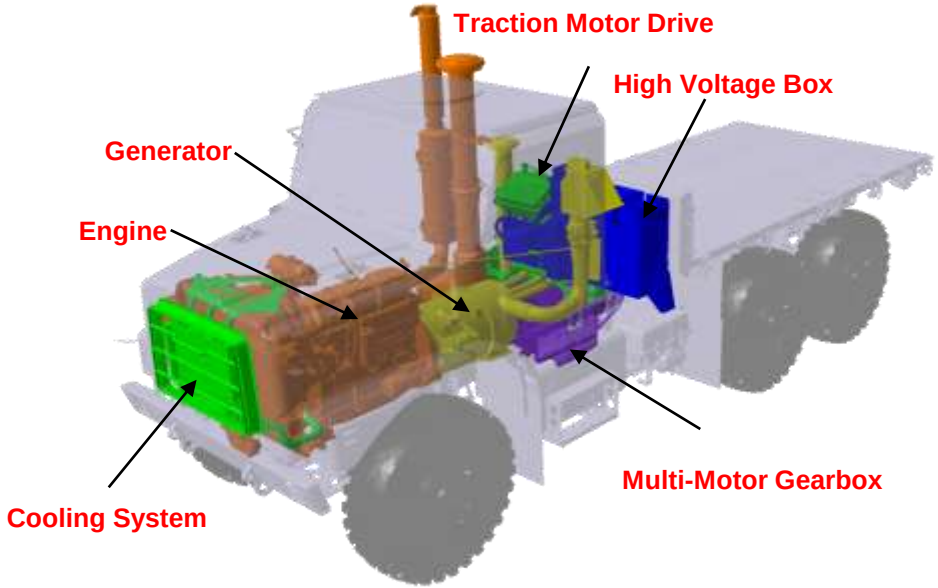
- Exportable Power Program Overview
- Transmission Integral Motor/Generator
  - HMMWV On-Board Vehicle Power System (OBVP) Overview
  - 3000 Series Transmission Integral Generator (“3TIG”)
  - Electric Torque Assist
- Medium Tactical Vehicle Replacement (MTVR) OBVP
- MTVR “Hybrid” OBVP
- Medium Electromechanical Infinitely Variable Transmission
- Summary & Link to ONR Long Range BAA

- DRS HMMWV
  - PM Generator Integrated Into HMMWV Mechanical Transmission
  - Power Electronics Converter For Fixed Frequency (60 Hz) Export And Mobile Power Over Range Of Engine Speed
  - 30kW Of Static Exportable Power, 35kW Of Static Power Surge, 10.5kw Of Mobile Power



- Oshkosh MTVR
  - Implements ProPulse Electric Propulsion System
  - 280 kW Generator, Configurable For 208/480 VAC
  - 120kW Static Exportable Power, 21 kW Of Mobile Power



HMMWV On-Board Vehicle Power System Overview

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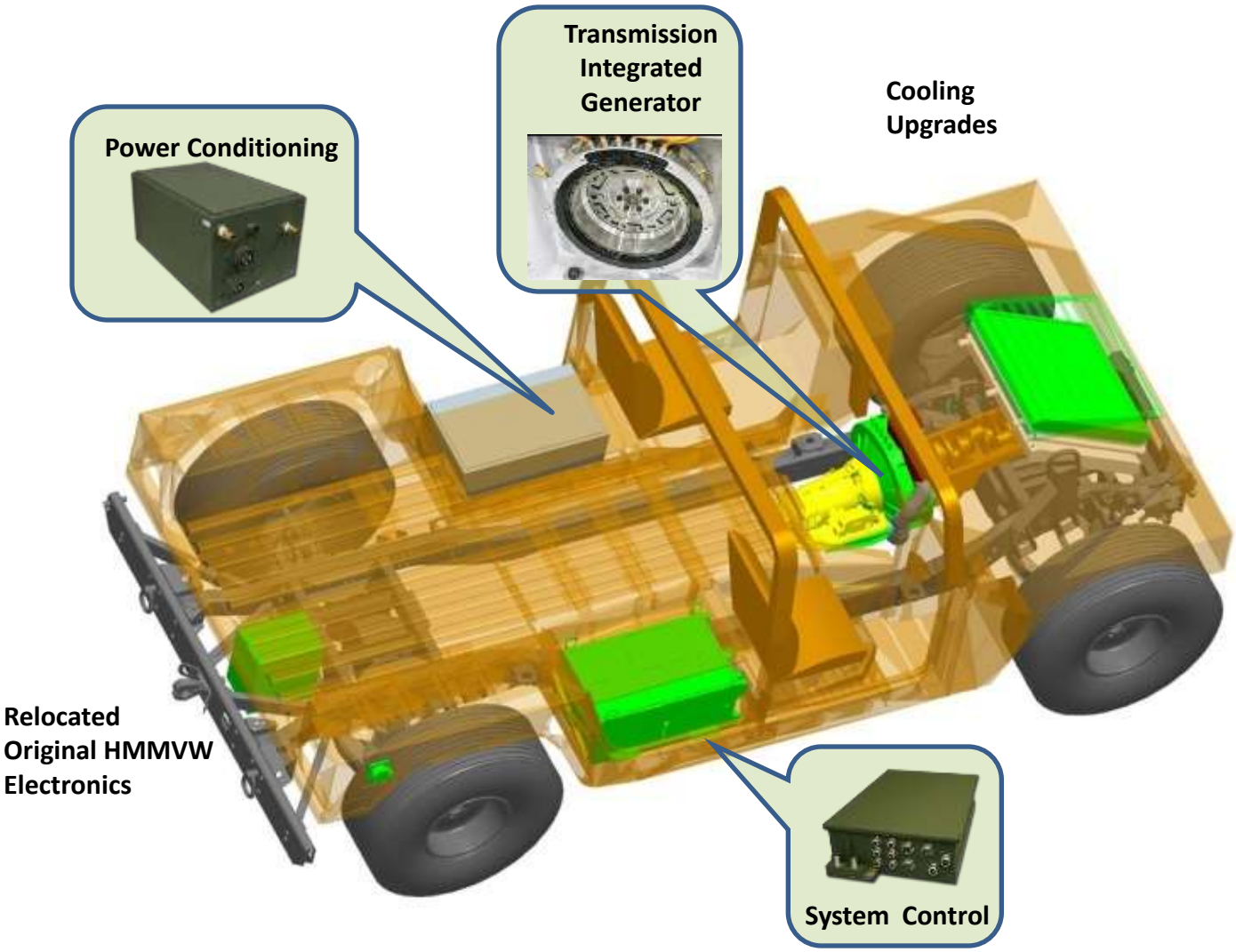

