System Considerations when Integrating New Battery Technologies into the XM1124 Hybrid Electric HMMWV

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DRS Test and Energy Management

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DRS TECHNOLOGIES

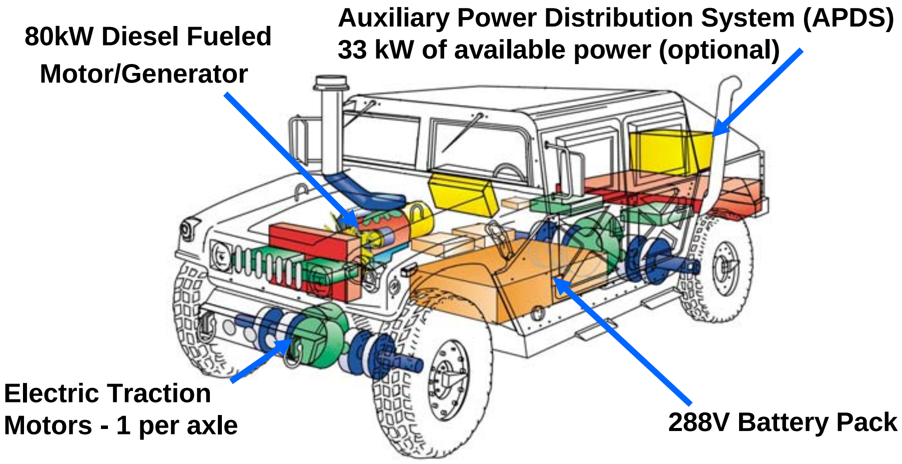
XM 1124 Overview

Description

- Replaces the conventional HMMWV drive train with a hybrid drive train while retaining the capabilities of the standard HMMWV
- Quiet, mobile platform for silent watch, reconnaissance missions
- Reduced thermal and acoustic signatures
- Power generation capability

Key Requirements

- ***Provide 33 kW of continuous power***
- ***C130 Transportability***
- Silent Mobility
- Silent Watch
- Multi-phase mobile power (AC/DC)
- Maintain HMMWV capabilities; mobility, transportability, and payload.
- Two level maintenance
- Open Architecture for upgrades



Integrated Battery Technologies

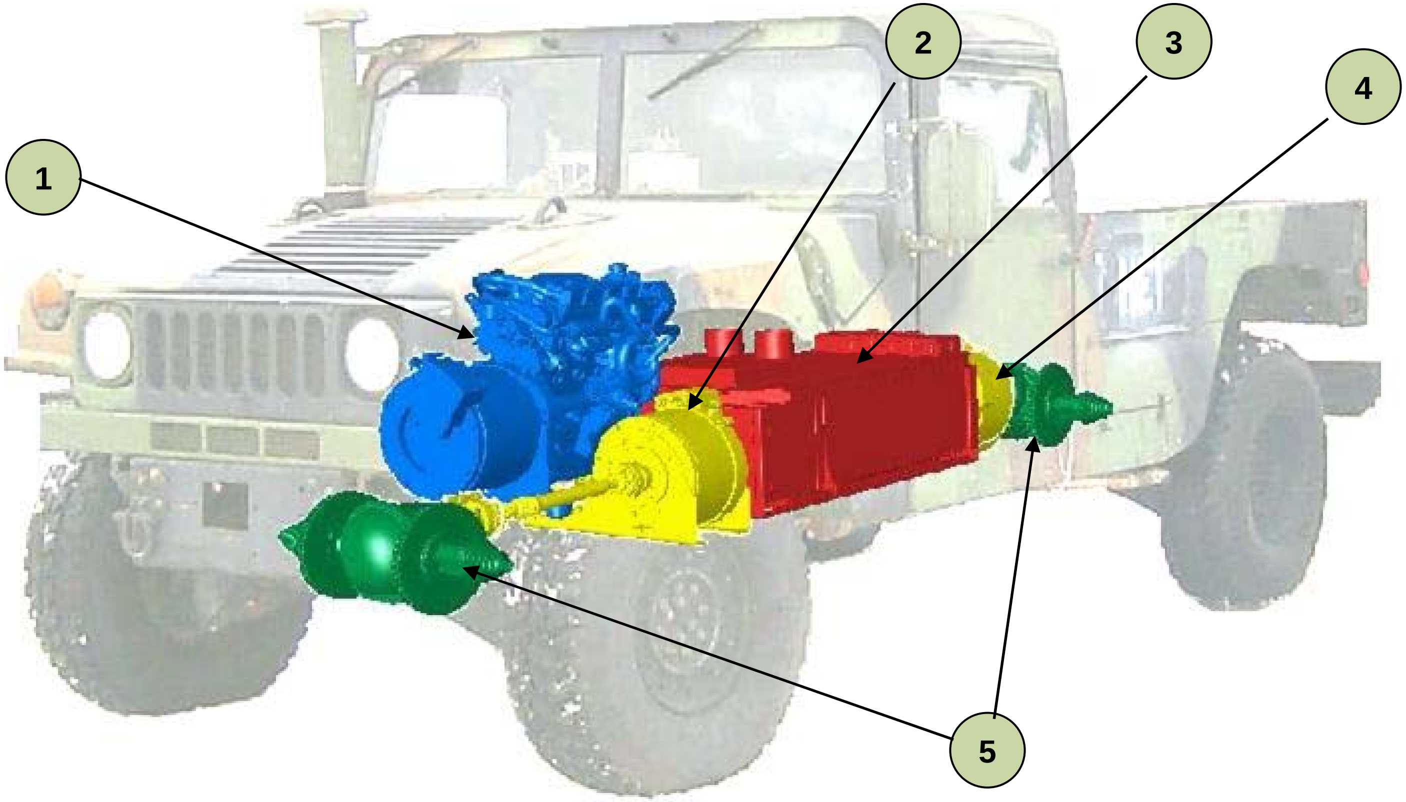
- Lead Acid (Optima Yellow Top)
- Lithium Ion
- Lithium Iron Phosphate

