Report Documentation Page

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
• Provide engineering support to the US Army, Program Manager for the Fielding of Heavy Tactical Vehicles (PM-HTV).

• PM-HTV is in the process of upgrades to the HEMTT production vehicle so as to increase vehicle reliability and safety, and reduce life cycle costs.
  
  o Vehicle upgrades may include the addition of electrical power management, vehicle sensor integration and monitoring, and driver-assist equipment.

  o In order to illuminate what this means in terms of future engineering changes this effort will conduct engineering, integration, test and evaluation of these systems.

  o Though these efforts and experience PM HTV will have an engineering foundation, set of performance data, and a technical data package to decide and carry on with implementation.

  o All deliverables are government owned.

• One of the main outcomes of this effort will be the delivery of a demonstration HEMTT A2 vehicle equipped with these systems for user evaluation and assessment.
Modular Hydraulic Power Generator

- Popular in fire/rescue and other industries since mid-1990s
- Completely integrated solutions available from 6-30kW
- Significant existing industry base:
  - Harrison Hydra-Gen
  - Cummins Onan
  - Hart-A-Gen Systems
  - Nartron Smart Power

Benefits:
- Allows flexibility of placement
- Not subjected to engine compartment temperatures
- Low cost APU capability
- Reliable operation, minimal maintenance required
- Multipurpose hydraulics: Power Steering, Winches, Power generation
Modular Hydraulic Powered Generator

• Approach: Repurpose the hydraulic drive for the winch

• Assembled and installed a bolt-on module

• Uses a hydraulically powered motor to drive a generator

• Existing alternator and this supplemental unit handle high power loads in place of large (>400A) belt driven system.
Key Findings- Modular Hydraulic Powered Generator

- Hydraulic powered alternator proved functional

- Provided higher, constant 5.6kw power output across wider engine speed ranges over current OEM equipment

- Need to add a flow control, by-pass feature to account for the effects of possible engine over-speed
Issues Supporting the Need for Primary Power Management

- Reliable engine starting after long term storage
  - AGM Battery loss on vehicles aboard Pre-Pro Ships (USNS Pomeroy)
  - War Reserve, National Guard, etc. with long periods of inactivity
- Higher total power needed for high electrical demands (e.g. A/C, C4ISR, CREW, IED countermeasures, lighting)
- Longer operation during ‘silent watch’
- Reduced logistics burden
- Lower lifecycle costs
- Simplified maintenance and diagnostics

Battery Graveyard, Kuwait
A common vehicle power & energy architecture across platforms

- Employs a split energy storage system to optimize energy delivery

- Uses ultracapacitor for vehicle starting

- Integrates power management & control

- Accommodates variety of batteries to meet mission requirements

- Uses a hydraulically-driven alternator /generator for high electrical power drive & accessory loads

- Evaluated the utility of a planetary gear starters

- Accepts modular external charging sources (e.g. BB-2590, Solar, etc).

- Provisions DC–AC, DC-DC Power Sources

- Uses a hydraulically-driven alternator /generator for high electrical power drive & accessory loads.
Primary Power Management System Built & Tested

Scalable across TWV’s

Ultracapacitor and controller for hybrid starting system

PPMS

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PPMS Split Energy Storage System Design Benefits

- Utilize ultracapacitors for engine starting
- Use the appropriate battery technology for specific mission requirements
- Meets the needs of the two different vehicle energy/power requirements
  - One for starting, other for low power, long duration
- No battery exists that can be optimized for both functions
Results- Energy Storage for Silent Watch and Life Cycle Costs

Silent Watch Runtime vs. FTTS Requirements

Runtime estimates based on 60A @ 24VDC, with battery pack = size/weight of (4) 6TMF batteries; assumes no energy required for engine start at conclusion of silent watch

FTTS Objective

FTTS Threshold

6TMF
Hawker Armasafe
Trojan J150
Cobasys NiMHax 9500

Total Life Cycle Costs

$17,280
$20,900
$8,960
$36,000

Lifecycle costs based on 25 year vehicle lifetime with two high intensity conflicts and 6000 charge/discharge cycles.

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Recharge of Hybrid Starting System with External Source

- PPMS and hybrid starting system accommodates multiple, new external charging sources (e.g. BB2590, hand-crake, solar panel)

- BB2590 External Recharge
  - 126 sec’s from dead to start; 6-7 charges from one BB2590 Battery
PPMS Key Findings

Findings:
• Hybrid starting system proved functional
• Works with wide range of batteries
• Ultracapacitors can restart vehicle many 1000’s of times
• Hydraulic powered alternator proved functional
• Ultracapacitor recharge control system proven using BB 2590, can also use BB390 NiMH, etc.

Impact:
• Life cycle cost reduction, reliability, improved performance in ‘silent watch’ runtime, modularity, applicability across family of TWV’s
PPMS Path Forward

- Better integrate and package the power and energy control system into the demonstrator vehicle with Vehicle Information Backbone (TRL-8)

- Perform electrical noise characterization and testing
  - Similar to a Mil. Std. 810 characterization, but short of certification)

- Conduct System Integration Test

- Update cost benefit analysis

- Complete performance specification for transition
Collision Detection System for Military Convoy Vehicles Operating CONUS

**Problem:** We have no acceptable fielded safety system for run-on crash avoidance.

Commercial RADAR systems are ineffective in tough terrain, environmental conditions, and with moving obstacles. Further, cost is too high to field on all vehicles.