- Transmission Integral Generator (TIG) exportable power approach
- Up to 30kW stationary exportable power
- 10 kW mobile exportable power
- Retrofit "Kit" Approach

HMMWV On-Board Vehicle Power Logistics Savings

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Existing Configuration to Deliver 30 kW with HMMWV Class Vehicle

HMMWVs

15 Kilowatt Generators

Soldiers

= 30 kW

USMC OBVP Equipped HMMWV Configuration to Deliver 30 kW

HMMWV OBVP

Soldier

= 30 kW

- Weight Reduction
- Volume Reduction
- Manning Reduction

Significant logistics savings achieved using HMMWV OBVP

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Scalability of Transmission Integral Generator Concept

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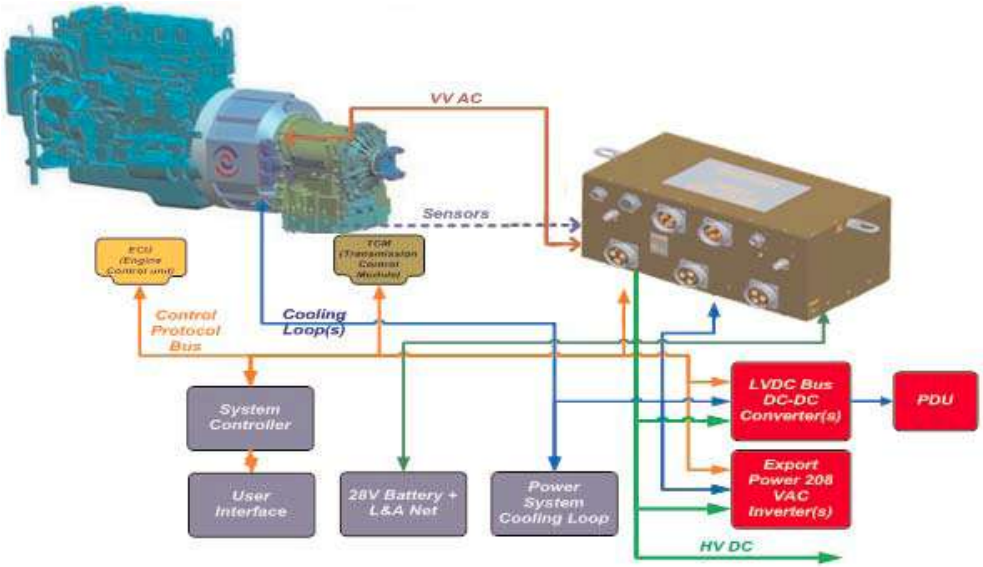