Considered Future Upgrades

- Integration of Hard Carbon and Lithium Titanium Oxide battery pack
- Upgraded traction motors
- Upgraded motor drives utilizing Silicon Carbide technology

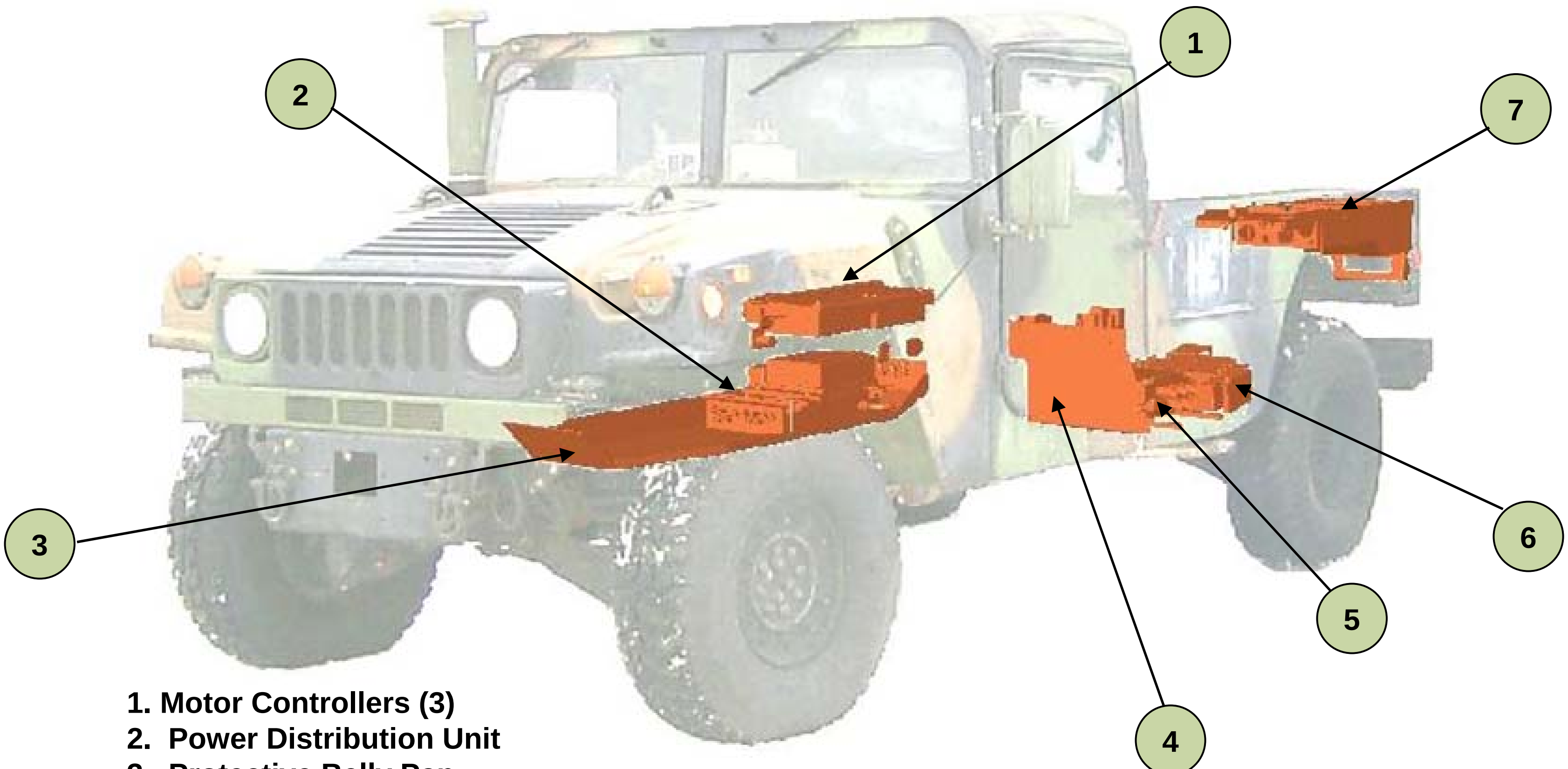
Hybrid Electric HMMWV XM1124

XM1124 and HE-DRIVE Components



