

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

Mark Brudnak, Mike Pozolo, AnnMarie Meldrum
U.S. Army RDECOM-TARDEC

Todd Mortsfield, Andrey Shvartsman
DCS Corporation

Wilford Smith, Jarrett Goodell
SAIC, Inc.

Dale Holtz
Realtime Technologies, Inc.



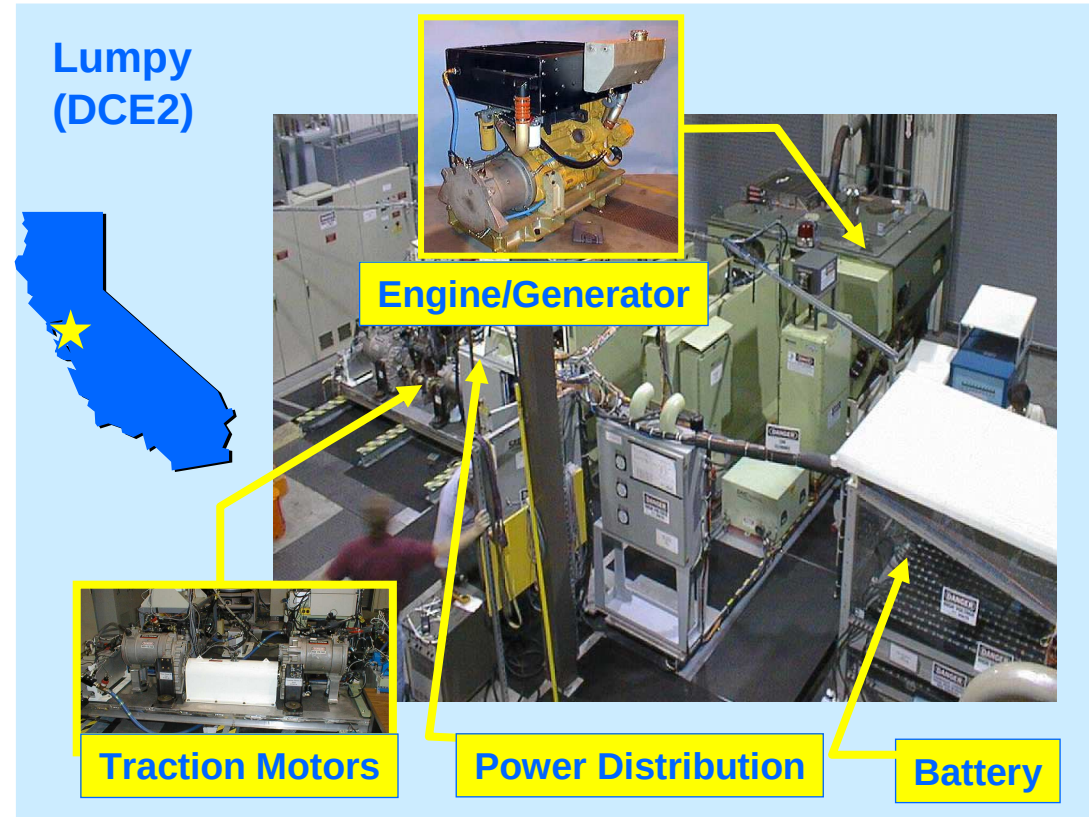
Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 16 APR 2008		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Virtual Combat Vehicle Experimentation for Duty Cycle Measurement			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Mark Brudnak; Mike Pozolo; AnnMarie Meldrum; Todd Mortsfield; Andrey Shvartsman; Wilford Smith; Jarrett Goodell; Dale Holtz			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000			8. PERFORMING ORGANIZATION REPORT NUMBER 18815		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S) TACOM/TARDEC		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S) 18815		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES Presented at SAE 2008 World Congress, April 14-17, 2008, Detroit, MI USA, The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 28	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Outline

- Motivation and Purpose
- Experiment Design
- Simulation Architecture and Design
- Results 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

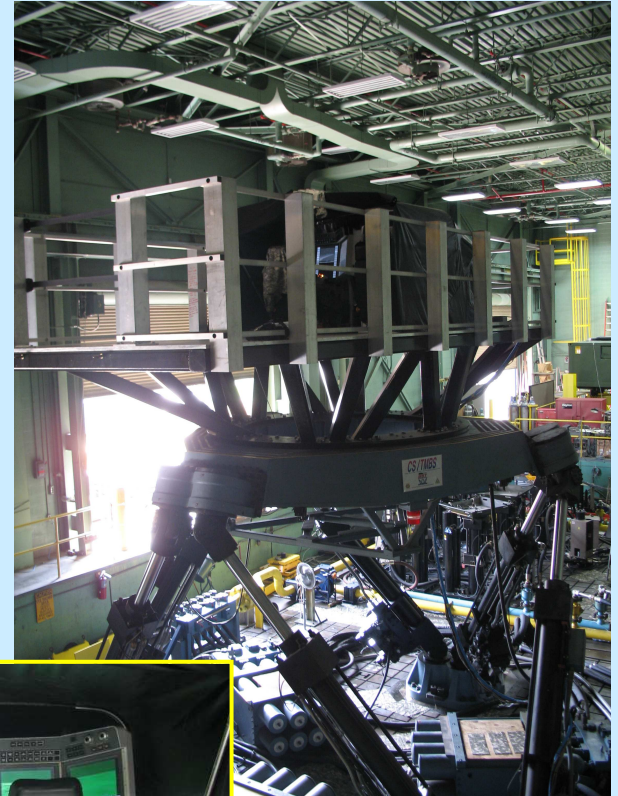


Hermit (DCE3)



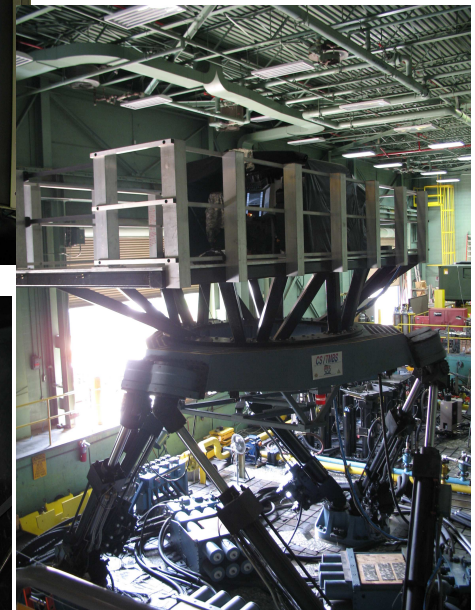
TARDEC Simulation Lab (TSL)

- 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.