3200TIG Transmission

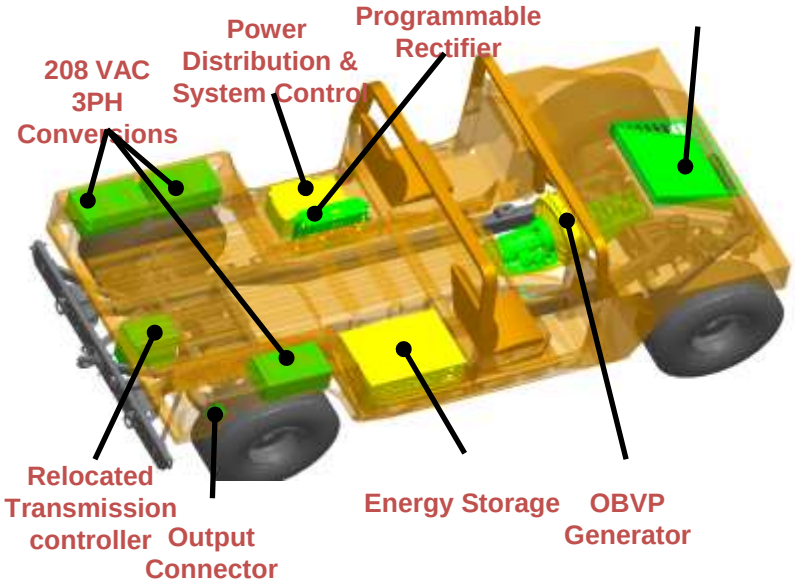
3200SP Transmission

No Impact to Drive Line Space Claim

- **Installs at factory or depot using standard tools and mounts**
- **More than 125 kW of continuous electric power while stationary**
- **No impact to the vehicle driveline**
- **High voltage output available (300 VDC to 600 VDC)**
- **120/208 VAC at 50/60 Hz**

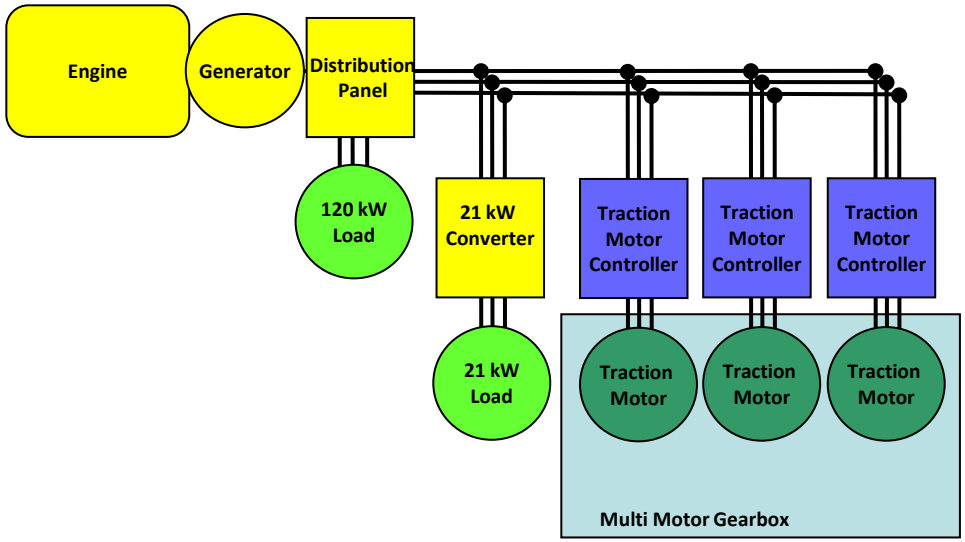
Exportable Power System Components Leveraged for Vehicle Fuel Efficiency Gain

- Electric Assist Components
  - Base HMMWV OBVP Kit
  - Accelerator Pedal and Other Sensors
  - **Motor/Generator Controller** (bi-directional power converter)
  - Battery System
  - Hybrid Electric Vehicle Controller