**Objective:** Assemble and package a modular collision avoidance system that could be used in vehicles operating CONUS.

**Technical Approach:**
- Compare instantaneous GPS positions between vehicles and inertial sensor data to compute inter-vehicle closing distance & stopping time.
- Provide audible/visual alert to driver inside their reaction time window.
- Use COTS components integrated into a modular package for allocation to vehicles on an as needed basis.

Between 1987 and 2006, 247 rear-end crashes occurred in low visibility during convoy operations at a cost of $6.26M and 4 lives*. We have no acceptable fielded safety system to reduce or prevent this - why?

Yuma Proving Grounds Jan 2010

* TACOM Safety Office Report

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Collision Detection System - Description

As-Built Prototype System for Test & Evaluation
- GPS and inertial sensors on each vehicle
- Wireless communication between vehicles
- Use of Netbook PC’s

Approach
- Share precise separation distance between vehicles
- Combine separation data and rate of closure to determine warning
- Present audible and visual driver alert

System Testing
- 2 and 3-vehicle testing conducted at Penn State test track
- 3-vehicle convoy testing conducted on PLS’s at Yuma Proving Ground

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Example- Yuma Hard Brake, Emergency Stop Test

• Three vehicle convoy, staggered in three parallel lanes on runway

• Accelerate to 30 MPH

• Vehicle 1 brakes suddenly, Vehicles 2 & 3 respond to Vehicle 1’s brake-lights with deliberate 1 sec reaction delay time

• System records vehicle positions as well as velocities and generates warning parameters indicated on a driver display to alert of a possible collision
Collision Avoidance Testing
Hard Brake / Emergency Stop

Immediate End of Test - all vehicles braked to a stop
Vehicle 2 “overran” Vehicle 1
Vehicle 3 stopped with headway between Vehicle 2

Takeaways:
• Red gives proper indicator of unsafe headway distance
• Need to tailor and adjust thresholds to optimize system performance and driver effectiveness
Collision Detection System - Findings & Next Steps

Key Findings:
• System performance unaffected in visually obscured environment
• Technique of combining GPS with inertial measurement meets the desired performance at lowest cost

Next Steps:
• Move from prototype to field ready package
• Develop capability to localize within the convoy
• Modify the Driver Alert Interface based upon feedback from drivers
On-Vehicle Sensor Integration for Monitoring and Diagnostics

Applied to existing vehicle data sources
- Integrate Vehicle Computer System (VCS)
- Develop and integrate common CBM graphical user interface
- Open data sources: J1939, J1708
- Proprietary data sources: ADM diagnostic messages, ADM operational parameters

Applied to new sensors
- Engine oil condition analysis
- Engine oil level
- Transmission oil level
- Coolant sensor level
- Hydraulic reservoir oil level
- Fuel level
- Fuel filter condition
- Tire pressure monitoring
- Brake wear monitoring

Applied to power system components
- Alternator: Voltage, Current, and Temperature
- Ultracapacitor: V, I, T, and SOC

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Automated Reporting Information System - Displays
History of Penn State Support to PM HTV

11865 Hydraulic System Diagnostics and Condition-Based Maintenance for Heavy Tactical Trucks
6 months

11899 Battery Diagnostics/Prognostics for Heavy Tactical Trucks - Preliminary Design and Demonstration System
13 months

12368 Demonstration of Hydraulic System Diagnostics and condition Based Maintenance for Heavy Tactical Trucks
8-Jun-04 – 7-Jun-05
13 months

13275 Hydraulic System Diagnostics for the HEMTT A2+Technology Demonstration Vehicle
12-Jul-2005 – 31 Dec-2005
6 months

13792 Hydraulic System Diagnostics for the HEMTT A2+ Technology Demonstration Vehicle FY06
9-Feb-2006 – 8 Aug-2006
7 Month

14982 Production Testing Techniques for Performance Assessment of the Primary Power System for TWV’s
12 months

16136 Advanced Technology Evaluation and Integration for Heavy Tactical Vehicles
24-Sep-2008 – 23 Mar-2010
18 months

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Supporting Vehicle Test Beds

Hydraulic Powered Alternator Assembly

Battery & Ultracapacitor Environmental Test Bench

Advanced Technology Demonstrator (GFE HEMTT)

Ground Vehicle Alternator Test Bed

Collision Avoidance Test System

Automated Reporting Information System and Model

Hardware-in-the-Loop Test Bench (engine, starter, alternator)

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Our Role, Process and Value to PM Tactical Vehicles

- Engineering of Embedded Diagnostics and Prognostics
- Architecture Design for Logistics/Command-Control Systems
- Full Time Dedicated Science & Engineering Staff
- US Citizens, Cleared for DoD
- Established Tech Transfer Processes

**NEED**

- Concepts
- Technologies
- Processes
- Products
- Solutions

**Trials & Evaluation**

**Draft Performance Spec and Technical Description**

**Acquisition**

**Standards**

**DOTMLPF**

- Doctrine
- Organization
- Training Materiel
- Leadership Education
- Personnel Facilities

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