US ARMY COMBINED ARMS SUPPORT COMMAND
Materiel Systems Directorate

Onboard Vehicle Power:

Talking Points on Emerging Requirements

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Overview

- Background.
- Onboard Vehicle Power (OBVP).
- Military Hybrid-Electric Vehicles.
- Summary.

Background

- OBVP installed on about 100 HMMWVs in Army / USMC Units:
  - 3rd Corps Support Command and 82nd Airborne Division (~2000).
  - 22nd Marine Expeditionary Unit (2005).
- Limited Operational & Technical Evaluations:
  - OBVP Concept Experimentation Program, CASCOM & ATEC 1998.
  - Final Report, CASCOM – May 2001.
  - PM LTV limited technical & safety testing - Sep. 2003.
  - Positive industry efforts - results may not apply to military environment.
  - DoD PM MEP Export Power Specification (MEP-STD-001) – 2003.
  - TACOM issued Ground Precautionary Message to Units – Dec. 2003.
  - USMC PM EPS Market Surveys & Onboard Power IPT - 2002-2004.
  - USMC OBVP [small] program – 2004.
  - TARDEC & CERDEC [PGB] Technical Evaluations - 2004-2005.
  - CASCOM Tactical Wheeled Vehicle On-Board Power Study -2005-2006.
  - USMC OBVP [medium & large] programs – 2005 – 2007 (ongoing).

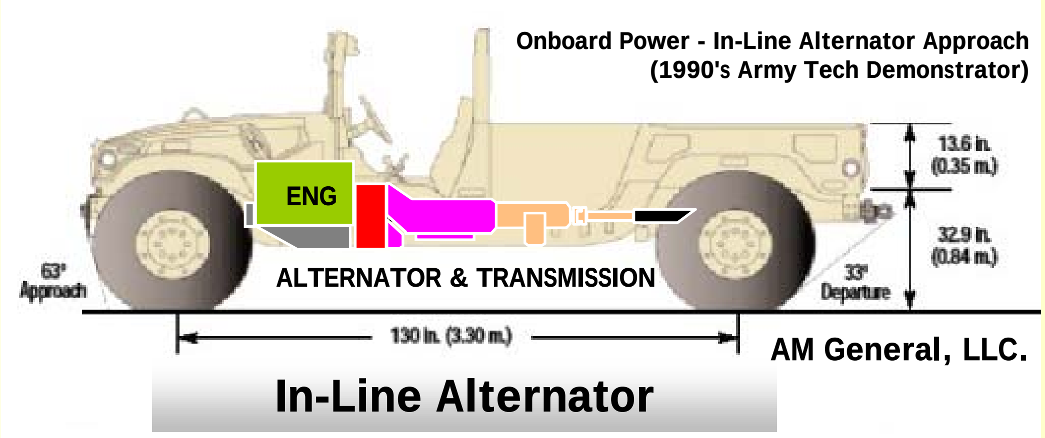
OBVP Overview

Onboard Vehicle Power

Exports AC power from an integral onboard power source to <u>external applications</u>. The underlying operational capability is "exporting tactical electric power". Output power has ranged to 20kW.

General Technical Approaches:

- Belt-driven alternator.
- Shaft-driven alternator.
- Hydraulic-driven alternator.



OBVP Overview

Technical & Operational Investigations.

USMC is investigating technical solutions and the US Army has studied the operational need. The intent is to identify technical approaches & mission applications where OBVP can provide an operational advantage.

OBVP Overview

Applications.

OBVP for tactical wheeled vehicles (TWV), developed for military environments, could power external applications throughout the Services & other Government agencies. They could export power to command & control (C2) systems much the same as conventional gensets. However, OBVP is generally limited to relatively short periods of operation compared to Tactical Quiet Generators (TQGs).

OBVP Mission Criteria

- Use when unit must minimize space needs aboard aircraft or watercraft.
- Use when powered equipment is on or near TWV.
- Use if TWV & supported systems never operate independently.
- Use when mission-critical equipment needs back-up power.
- Use as auxiliary power for onboard systems when on-the-move.
- Unit must consider temporary loss of mobility given METT-T*.

* **METT-T:** mission, enemy, terrain, troops available & time available

OBVP Design Criteria

Design must encompass user needs –

- Export Power - MEP-STD-001.
- Power quality - MIL-STD-1332B.
- Minimize fuel consumption increases.
- Minimize onboard weight and space claims.
- Endure severe operational & climatic environments.
- No adverse affect on host vehicle reliability & maintainability.
- OBVP should minimally affect cargo capacity or towing capabilities.