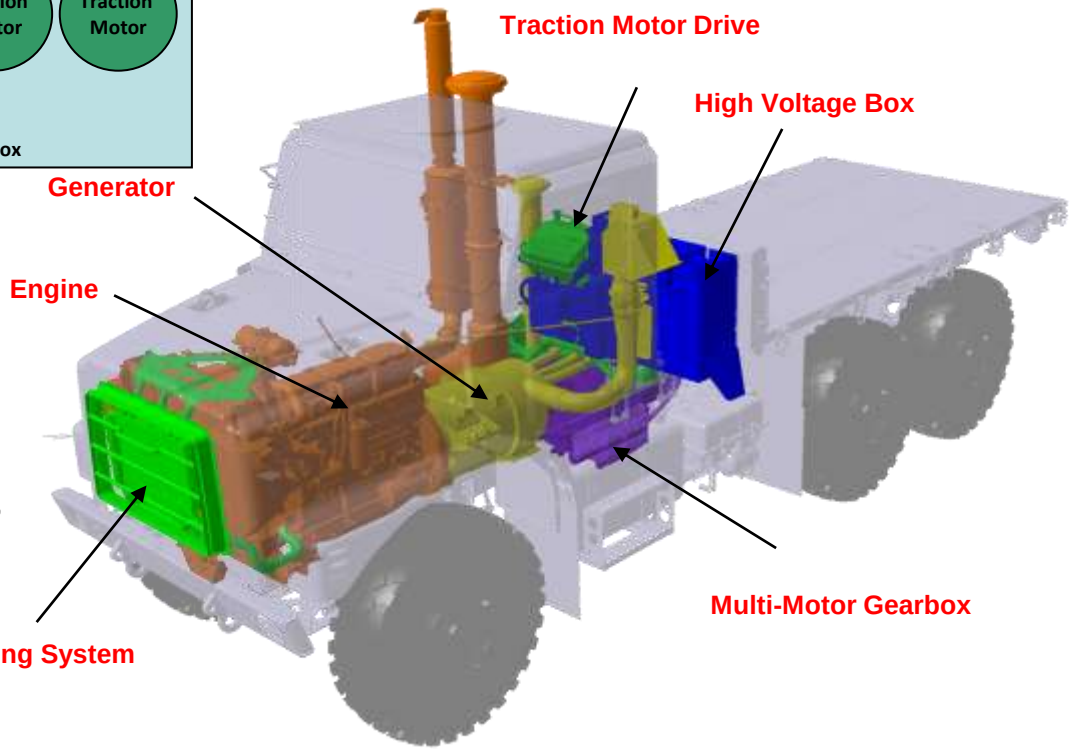


- Load Split Algorithm
  - System uses the **electric machine as generator** to charge the battery when drive system is operating at high efficiency
  - System uses the battery and **electric machine as motor** to assist when drive system is operating at low efficiency
- Additional Efficiency Through Regenerative Braking
- Improve Efficiency of Exportable Power Transient Performance

Approach Applicable for other Transmission Integral Motor/Generator Systems



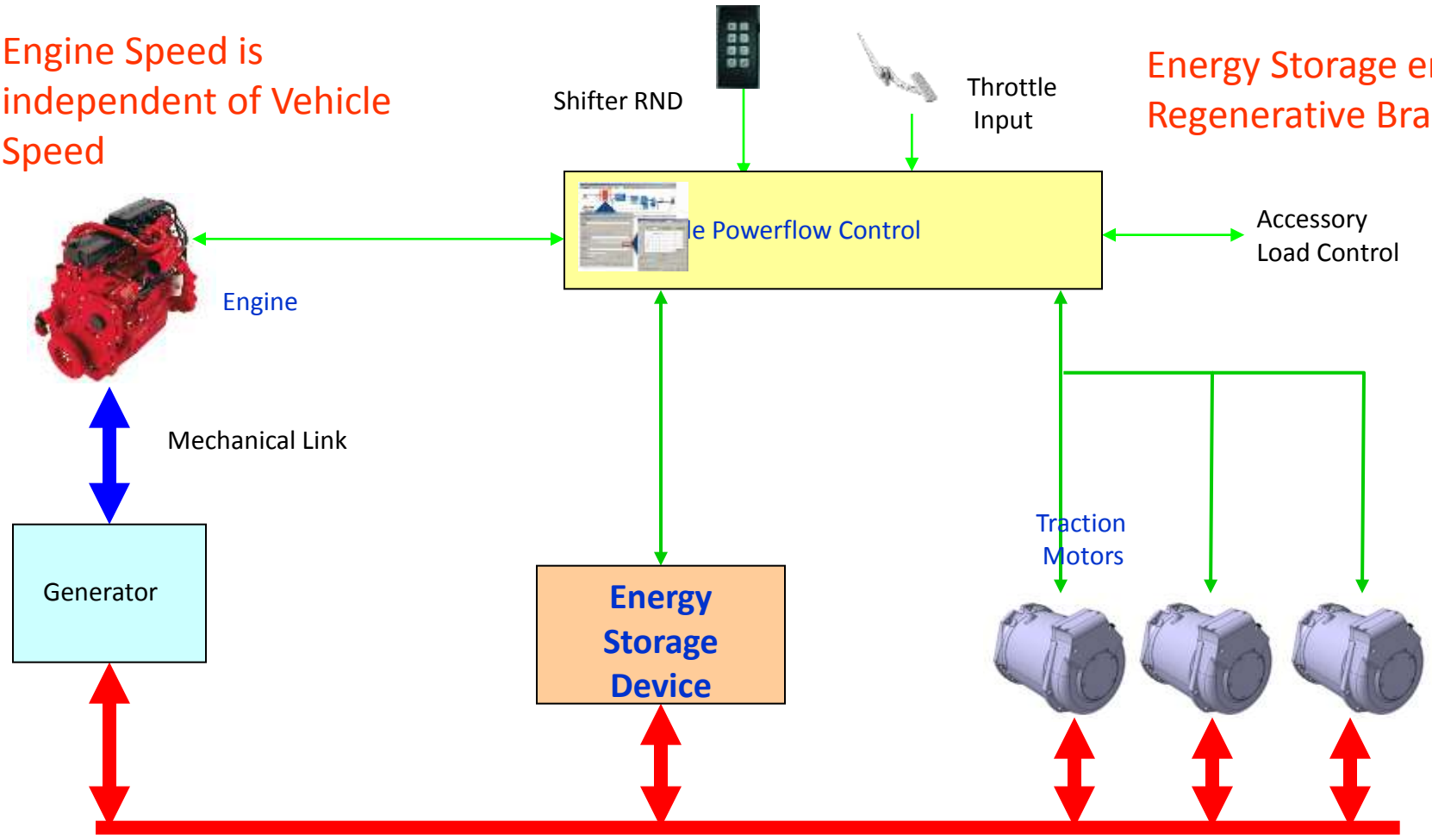
- Diesel electric Propulsion
- 120kW stationary exportable power
- 20kW mobile exportable power