1. Engine and Generator
2. Front Traction Motor
3. Battery Pack
4. Rear Traction Motor
5. Modified HMMWV Differentials

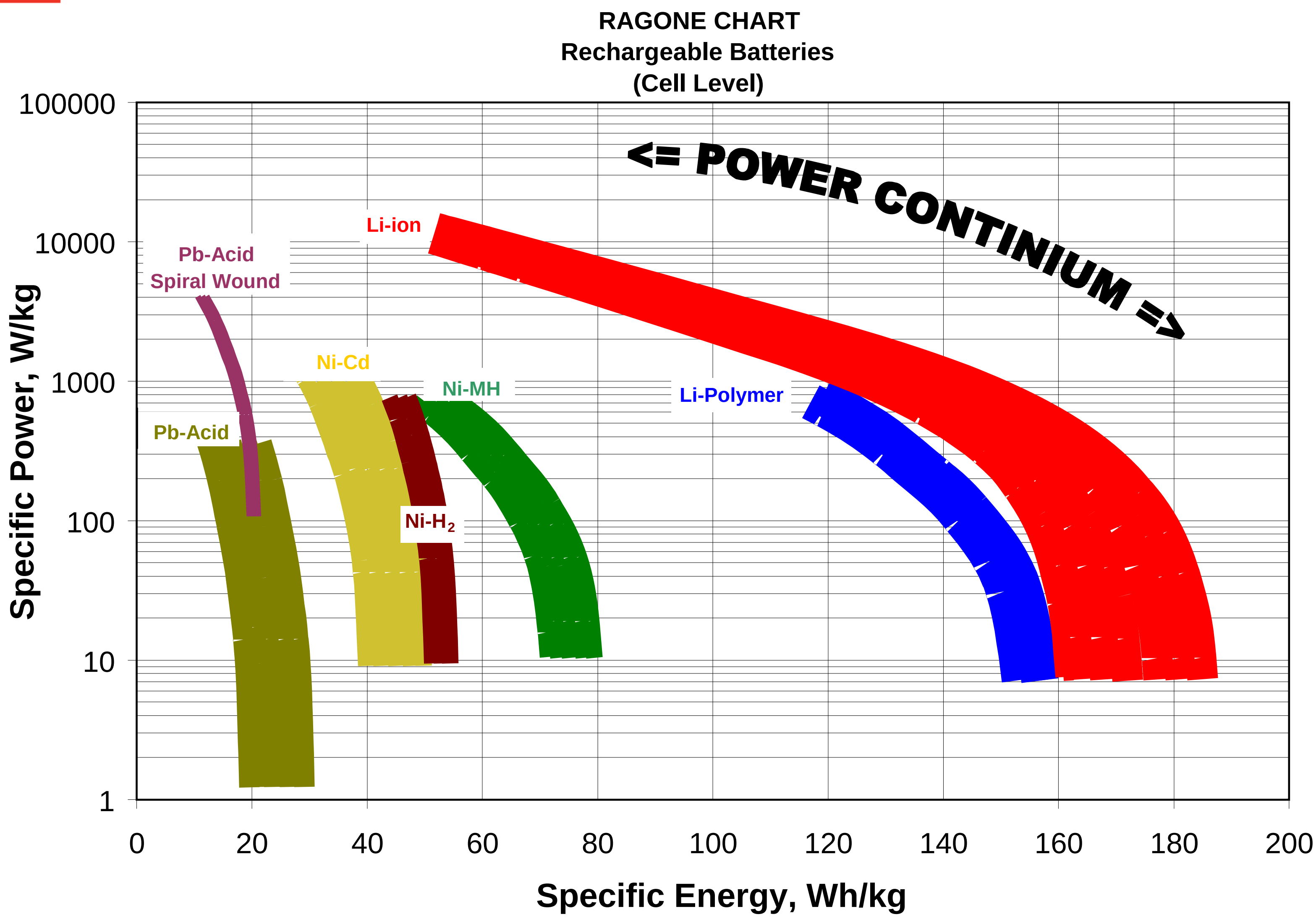
XM1124 and HE-DRIVE Electronics



1. Motor Controllers (3)
2. Power Distribution Unit
3. Protective Belly Pan
