Amphibious High Water Speed Focus Area Forum

Powertrain/Power Generation/Fuel Efficiency

Technology Area

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Topics

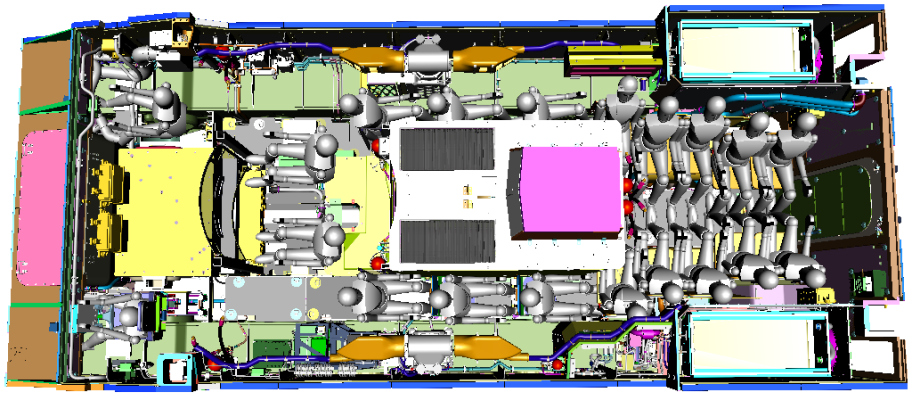
- Operational Environment
- Lessons Learned
- Current State-of-the-Art
- Technology Challenges

Operational Environment

- Climate & Terrain
  - Extreme temperature variations (Hot 120F to Severe Cold -60F) MIL-STD-810G
  - Water and Land mobility
    - High speed water operation
    - Seamless transition between water and land configurations
    - Robust land mobility 70% off road / 30% on road
  - Coastal to Desert, Rainforests to Mountainous
  - High humidity
  - Corrosive Sea water/Sea spray
  - Sand and dust
  - Fine and coarse grain sand mobility
  - Ability to operate in difficult and challenging coastal and inland terrains.

EFV Lessons Learned

- High speed water operation drives the engine sizing.
  - 2700HP for water, less than 900HP for land, Engine drove interior arrangements. Operate 90% land mode, 10% water mode.
- Land operation (where most of the fuel is consumed) fuel efficiency is traded off when operating with a single engine sized for the demands of water mode.
- Thrust for high speed water operation approaches thrust required to fly a plane (i.e. DC9).
- Power Transfer Unit to split power from a single engine for water/land/transition operations adds unique complexity, that consumes additional weight & space.
- Large variations in Fuel (JP8) quality requires unique design consideration to adapt commercial engines.



http://www.marines.mil/Photos.aspx

EFV Lessons Learned

- There may be additional design considerations required for water mode operation (i.e. oil sump). Ship motions are different then land operations.
- The combination of sea water + high heat from engine exhaust yields an extremely corrosive environment
  - Exhaust system had a short life
  - Heat Exchanger contamination and fouling from saline environment
- Challenge of Dual Mode cooling – cooling for land operation is a limiting design factor, because it is much more challenging to reject waste heat to air then to the sea for water operation, even though there is much less engine power required on land.
- Gross vehicle weight drives the powertrain sizing (both water and land operations).
- Cost matters. Solutions that are unaffordable sink programs.
- Using titanium Hydraulic Suspension Units for track retraction, which required high pressure hydraulics, was one of the most expensive systems on EFV.

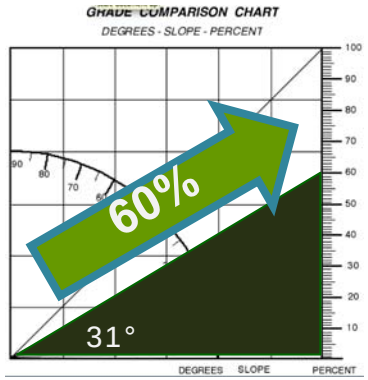
Land Mobility Design Challenges

Gradability and top speed drive land operation engine sizing.

60% Grade

- Naturally occurring, negotiable grades seldom exceed 60% on various terrains & soil conditions. But we must design for this condition.
- Testing on a 60% grade allows for **evaluating lube, fuel, and brake systems** to measure vehicle performance.
- The evaluation of the gradeability performance test of a vehicle provides an assessment of its **tractive effort capability**.

