Virtual Combat Vehicle Experimentation for Duty Cycle Measurement (2008-01-0776)

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**Report Documentation Page**

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Standard Form 298 (Rev. 8-98) Prescribed by ANSI Std Z39-18
Outline

■ Motivation and Purpose
■ Experiment Design
■ Simulation Architecture and Design
■ Results and and Conclusion
P&E SIL

- Series Hybrid-electric power system
- Laboratory based evaluation of design alternatives
- Driven by automated controller
- Requires a-priori duty cycle
TARDEC Simulation Lab (TSL)

- Man-rated motion base simulation lab
- Integrated immersive simulation environment
- Real-time vehicle models
- Integrated CAT Crewstation
- Integrated simulated forces simulation
Duty Cycle Experiments (DCE)

- Work is done for TARDEC Ground Vehicle Power & Mobility (GVPM) R&D Group
- Began in 2005
- Measure the “duty cycle” of a military vehicle in a relevant scenario.
- Use a high-resolution simulation environment to stimulate realistic behaviors.
- Measure mobility and non-mobility loads.
- Data are used by GVPM to develop power systems.
Duty Cycle: Definition

A military vehicle's *duty cycle* is specific to the mission and platform type but is a design- and configuration-independent representation of events and circumstances which affect power consumption.

Such events and circumstances encompass (1) vehicle operation along the course such as speed, grade, turning, turret/gun activity, and gun firing plus (2) external scenario components that affect power consumption like incoming rounds, ambient temperature, and soil conditions.

The event inputs can be distance based when the vehicle is moving or time based when the vehicle is stationary, or even triggered with some other state condition.
Experiment Purpose

- To measure the duty cycle of a Future Combat Systems (FCS) Mounted Combat System (MCS) in a relevant scenario.
- Build a high fidelity representation of the vehicle and power system.
- Bring in professional operators to run the simulation.
- Operate in real-time with the P&E SIL by integrating it over the Internet.
# Past Work

## DCE1

![DCE1 Image]

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<th>Role</th>
<th>DCE1</th>
<th>DCE2</th>
<th>DCE3</th>
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<td>Wingman</td>
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## DCE2

![DCE2 Image]

## DCE3

![DCE3 Image]
Experimental Design: Vehicle

FCS-MCS
- 27 Ton chassis
- Series hybrid-electric drive
- Includes defensive and offensive weapon systems.
Experimental Design: Terrain

- Used a Continental US location for the experiment.
- One-way route is approximately 19 mi (31 km) long.
- 394 ft (120 m) elevation range
- -20% to +39% grade range.
- 3.9% mean absolute grade.
Experimental Design: Scenario 1

UAMBL: 3 phases
1. Advance to objective
2. Support by fire
3. Exfiltrate
Experimental Design: Scenario 2

CASTFOREM (Single phase).

- Advance to objective.
- Conduct Line-of-sight (LOS) and Non-line-of-sight (NLOS) engagements.
- Await further orders.
Experimental Design: Crew Stations

- Motion Base
- Primary Gunner/Driver
- Secondary Gunner
- Secondary Driver
Experimental Design: Run Matrix

- 4 soldiers per week.
- Each soldier runs as
  - Primary team
  - Secondary team
  - Driver
  - Gunner
- Practice & training are on Mon. and Wed.
- Record runs on Tues. and Thurs.
- A & B variants of the scenario.
Architecture and Design

- 29 Computers
- Motion: TMBS
- Visuals:
  - IG by Night Vision Labs
  - GeForce 7800 GT
- Dynamics:
  - SimCreator® Multi-body Dynamics
  - Custom track model
  - Simulink® power train
- Infrastructure:
  - SimCreator
  - 100Base/T Ethernet and SCRAMNet
- Driver Interface:
  - 2 CAT crewstations
  - Secondary crewstations
Architecture and Design: CS/TMBS

- Crew Station / Turret Motion Base Simulator (CS/TMBS)
- 6 DOF
- 50,000 lb (22,680 kg)
- Multi-occupant
- Hydraulically powered.
- 10 Hz bandwidth
Architecture and Design: CAT Crewstation

- Crew-integration and Automation Testbed (CAT) Crewstation
- Three 17”x13” touch screens
- Six virtual screens
- Yoke, pedals
- Hard/soft buttons
- Multi-role support
Architecture and Design: Infrastructure

- Multi-infrastructure:
  - Commercial Integration Software (shown)
  - Distributed Interactive Simulation (DIS)
  - Operating Environment (OE)
  - Long Haul (custom)

- Network
  - Three subnets
  - UDP/IP
  - Fiber optic deterministic network.
Architecture and Design: Vehicle Dynamics

- 15-body model using a commercial real-time modeling tool.
- Trailing-arm suspension, turret, gun
- Skid steer with track model
Architecture and Design: Power System

- Series Hybrid-electric
- Implemented in commercial modeling tool
- Generate C-Code using commercial code generator
- Integrate into integration framework as a component
Long Haul Connection

- Operate the TMBS with the SIL in real-time.
- 2,450 mile separation
- 94 ms round trip time
- Internet as communication channel
Long Haul Connection: Design

Driver/Gunner (TSL)

Throttle, Steer, Brake

Motion

FCS Vehicle Control

Power Distribution Control

Thermal & Auxiliary Control

Traction Motor & Control #1

Traction Motor & Control #2

Power Train Observer

Sprocket Speeds

Sprocket Torques

Vehicle Dynamics and Terrain

State

Internet

Throttle, Steer, Brake

Power Train (SIL)

Sprocket Speeds

Sprocket Torques

Vehicle Dynamics and Terrain Observer

State
Results

- 12 soldiers participated.
- 3 weeks
- Recorded:
  - Vehicle position, velocity
  - Power System states
  - Operator commands
  - Force activities
Results: Path
Results: Elevation & Grade

Approximate Elevation and Grade Performance (measured from vehicle global position)

- Elevation (m, + = up)
- Grade (% , + = incline)
- Distance (km)
Results: Driver Commands

Longitudinal Performance
- Acceleration command (0-90)
- Brake command (N)
- Speed (kph)
- Distance (km)

Lateral Performance
- Steer command (-1 - +1)
- Yaw rate (deg/sec, + = CW)
- Distance (km)
Results: Turret/Gun & Battery

Turret/Gun Activity

Turret angle (deg, + = CW)

Gun angle (deg, + = up)

distance (km)

Battery Performance

SOC (0-1, + = full)

Voltage (Volts)

Current (Amps, + = in)

Power (kW, + = in)

distance (km)
Conclusion

- An experiment was designed to measure duty cycle of a future combat systems (FCS) mounted combat system (MCS) in a relevant operational environment.

- It involved the integration of:
  - Real-time vehicle dynamics
  - A power system model
  - The Power & Energy SIL

- It successfully measured a set of 12 duty cycles for two different scenarios.