4. System Control Unit
5. Battery Control Unit
6. Auxiliary Power Converter
7. Auxiliary Power Distribution System (Option)

Battery Comparison

A trade-off between power and energy



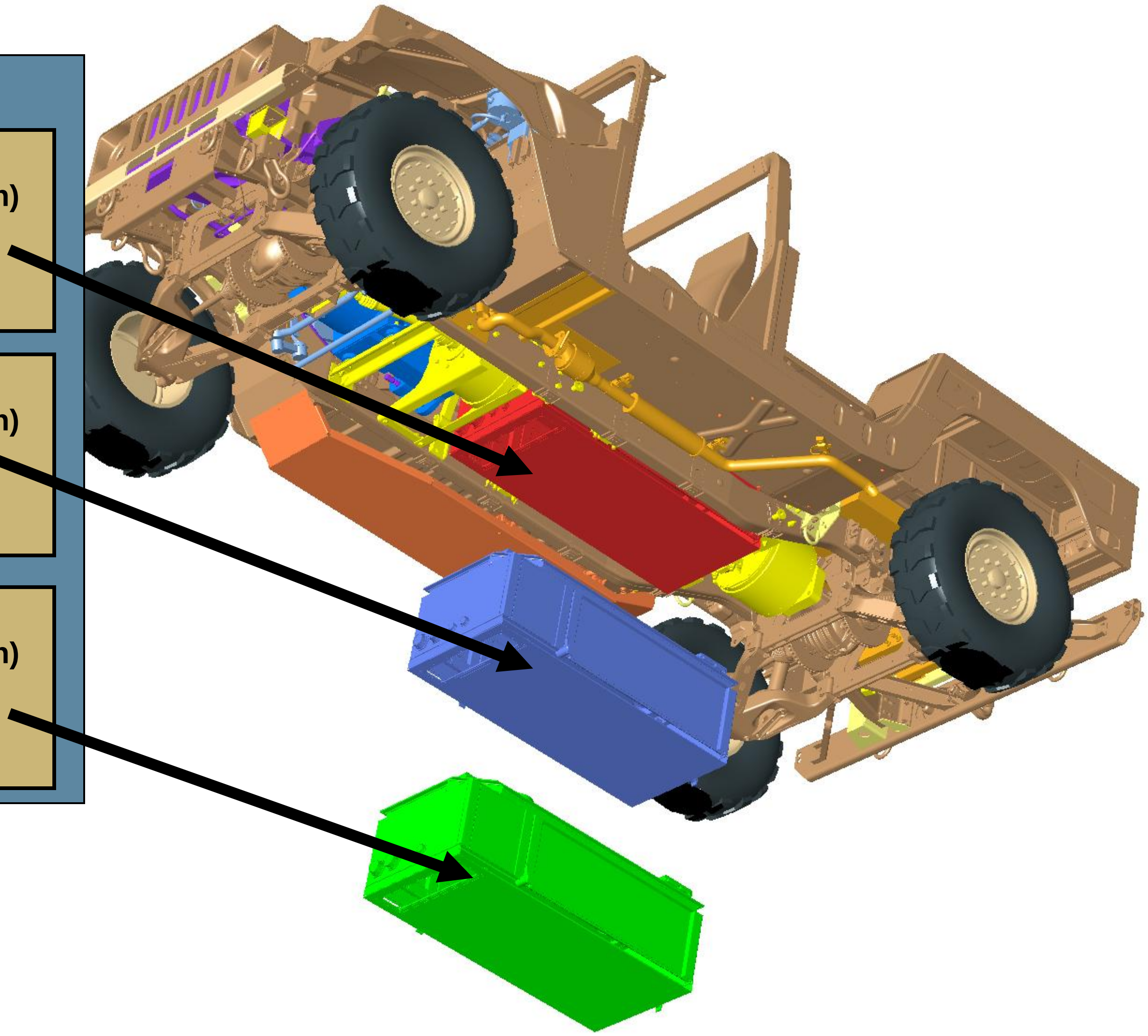
HE HMMWV Configuration Flexibility
Pick-a-Power and Payload Capacity