5

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.

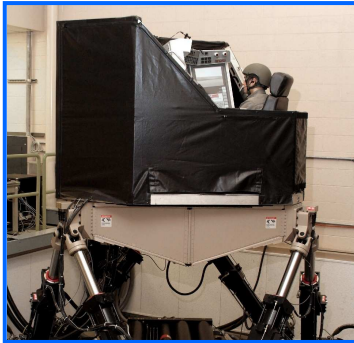
The event inputs can be distance based when the vehicle is moving or time based when the vehicle is stationary, or even triggered with some other state condition.

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



■ DCE2



	DCE1	DCE2	DCE3
Date	Nov '05	June '06	May '07
Participants	Civilian	Military	Military
Runs	7	12	12
Scenarios	1	1	2
Vehicles	1	1	2
Roles	Drive	Drive/Gun	Drive/Gun
Motion base	RMS	RMS	TMBS
Length	11 km	13 km	61/38 km
Duration	25 min	25 min	100/40 min
Long Haul		Yes	Yes
BLOS			Yes
NV/IR			Yes
Moving troops			Yes
Wingman			Yes

Experimental Design: Vehicle

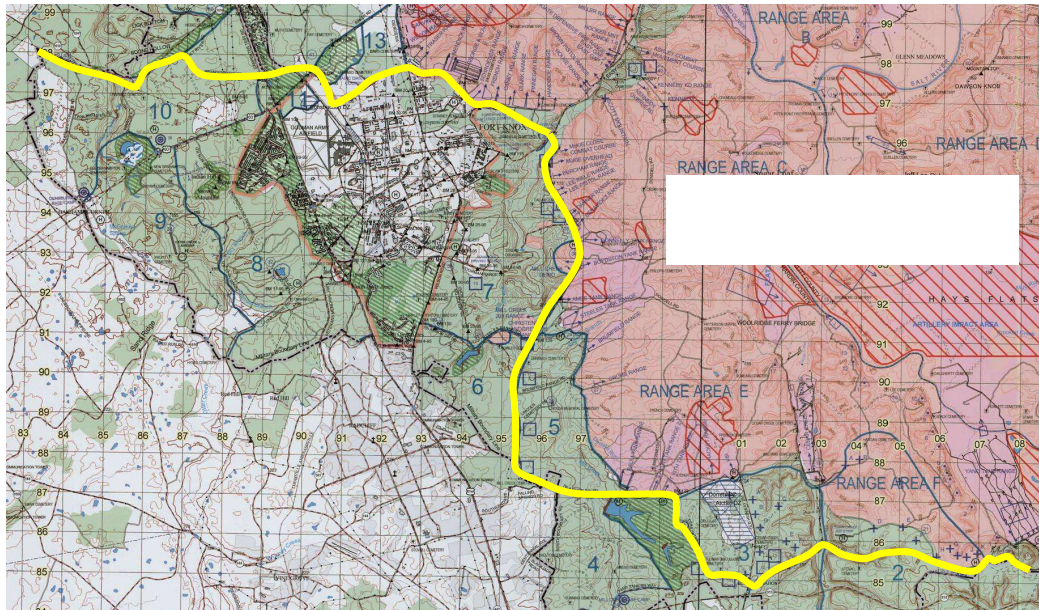
FCS-MCS

- 27 Ton chassis
- Series hybrid-electric drive
- Includes defensive and offensive weapon systems.



Experimental Design: Terrain

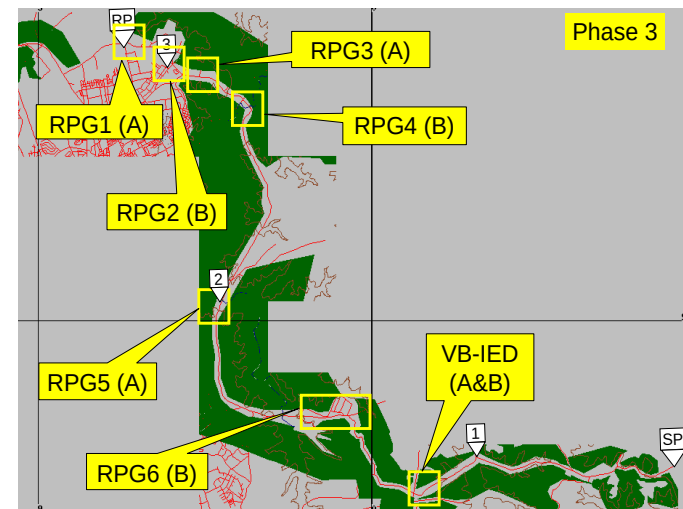
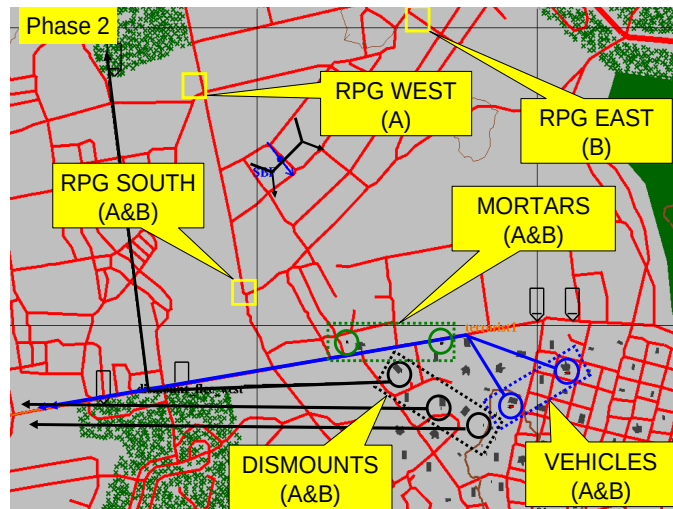
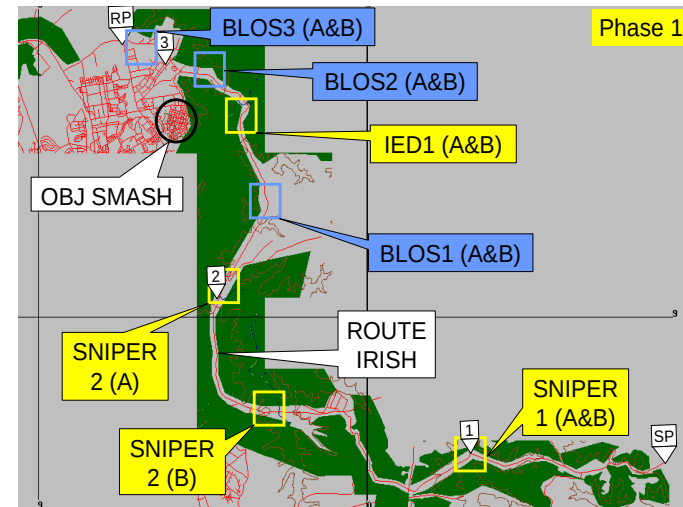
- Used a Continental US location for the experiment.
- One-way route is approximately 19 mi (31 km) long.
- 394 ft (120 m) elevation range
- -20% to +39% grade range.
- 3.9% mean absolute grade.