http://www.marines.com



Land Mobility Design Challenges

Tractive Effort

- The Force (push or pull) that the powertrain can generate to move a vehicle.
- Tractive Effort / Weight is the ratio of forces, Force Available / Vehicle Weight
- 1.0 TE/Wt is the maximum design point for combat vehicle operation at finite life
- 60% Grade is equivalent to 0.55 TE/Wt
- 0.7 TE/Wt is the Design Cooling Point at 125F for the continuous operation of vehicles to achieve all the mobility requirements which includes 60% grade. **This can also be encountered during amphibious operations (sand/mud).**

http://www.marines.com/operating-forces/equipment/vehicles/aav-7

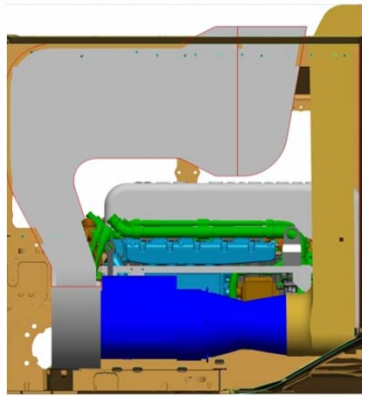
Alternate Powertrain Studies Packaging Risks Matrix

High
Med
Low

Integration Item	Baseline	COA 1 Dual Turbines	COA 2 Single Turbine	COA 3 Single Diesel (land) / Single Turbine (water)	COA 4a Electric Drive w/ Dual Diesel Engines in sponsons	COA 4b Electric Drive w/ Dual Turbine Engines	COA 4c Electric Single Diesel / Single Turbine	COA 5 Dual Diesels in sponsons
Power Plant (engine, induction / filtration, Hybrid Generators)		Significant interference with air/water separator and multiple vehicle subsystems	Air/water separators fit within baseline engine compartment	Air/water separators fit within baseline engine compartment	Repackaged engines in sponsons and repositioned seats	Significant interference with air/water separator and multiple vehicle subsystems	Minor interference with diesel genset and rear bulkhead	Repackaged engines in sponsons and repositioned seats
Drivetrain (Automotive / Land)		Minor interference with rear bulkhead due to overall length with combining gearbox	Same as baseline. Reduction gearbox required	Modified PTM with dual input	Replaced transmission with scaled traction drive, removed PTM, and added torque transfer gearbox	Significant interference with rear bulkhead due to overall length with generator and combining gearbox.	Replaced transmission with scaled traction drive, removed PTM, and added torque transfer gearbox	Modified PTM with dual input and added torque transfer gearbox
Drivetrain (Marine/Water))		Same as baseline	Same as baseline	Same as baseline	Same as baseline	Same as baseline	Same as baseline	Same as baseline
Exhaust System		Routing issues due to forward exhaust location	Custom exhaust system required	Custom exhaust system required	Custom exhaust system required	Routing issues due to forward exhaust location	Custom exhaust system required	Custom exhaust system required
Cooling System		Smaller than baseline	Smaller than baseline	Same as baseline	Same as baseline	Same as baseline	Same as baseline	Same as baseline
Fuel System		Added 215 gal (max) in right rear sponson	Added 215 gal (max) in right rear sponson	Same as baseline	Same as baseline	Same as baseline	Same as baseline	Same as baseline
Chassis Electrical		Similar to baseline LV system	Similar to baseline LV system	Similar to baseline LV system	HV installation	HV installation	HV installation	Similar to baseline LV system
Hull Appendages		Significant interference with air/water separator and top deck/intake cap	Custom intake cap required	Custom intake cap required	Custom intake cap required	Significant interference with air/water separator and top deck/intake cap	Custom intake cap required	Custom intake cap(s) required

Current State of the Art

- High Density Powerpack Development
  - Opposed Piston Design
  - Binary Logic Transmission
  - Military Controller and Software
  - Focus on reducing support systems
- Improved Turbine Engine Program (ITEP)
  - In development for Helicopter application
  - More power, same footprint, significant weight savings
  - Consumes more fuel, salt water ingestion concerns.
- Active suspensions & Semiactive suspensions.
  - Could be Modified to become retractable
- Li-Ion batteries technology
  - Lighter, but more expensive
- Rare Earth magnet based motor/generators for high power density.



Technology Challenges

- Unconventional alternative mobility options for high speed water operation need consideration.
  - Engines that could fit in sponsons (more room for marines).
  - External detachable propulsion pods
  - Beaming power from the ship to reduce the installed engine size required.
- Reduced fuel consumption technologies
- Modifying an air platform turbine engine (ITEP) for Marine use.
- Flexible Power Generation
  - From Silent watch to Quick Movement – eliminate need to idle
  - Increasing auxiliary power demands require more electric power
- Lightweight, affordable, high power density components for powertrain and support systems (engine, batteries, transmission, APU, etc.)
- Water to land transfer typically involves steep grades on soft/wet ground causing significant trafficability issues.
- Track/Suspension challenges (retracting tracks, active & Semi-active suspensions)
- Air filtration for water mode takes up a significant space claim. Creates a packaging challenge.