Oshkosh MTVR Hybrid-OBVP High Level Control Schematic

Engine Speed is independent of Vehicle Speed

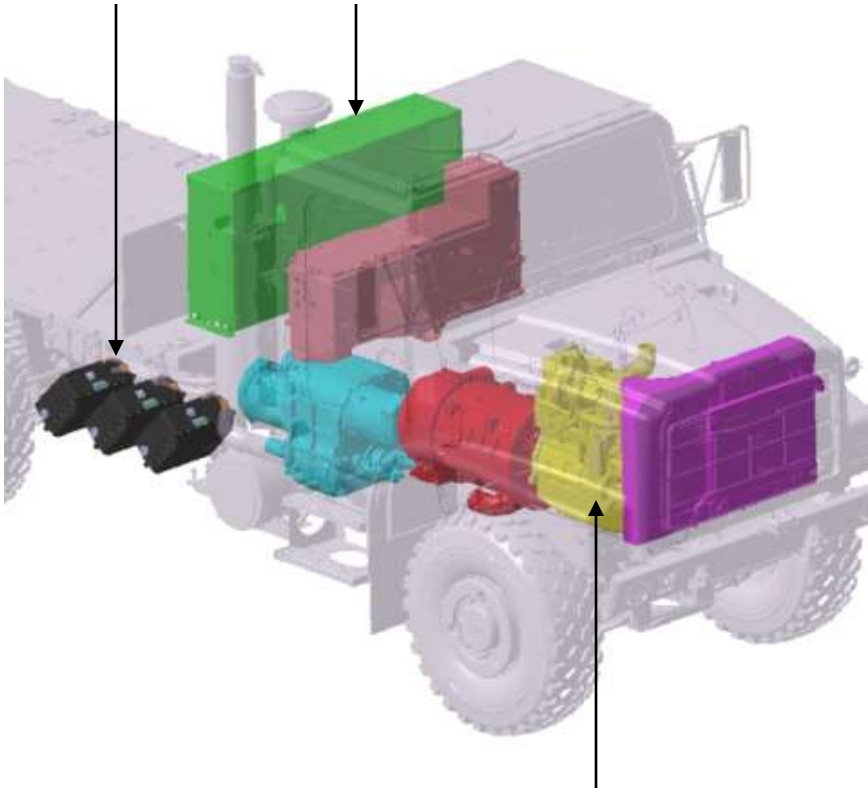
Energy Storage enables Regenerative Braking



Oshkosh MTVR Hybrid-OBVP

- **Technical Approach**
  - Build on MTVR OBVP ProPulse® Drive System, capitalizing on continuously variable nature of series electric drive through the addition of regenerative braking and selecting a power dense (vs. torque dense) engine.
  - **"Hybridize"** with Regenerative Braking Subsystem
  - Capacitor based energy storage modules
  - Develop charge/discharge control algorithms to optimize regenerative braking
  - **"Repower"** with power dense engine
  - Continuously variable nature of series electric drive allows prime mover to make requisite mobility power at any optimum efficiency speed
  - No low end torque requirement allows lighter weight options.
  - Decrease in engine weight achievable

Hybridize with Energy Storage and ProPulse® Drive System



Repower with power dense engine

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Oshkosh Electromechanical Infinitely Variable Transmission