Experimental Design: Scenario 1

UAMBL: 3 phases

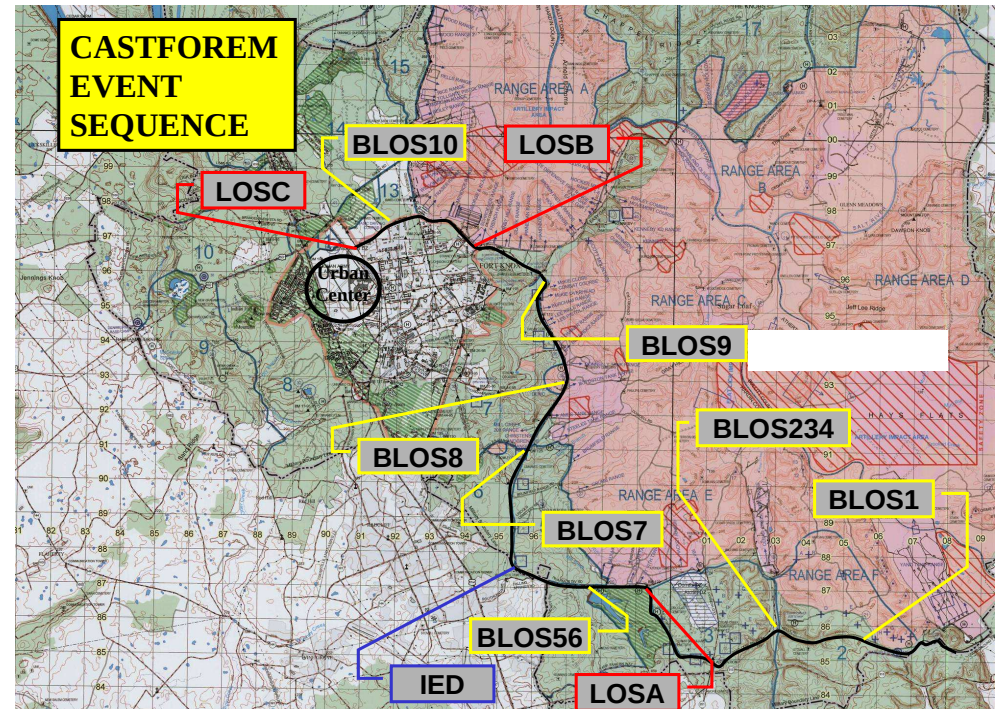
1. Advance to objective
2. Support by fire
3. Exfiltrate



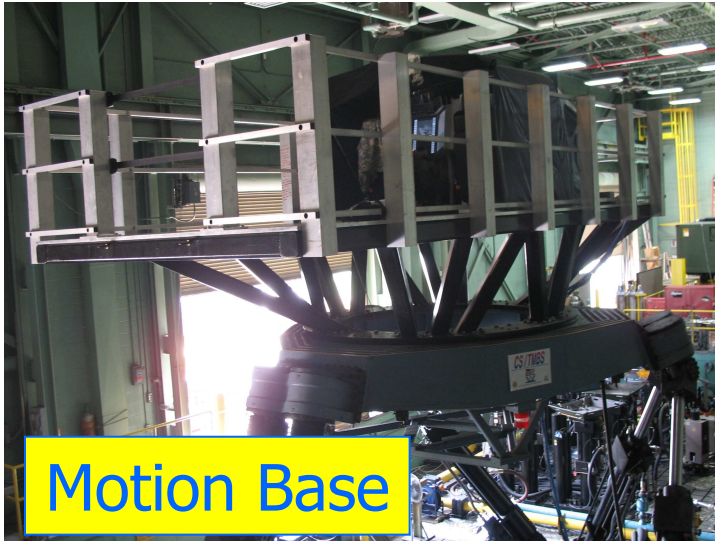
Experimental Design: Scenario 2

CASTFOREM (Single phase).