Sample Applications for OBVP

- **Power for maintenance & construction (power tools).**
- **Charging individual Soldier equipment batteries.**
- **Power-on-the-move for C2 - niche now filled by 5kW &10kW auxiliary power units - APUs.**
- **Powering isolated company-level Command Posts for 2 to 3 days (scenario dependent).**
- **Onboard power for weapons, IED-defeat & targeting systems.**
- **Floodlights at security check-points.**

10kW Output Range

Sample Applications for OBVP

- Power for tactical unmanned aerial systems (UAS) support equipment.
- Early entry forces, when high speed mobility is essential & cannot tow gensets.
- Back-up power for Command Posts, Tactical Operations Centers (TOCs) & other activities.
- Emergency power for equipment supported by 3kW to 10kW TQGs.
- Provide power to teams, patrols, convoys, during unexpected delays.
- Power for movement control teams-lights, communications, battery charging.

OBVP Operational Benefits & Drawbacks

Benefits

- Power flexibility for onboard & off-board applications
- Backup power for critical systems
- Provides power where it's unavailable
- Another power option for combatant commander
- Eliminates towed genset when that's a mission need
- Least complex to implement as a kit
- Good general purpose power option until gensets become available

Drawbacks

- TWV becomes a stationary genset
- Increased fuel needs (~30%)*
- Engine wet-stacking likely
- Space claims & increased weight
- Loss of cargo space on genset trailer
- Scheduled maintenance conflict – engine hours or mileage; now both
- Added engine wear & potentially reduced system reliability

One Example

* If operated according to the Tactical Electric Power Operational Mode Summary / Mission Profile (OMS/MP)

10kW OBVP HMMWV vs. TQG Fuel Costs

- **Fuel costs - 10kW TQG[1]** (300 hrs = peacetime genset fleet average).
  - 0.97 gal/hr X 300 hrs = 291 gals.
  - Fuel cost[2] = $15.30/gal X 291 gals = <u>$4452.00</u>
- **Fuel costs - HMMWV (with 10kW OBVP alternator):**
  - 1.4 gal/hr X 300 hrs = 420 gals.
  - Fuel cost[2] = $15.30/gal X 420 gals = <u>$6426.00</u>

~44% more fuel used

1. DoD PM MEP Handbook-Standard Family of MEP Generating Sources, 2002.

2. Fuel cost = $15.30 per gallon, FY07 DESC-subsidized cost of $2.30 per gallon for JP-8 and $13.00 per gallon for handling. Fuel handling data extracted from "More Capable Warfighting through Reduced Fuel Burden", DoD Science Board Study, January 2001.

OBVP Study Conclusions

- 10kW OBVP recommended for ~7% of light/medium TWV fleet based on mission needs.

- 10kW OBVP system would meet most unit needs (many applications under 10kW).

- Key operational benefit is back-up power for mission-critical systems.

- OBVP will not reduce trailer needs; they have additional uses (cargo).

- OBVP can supplement, but would not eliminate conventional generator sets.

- OBVP can provide power where it’s unavailable now.

OBVP Study Conclusions

- 10kW OBVP increased operating costs (fuel) are significant if employment matches TEP OMS/MP.

- OBVP can augment vehicle power for platforms with more weapons & other onboard systems.

- Most likely OBVP uses include augmentation, backup & setup/teardown at operational sites.

- Mitigating the truck vs. genset functional conflicts within units can be significant.

Potential Power Generation Capability for selected TWVs in Army Fleet

Tactical Hybrid Electric Vehicles

(HEV)

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Many thanks to Mr. Bob Crow, Mr. Rob Roche (AMSAA) & Dr. Jim Cross, RDECOM.

Tactical H E Vs

Why haven't we fielded them yet?

Component-level progress:

- **Power Electronics.**
- **Batteries.**
- **Motors.**

System Progress?

~$100M invested in HEV programs since 1995.

Many HEV components developed: motors, alternators, controls, improved semiconductors, cooling systems, etc.

Many of the basic components are almost ready to go.

But…

Two primary issues are preventing successful design and demonstration of military HEVs:

- Development of military vehicle driving cycles.
- Suitable energy storage media for a military environment.

Examples of Drive Cycle Data

- **Drive cycle data collection acquires detailed time-sampled information on how Army TWVs are actually used.**
- **Designers use this data for systems analysis & design, e.g., design of military HEV propulsion batteries**
- **Before HEVs (no energy storage), driving cycles were not as important as they are now.**

HEV propulsion battery design & life depends greatly on how the vehicle is used.