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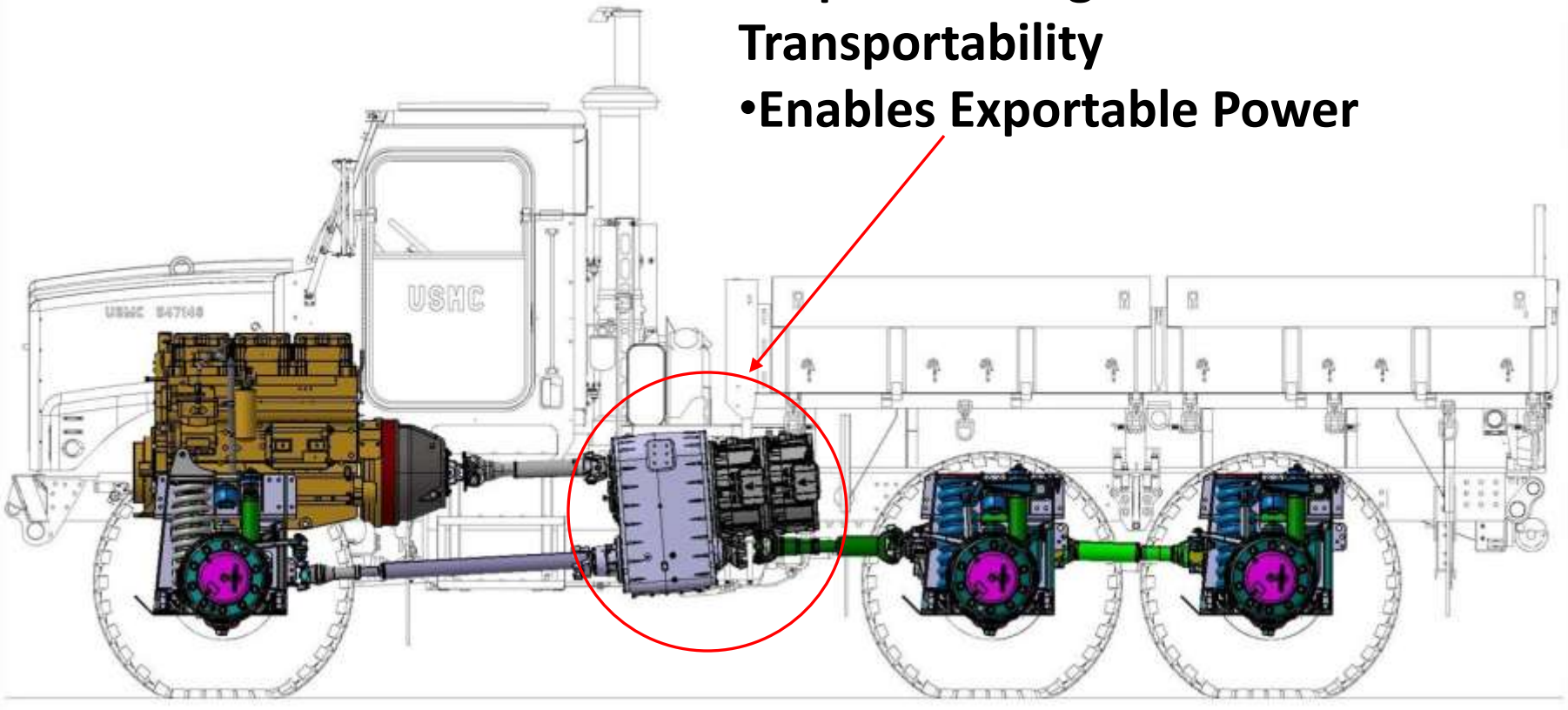
- Alternative powertrain for medium vehicles
- Transfers weight from front axle
- Improves weight distribution for Air Transportability
- Enables Exportable Power



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Oshkosh EMIVT Control Schematic

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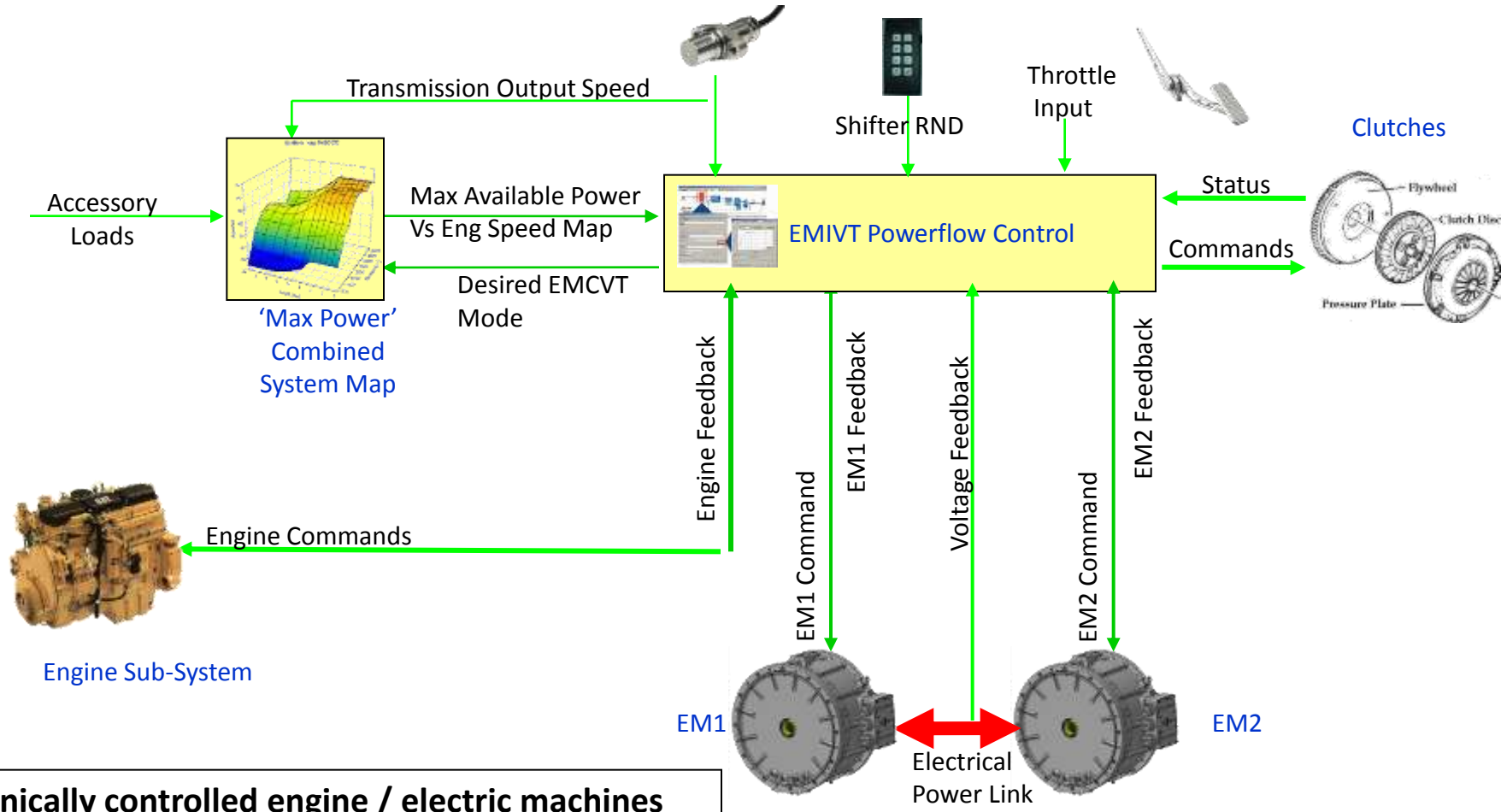
System Controlled to Minimize Combined System Losses