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

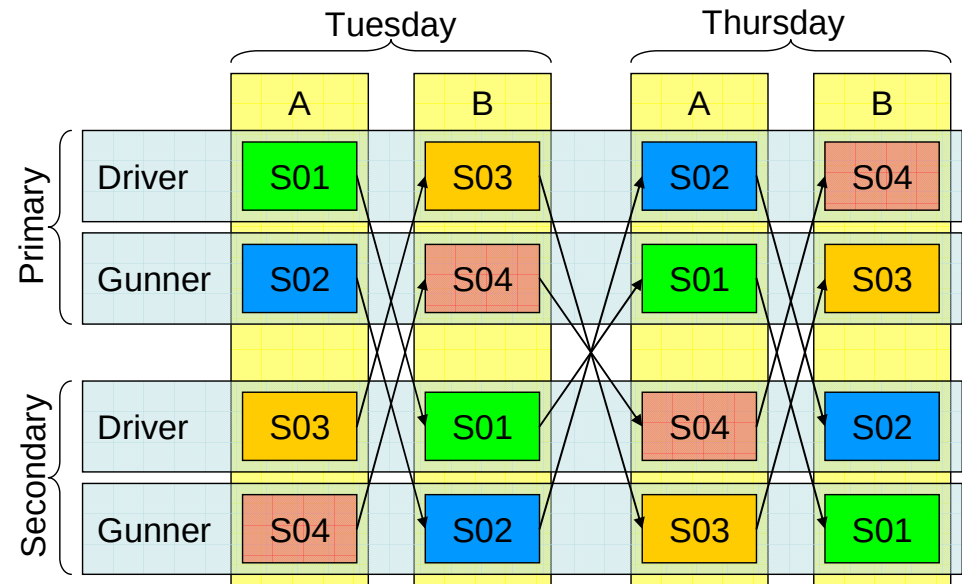


Experimental Design: Crew Stations



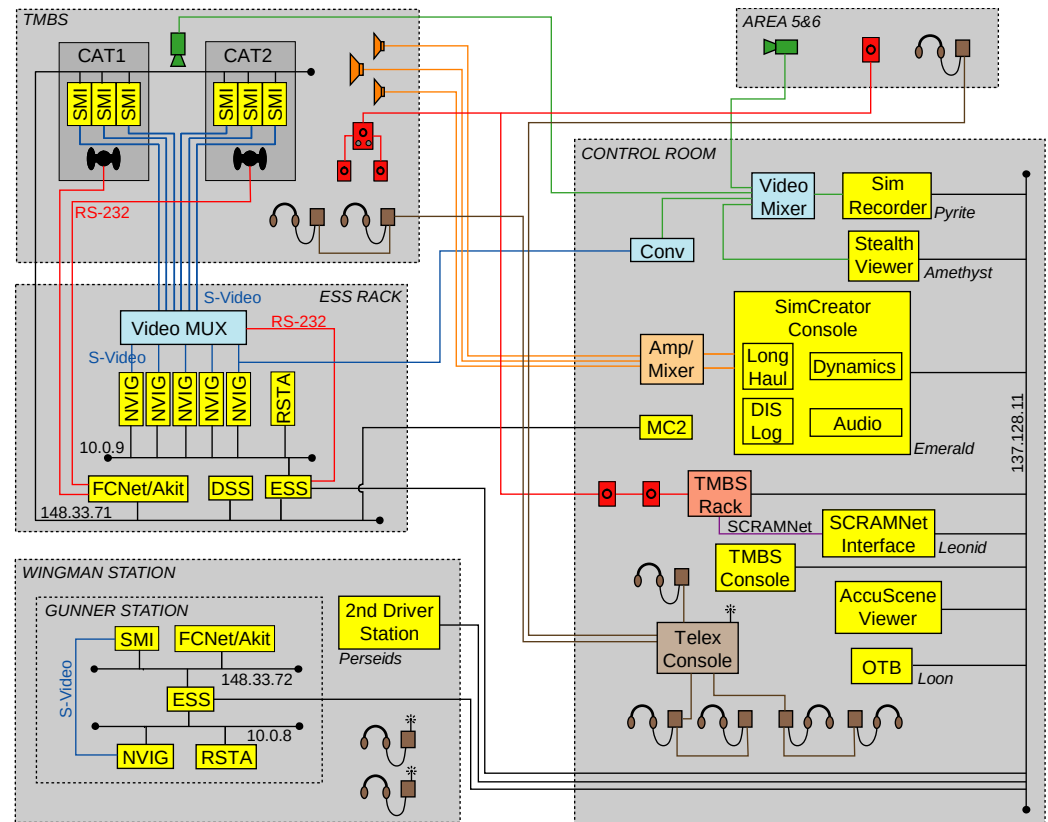
Experimental Design: Run Matrix

- 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



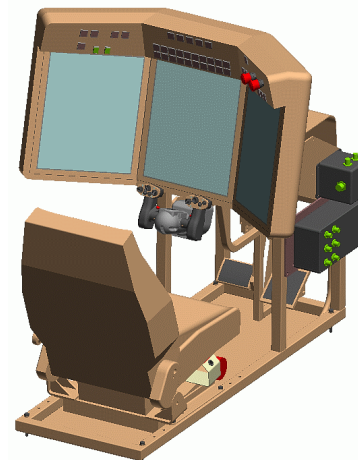
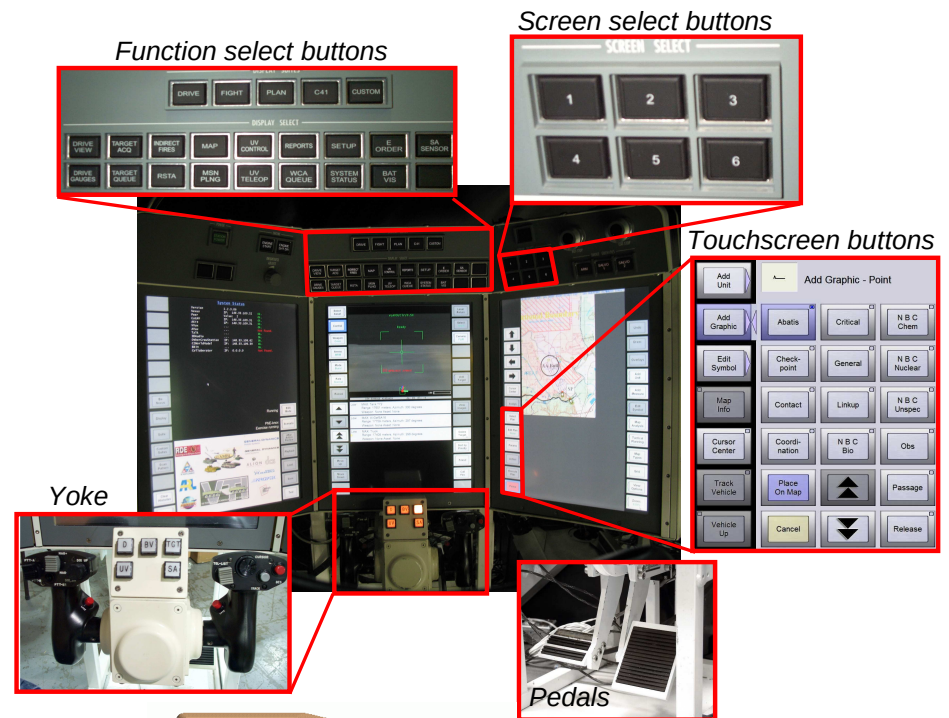
Architecture and Design: CS/TMBS