Plug 'n Play Battery Packs

Mobility Pack (Pb Acid)
Export Power: 125 kW Peak (6 min)
75 kW Continuous
Silent: 15 kW (18 Minutes)

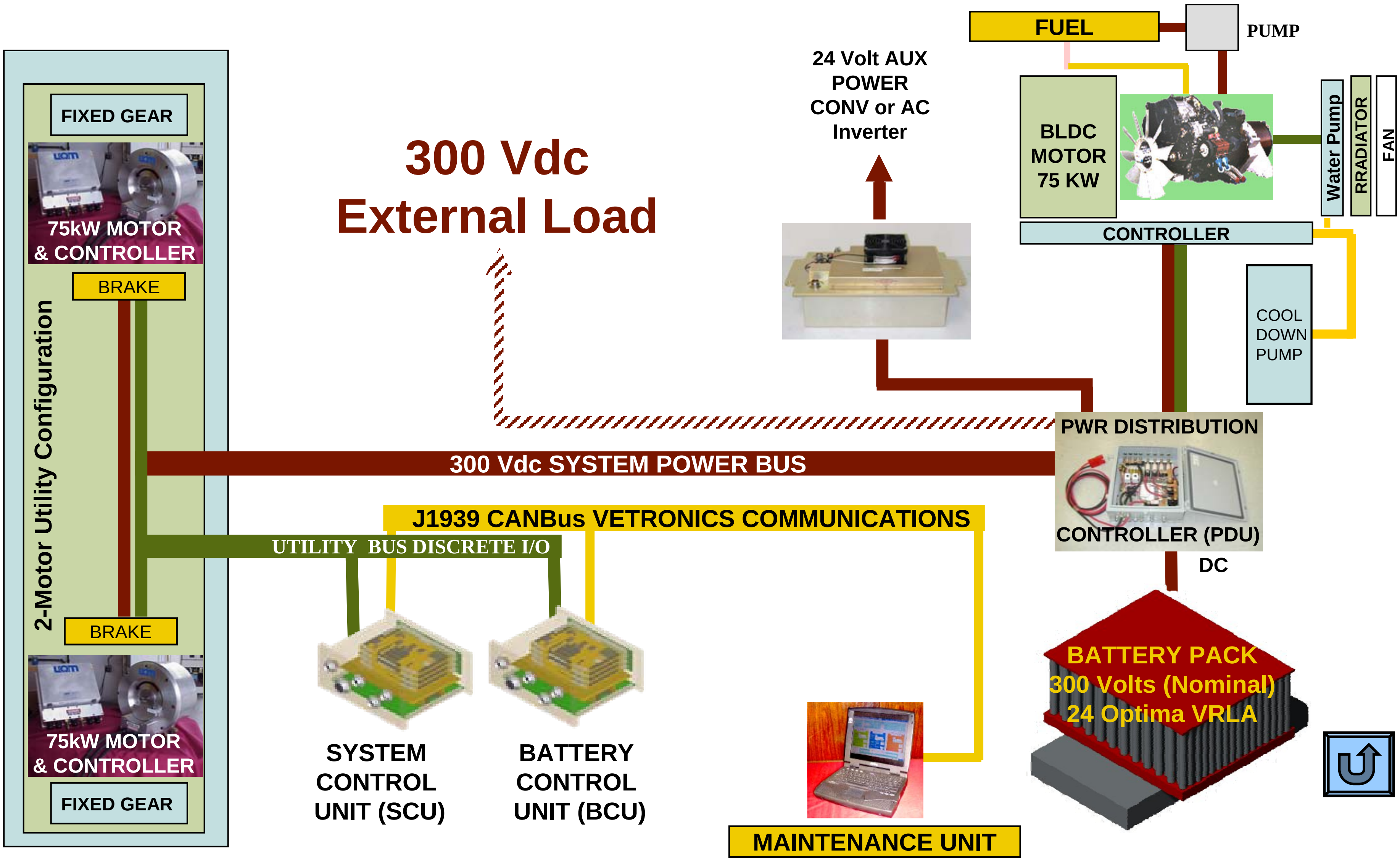
Mid-Energy Pack (LiFePh04)
Export Power: 175 kW Peak (6 min)
75 kW Continuous
Total energy Storage: 4.8kW