Inputs

Examples of Drive Cycle Data

Inputs

Mission Inputs:

- Vehicle speed & acceleration.
- Throttle position.
- Brake pedal apply force.
- Steering control position.
- Mission equipment electrical loads (radios, turret, etc.)

Environmental Inputs:

- Terrain Types.
- Primary & secondary roads.
- Cross-country (soil composition).
- Terrain slope.
- Terrain roughness.
- Ambient temperature.
- Crew-compartment temperature.

Drive Cycle Data

- The Army needs to develop driving cycles that are scientifically based on vehicle usage in a tactical environment (real data from field operations).

- Accurate & well-defined driving cycles are essential to military HEV propulsion battery design.

- Without driving cycle data, poor battery design results in a vehicle that fails to achieve expected HEV benefits.

Drive Cycle Data

Driving cycle development begins with –

- **Instrumenting vehicle fleet & collect usage data.**
- **Statistical analysis then defines vehicle performance & becomes input for simulations.**
- **Designers use these simulations to model electrical loads during HEV system development.**

Result =

Efficient HEV Design That Meets User Needs.

Energy Storage

Efforts are on-going to develop large format, energy dense batteries for HEV propulsion.

Technical issues still remain:

- **Energy density, charge & discharge cycles.**
- **Cell-balancing, power vs. energy density trade-offs.**
- **Operating at temperature extremes and safety.**

Example: Each cell must have almost identical characteristics; having essentially the same internal resistance is critical.

Energy Storage

Other Technical issues...

- Weak cells can become an electrical load and/or reduce energy content & degrade output.

- Safety – lower resistance or shorted cells can become hotter & can ignite; many existing electrolytes are flammable & lithium electrodes can be very reactive.

- Better quality control, electronic cell-balancing, cell conditioning techniques & modular battery assemblies will help resolve these issues (more work is needed).

- Existing battery candidates are not suitable for military systems that experience severe climatic extremes.

- High temps accelerate self-discharge rates & complicate thermal management. Low temps reduce battery output.

Energy Storage

- **Charge management, thermal, weight & space claim issues much greater vs. commercial HEVs.**
- **Military systems are much heavier**
- **Shock & vibration more extreme.**
- **Military temperatures are more extreme.**

Energy Storage Issues

- Must have consistent battery chemical 'mix' (batch-to-batch & year-to-year).

- Must have consistent plate material, spacing & thickness.

- Same internal resistance for all cells (most desirable).

- Need rigorous process control & Acceptance Testing.

HEV Summary

- Technical issues - significant R&D needed for military HEV propulsion batteries.
- Scientifically based MILITARY driving cycles are needed…. Data from a tactical environment.
- Propulsion battery design relies on having accurate & detailed driving cycles.
- Without operationally derived driving cycles, vendor fuel economy claims cannot be verified.
- If the battery is undersized for the load, reliability & life suffers.
- Battery life & reliability are dramatically affected by how it is used & misused.

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References

MEP-STD-001, General Specification, Export Power-Vehicle Mounted (to 30kW), DoD Project Manager - Mobile Electric Power, 5 May 2004.

Onboard Power White Paper, Timothy Raney, MTC Technologies, Inc., for DoD Project Manager - Mobile Electric Power, 8 September 2005.

Tactical Electric Power Operational Requirements Document, CARDS# 16125, 11 August 2004.

MIL-STD-1332B, Definitions of Tactical, Prime, Precise and Utility Terminology for Classification of the DoD Mobile Electric Generators, 13 March 1973 (reactivated 10 July 2001).

DoD Directive# 4120-11, Standardization of Mobile Electric Power Generating Sources, 9 July 1993.

MIL-STD-1275B, Characteristics of 28V DC Electrical Systems in Military Vehicles, US Army Tank-Automotive & Armaments Command, 20 November 1997.

MIL-STD 461-E, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems & Equipment, 20 August 1999.

MIL-STD-705C, Generator Sets, Engine-Driven, Methods of Tests & Instructions, 24 April 1989.

MIL-STD-1474D, Noise Limits for Army Material, 12 February 1997.

Army Regulation 700-101, Joint Operating Procedures Management and Standardization of Mobile Electric Power Generating Sources, 29 November 1999.

DoD Military Handbook-633F (Draft), Standard Family of Mobile Electric Power Generating Sources: General Description Information & Characteristics Data Sheets, May 2001.

Questions?

Thank You for Your Attention!