- 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



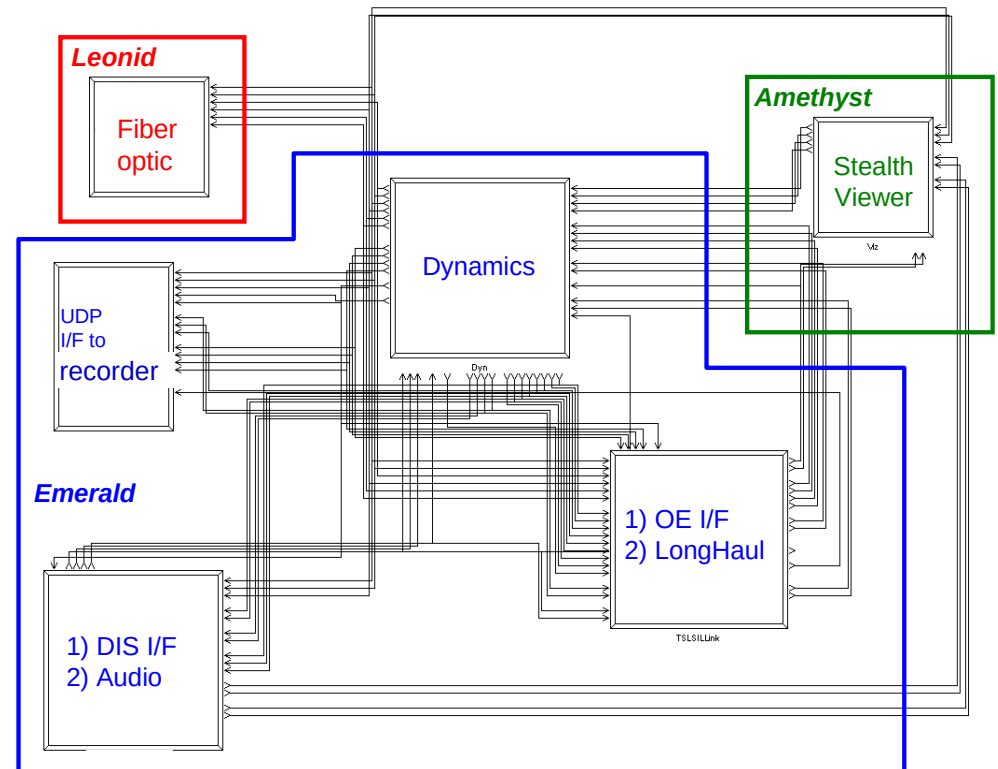
Architecture and Design: Infrastructure

■ Multi-infrastructure:

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

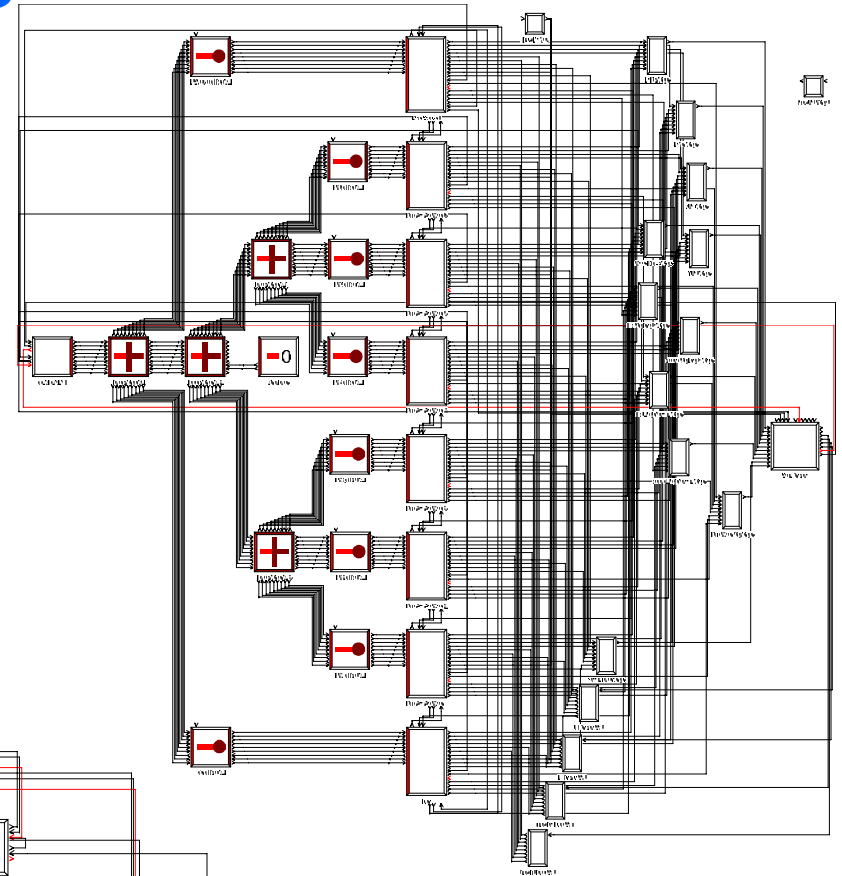
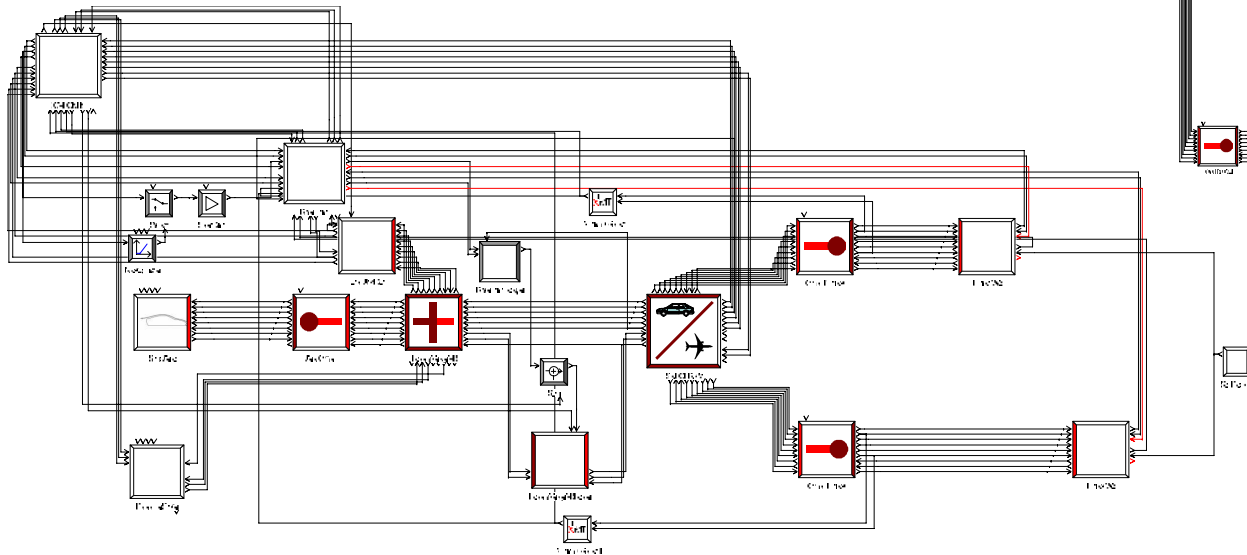
■ Network

- ≡ Three subnets
- ≡ UDP/IP
- ≡ Fiber optic deterministic network.