High-Energy Pack (Li Ion)
Export Power: 225 kW Peak (6 min)
75 kW Continuous
Silent: 15 kW (1.1 Hour)

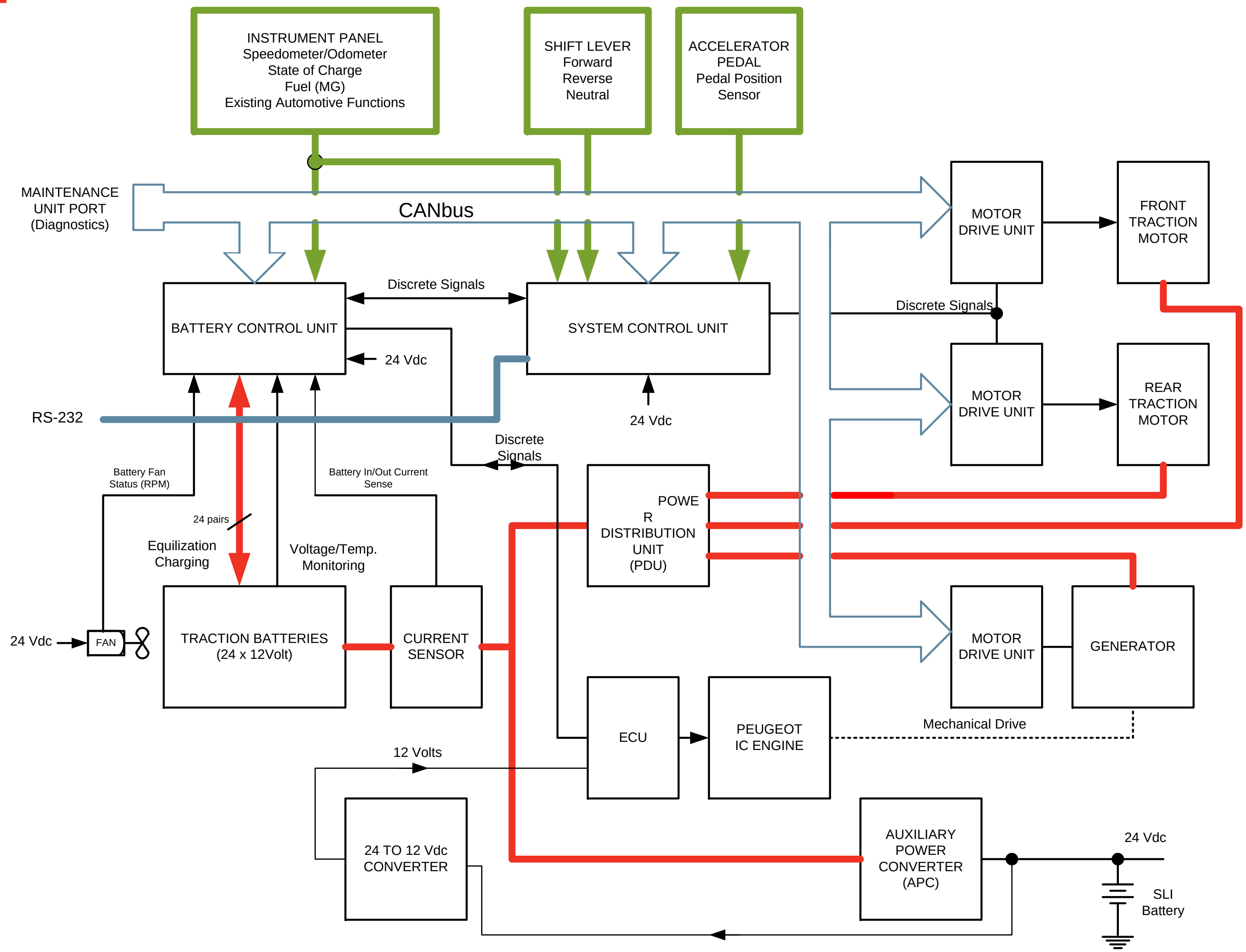


Note: Payload capacity already includes:
- **Soldier Load and BII (580lbs)**

XM1124 System Block Diagram

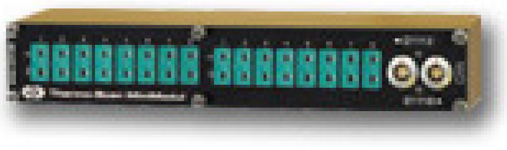


Control Topology



Hardware Modifications

- Thermocouples/RTDs
  - Sometimes part of BMS
  - Location is EXTRMELY important