- **Electronically controlled engine / electric machines**
- **System architecture yields efficient, redundant operation**
- **Power management algorithms optimize efficiency**

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Oshkosh EMIVT Fuel Economy Simulation

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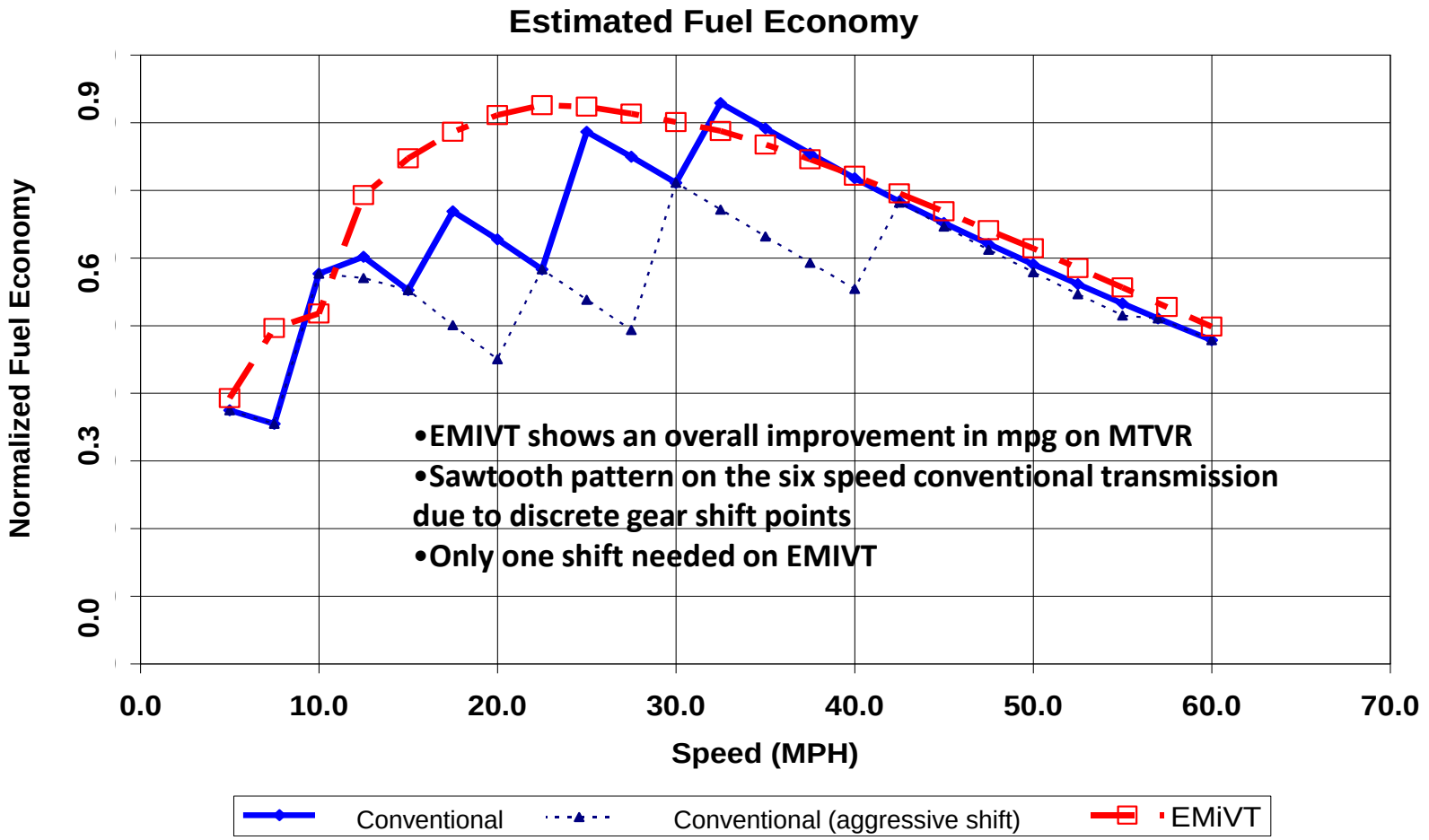
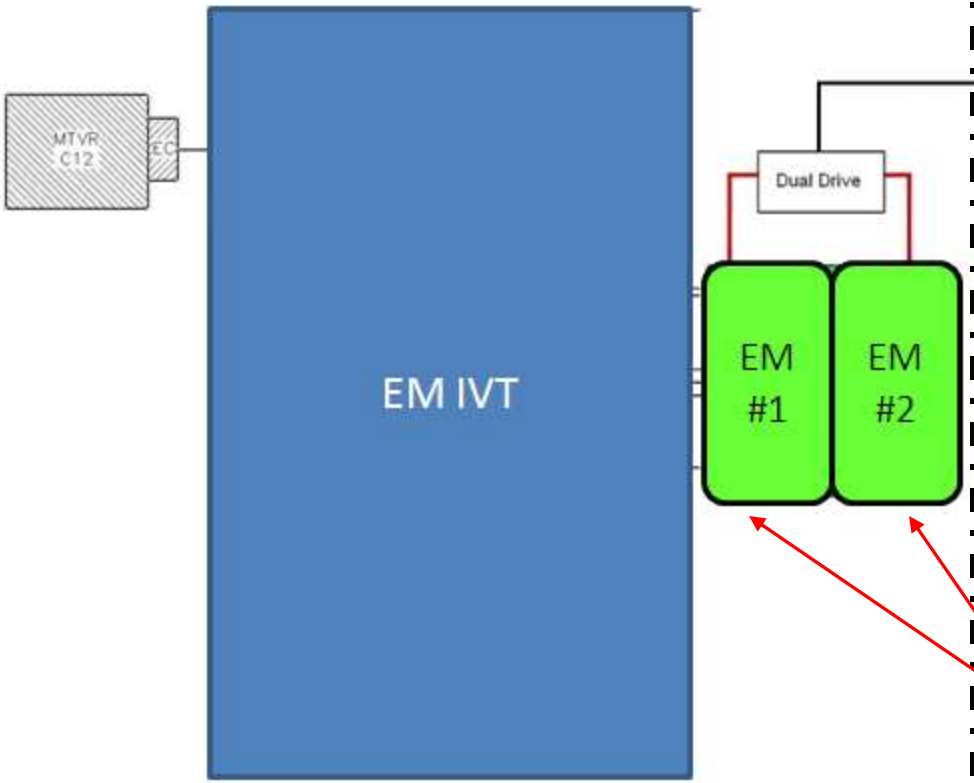
- Preliminary comparison between **conventional powertrain and and EMIVT**
- Simulation of **cruising** "steady state, flat road" operation - **no energy storage**
- Addition of **energy storage** can further improve mpg by **10-15% depending on drive cycle**



Oshkosh EMIVT Control Schematic



Future Options

- Regenerative Braking with the addition of Energy Storage option for Improved Fuel Economy
- Export Power capability with addition of DC to AC inverter
- 150kW stationary power
- 30kW mobile power

Both electromagnetic machines may be operated as generators

ONR Fuel Efficiency and Battlefield Power Program Summary

- Marine Corps Expeditionary Energy Strategy
  - **"By 2025… the only liquid fuel needed (by Marine Expeditionary Forces) will be for mobility systems, which will be more energy efficient than systems are today."**
  - *Mobility systems will also provide exportable power for battlefield needs.*
- Integration of electromechanical power systems (generation, storage, conversion, and control) with vehicle drive systems enables fuel efficient mobility and exportable power.
  - Series Electric Drive – High Power Applications
  - Transmission Integral Motor/Generators – Small/Medium Applications
  - EM IVT – Alternative Mobility/Exportable Power System
  - ***Future Capability Enabler – Directed Energy, Energy Based Survivability***
- Other Applicable Approaches
  - Fuel Cells, Auxiliary Power Units
- Science and Technology Needs – High Temp, Power Dense Components
- **COST - Acquisition Cost as Important as Lifecycle Cost Savings**
- ONR Long Range BAA
  - **http://www.onr.navy.mil/en/Contracts-Grants/Funding-Opportunities/Broad-Agency-Announcements.aspx**