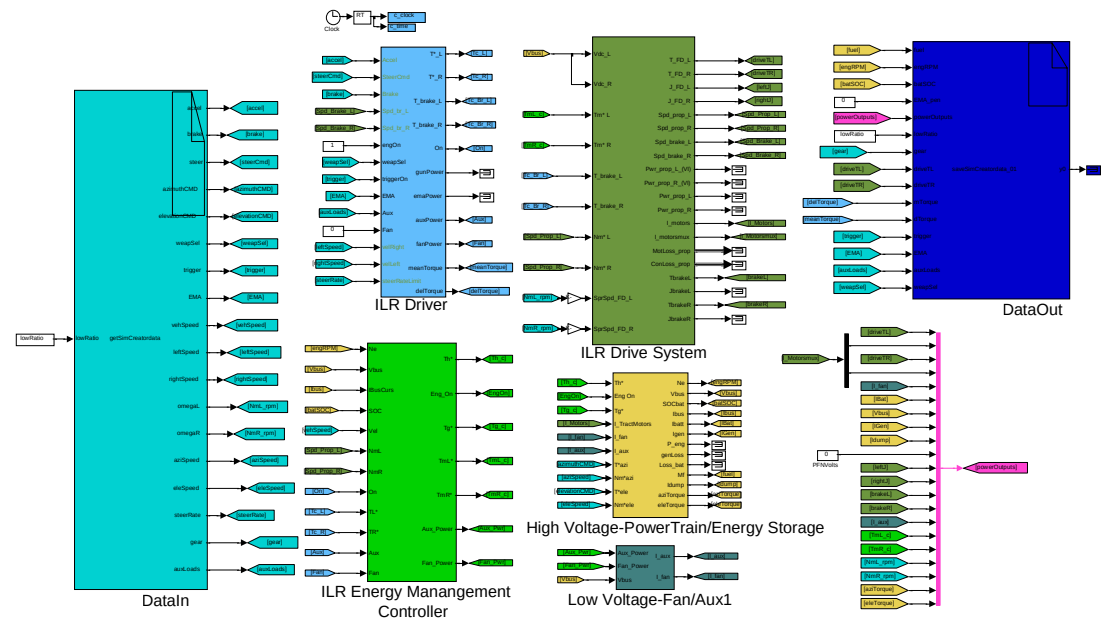
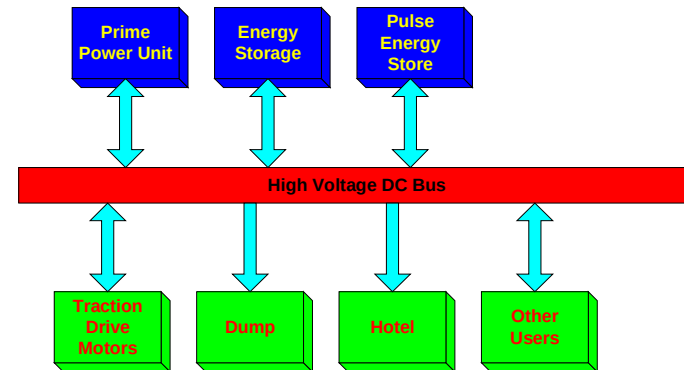
Architecture and Design: Vehicle Dynamics

- 15-body model using a commercial real-time modeling tool.
- Trailing-arm suspension, turret, gun
- Skid steer with track model



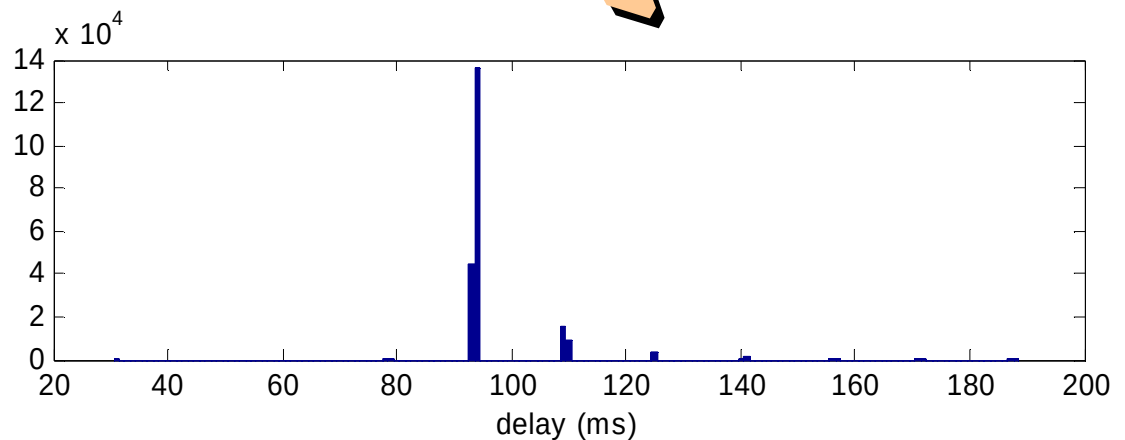
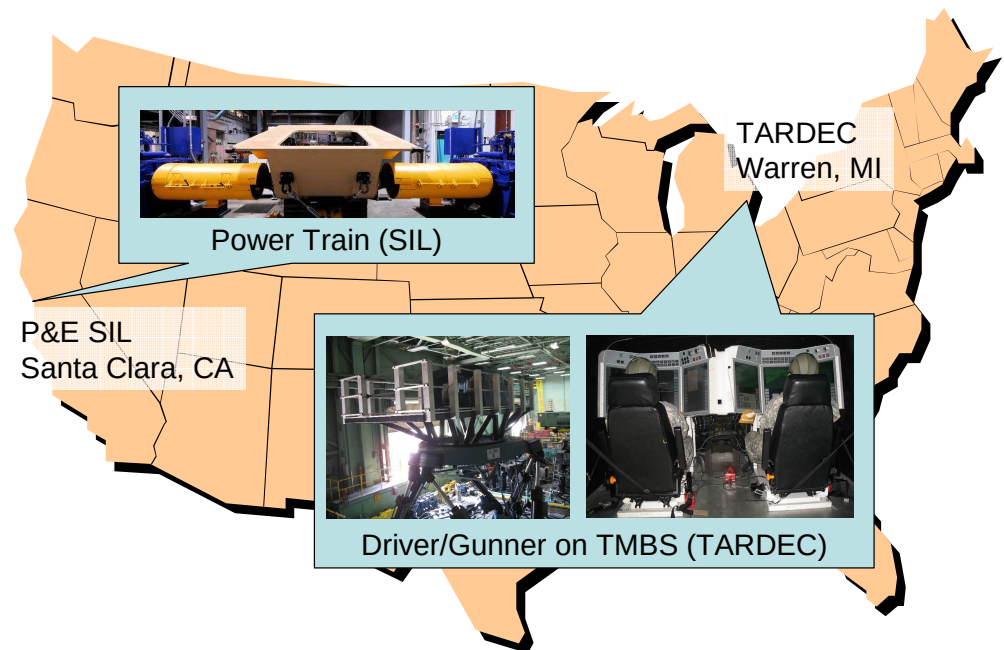
Architecture and Design: Power System