- System Controller
  - If multiple batteries/modules
  - Monitors all of the module/battery information and reports highs/lows and faults to Battery Control Unit (BCU)
  - Is used to compute SOC and other critical battery status
- Interface Hardware
  - Connectors
  - Cabling
  - Need to be compatible (to include type and pinout) with existing vehicle hardware
- Grounding
  - Need to ensure any added harware is properly grounded for safety and noise
  - Pack needs to be connected to chassis ground with a resonable impedance to prevent touch voltages

Software Modifications

- Communication
  - Need to ensure added hardware can communicate to the system controller (typically vis CAN messages)
  - A complete ICD needs to be provided with pack hardware
  - Essential data from CAN message needs to be identified along with "don't care's" from existing battery pack
  - What happens when communication is lost?
- SOC calculation/Battery Management
  - Need to ensure the battery pack's SOC is calculated correctly and reported to the Battery Control unit (BCU)
  - Methods need to ensure temperature compensation
  - SOC calculation for various chemistries can be tricky
    - Lead acid has a "predictable" V-I curve
    - Lithium Ion has a very "flat" V-I curve
- Maintenance Unit
  - Needs to monitor new hardware if added (such as Thermocouples)
  - Modify the user's GUI to reflect any new hardware or features added

Algorithm Modifications

- Safety
  - The possibility of cooling with 120F ambient air creates a challenge for each energy storage unit
  - Protection during fault; how many times does the system retry
  - What to do if pack exceeds temperature, voltage, current, etc.
- Pack Specific Operating points
  - Maintain the pack in a SOC window (Ensure you account for regenerative systems)
  - Need to incorporate limits (current, voltage, temperature) based on the safe operating parameters of the battery pack
- Timing
  - How often is data being sent
  - Is there too much chatter on CAN line
  - Need to ensure delays are inserted where they need to be (startup, controlled shutdown, etc.)
- Faults
  - What do you do in case of a fault
  - Controller shutdown vs. Emergency shutdown
  - Who controls the Master Relay

Verification – Bench Testing

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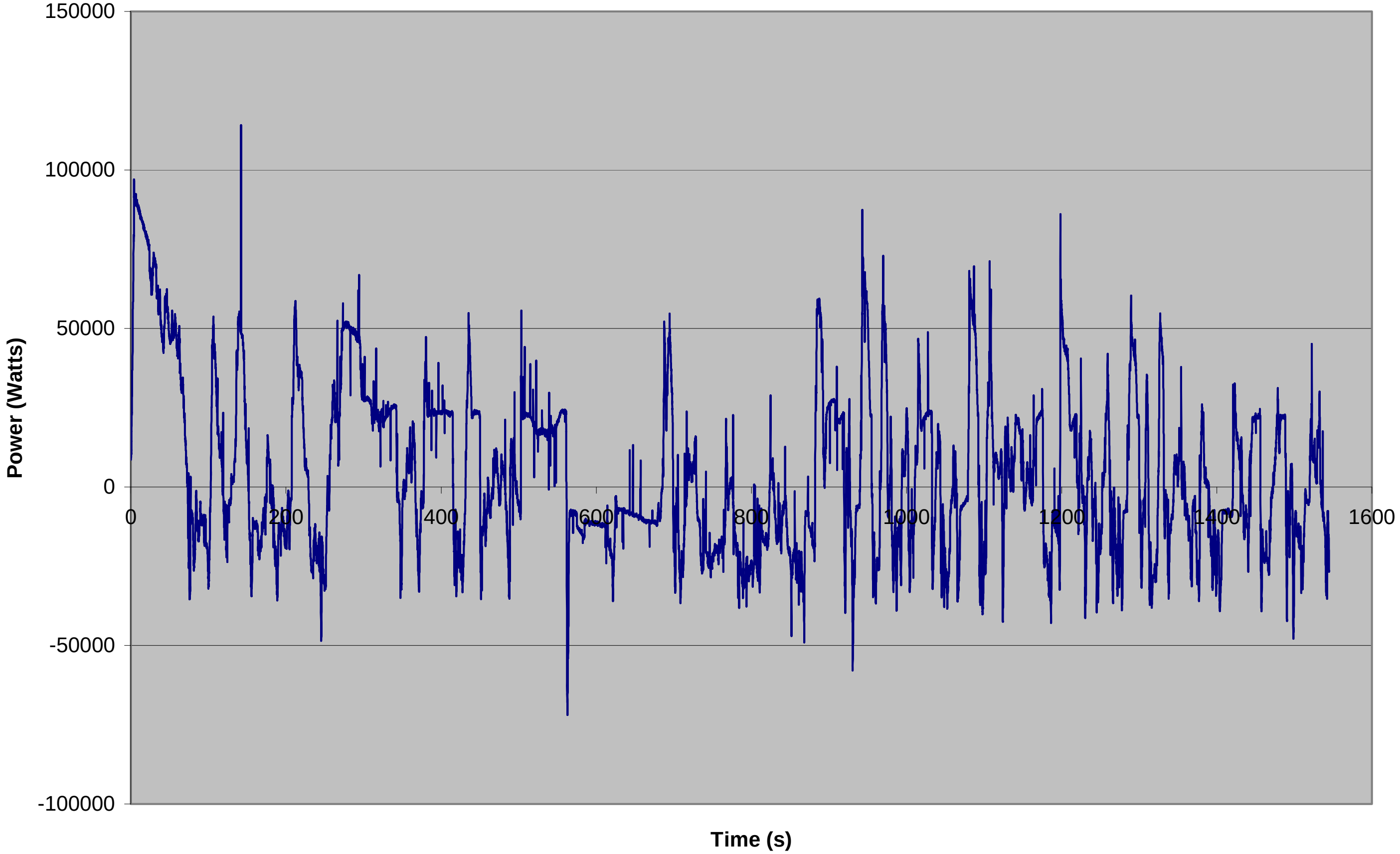
- HAVE A TEST PLAN!!!!
  - A standard test plan needs to be used to do “apples to apples” comparison of battery technologies
- Objective of bench testing is to determine if pack is safe to integrate to vehicle
- Can also validate safe operating conditions from data sheet of pack
- Reference Performance Test
  - Performed between each major test
  - Shows any degradation of the pack
- Discharge/Charge Test
  - Essential to monitor temperature rise
  - Perform at various levels up to the levels the pack will see in the vehicle
- Cycle/Pulse Testing
  - Much like the pack will see when integrated to the vehicle

ABC-150 Power Processing System

Verification – Bench Testing

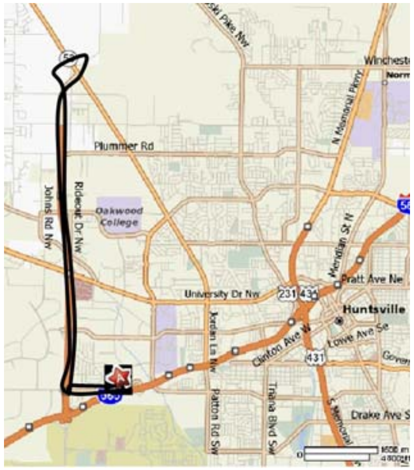
- Subject the pack to typical operating conditions
  - Known charge/discharge profiles



Power profile of XM1124 Navigating Hartford Loop at APG

Verification – Vehicle Testing

- Pack will be integrated once successful bench test is complete
- Lessons learned during bench test can be applied to pack prior to integration
  - Verification of SOC values
  - Verification of Temperature sensing
  - CAN communication and adequate control and protection



- Functional Test
  - Usually a “drive slowly around the parking lot” test
  - Ensure all systems are functioning properly and safely
- Acceleration Test
  - Determine how well the pack allows the vehicle to accelerate over a known distance
  - Perform at various battery SOC levels and compare
- Road Test
  - Include various terrain (hardball vs. dirt) and slopes (flat vs. hilly)
  - Finalize with an “extended” test that will simulate driving conditions in the field (at least two hours)
    - Monitor Temperature <u>CAREFULLY!</u>

Conclusion

- Safety is extremely important when integrating new battery technologies
- Hardware/Software/Algorithms need to be considered to accommodate the new technology
- Bench testing needs to be performed prior to integration to the vehicle to ensure safety during vehicle operation
- Upon integration on vehicle, sufficient testing using realistic scenarios/conditions needs to be performed
- Having a detailed, consistent test plan will allow for comparison between technologies
- The best measure of performance comes from the person sitting in the driver's seat!

Acknowledgements/Contact

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