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

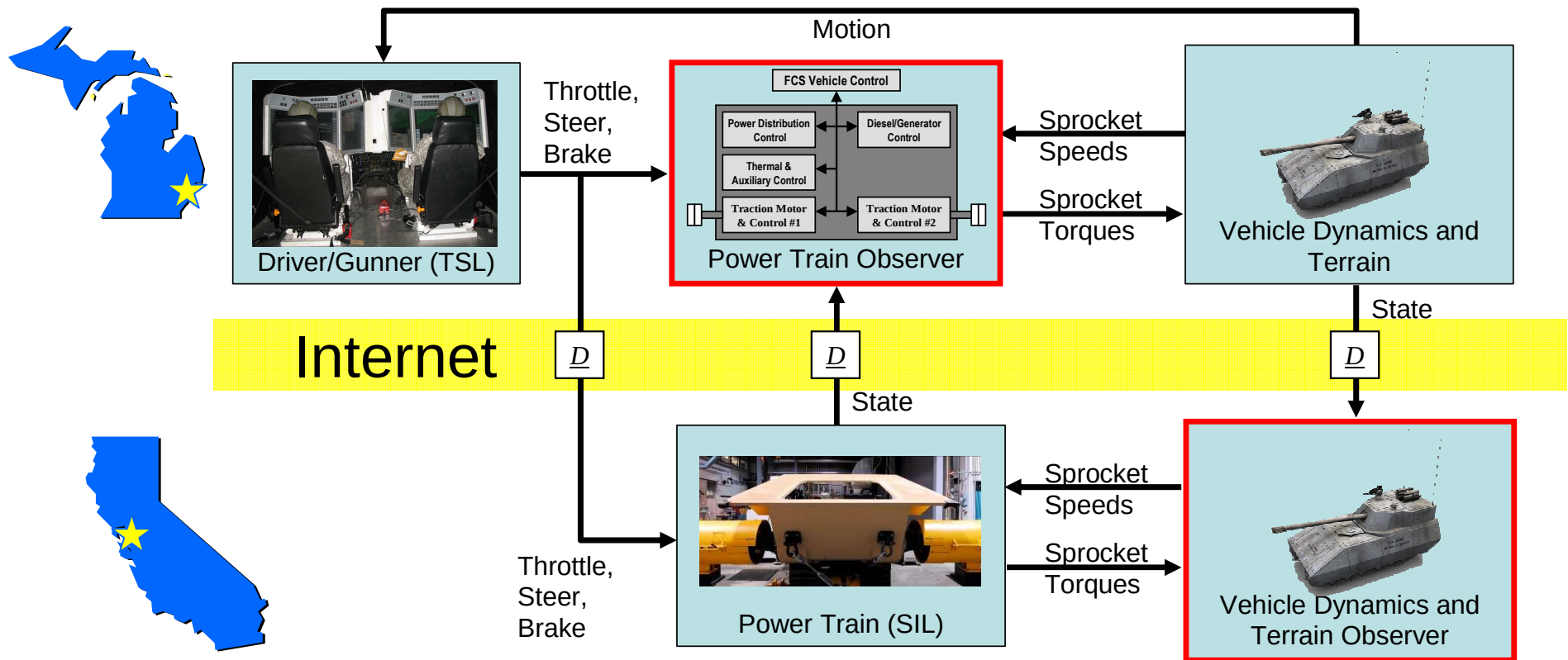


Long Haul Connection

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



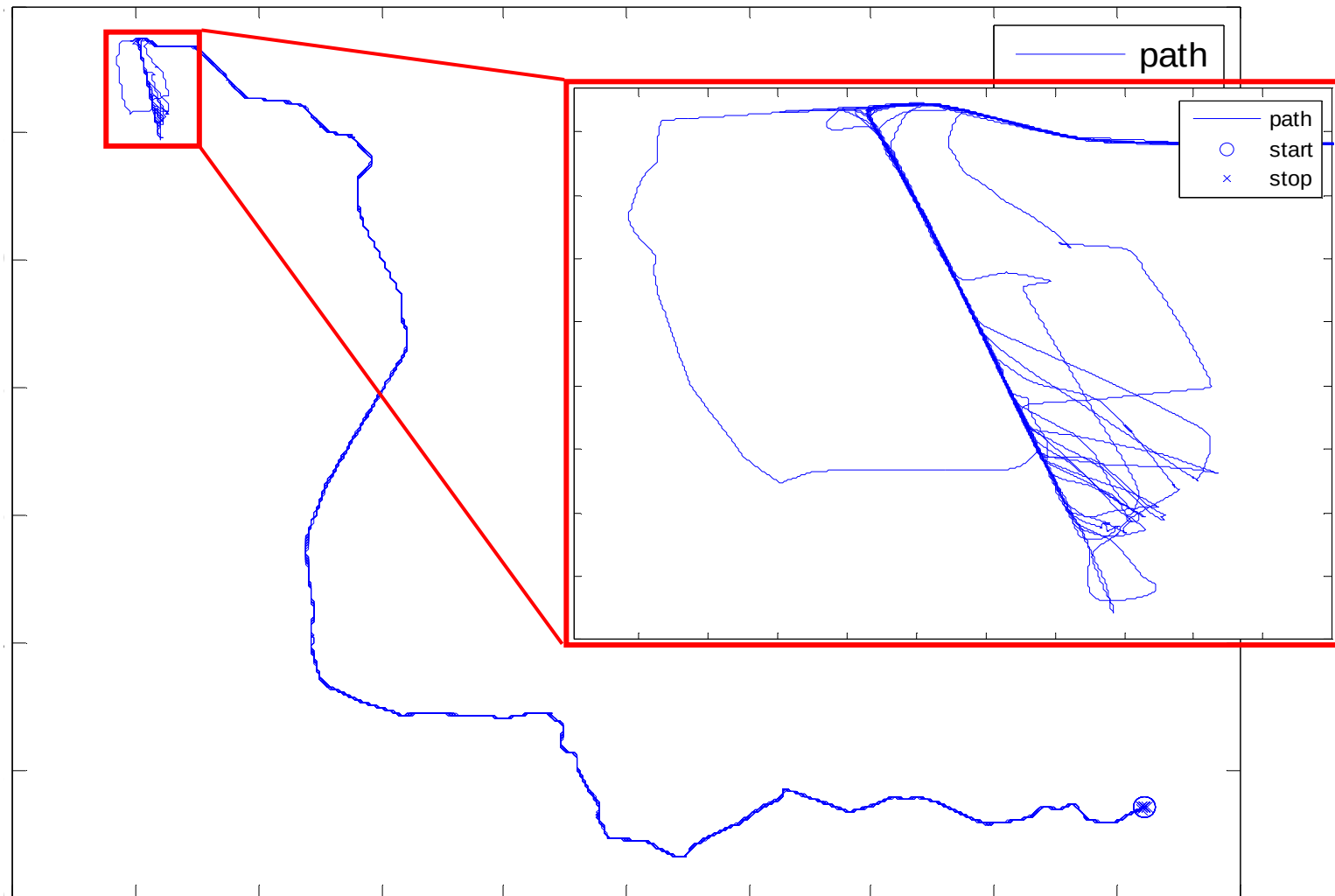
Long Haul Connection: Design



Results

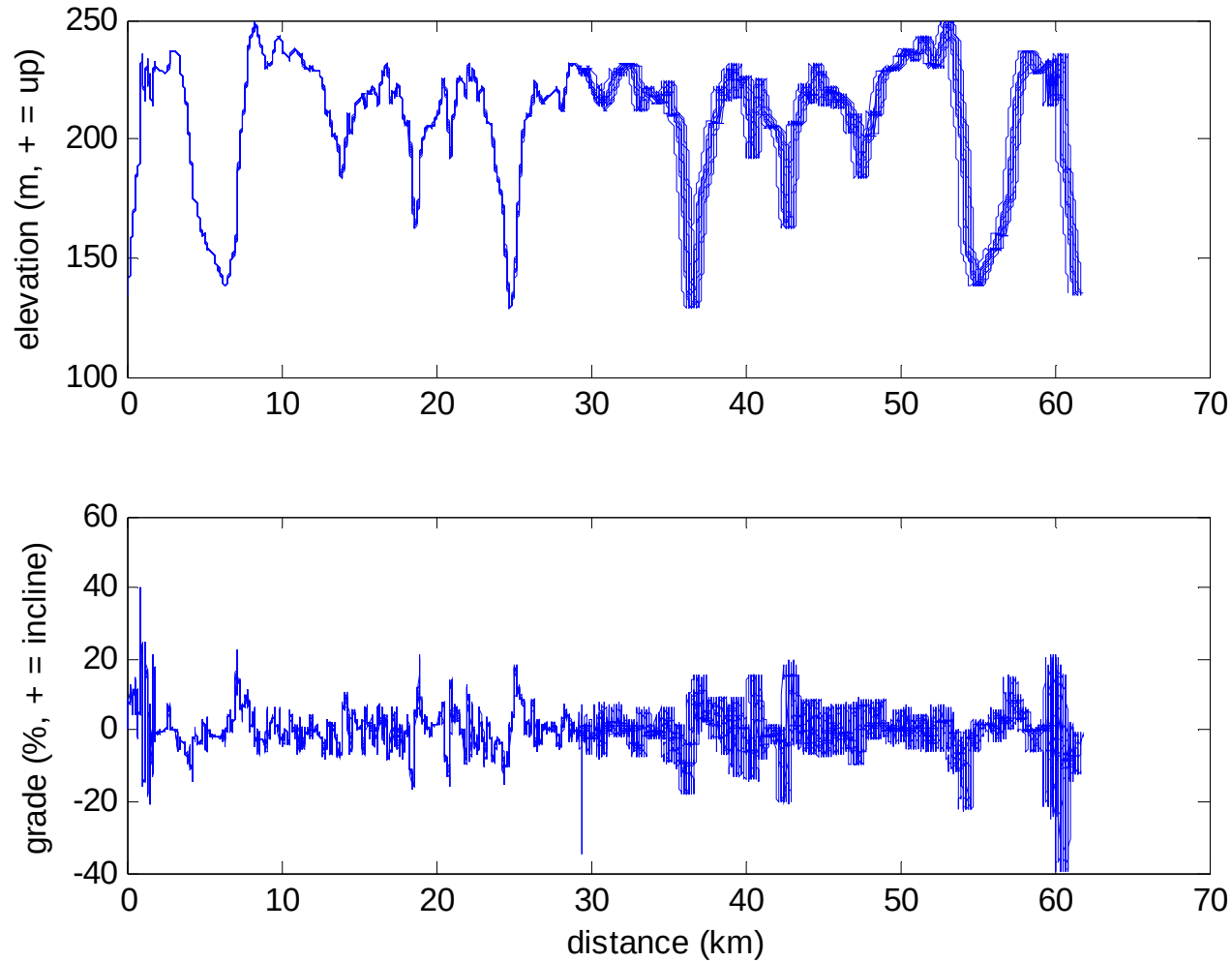
- 12 soldiers participated.
- 3 weeks
- Recorded:
 - ≡ Vehicle position, velocity
 - ≡ Power System states
 - ≡ Operator commands
 - ≡ Force activities

Results: Path

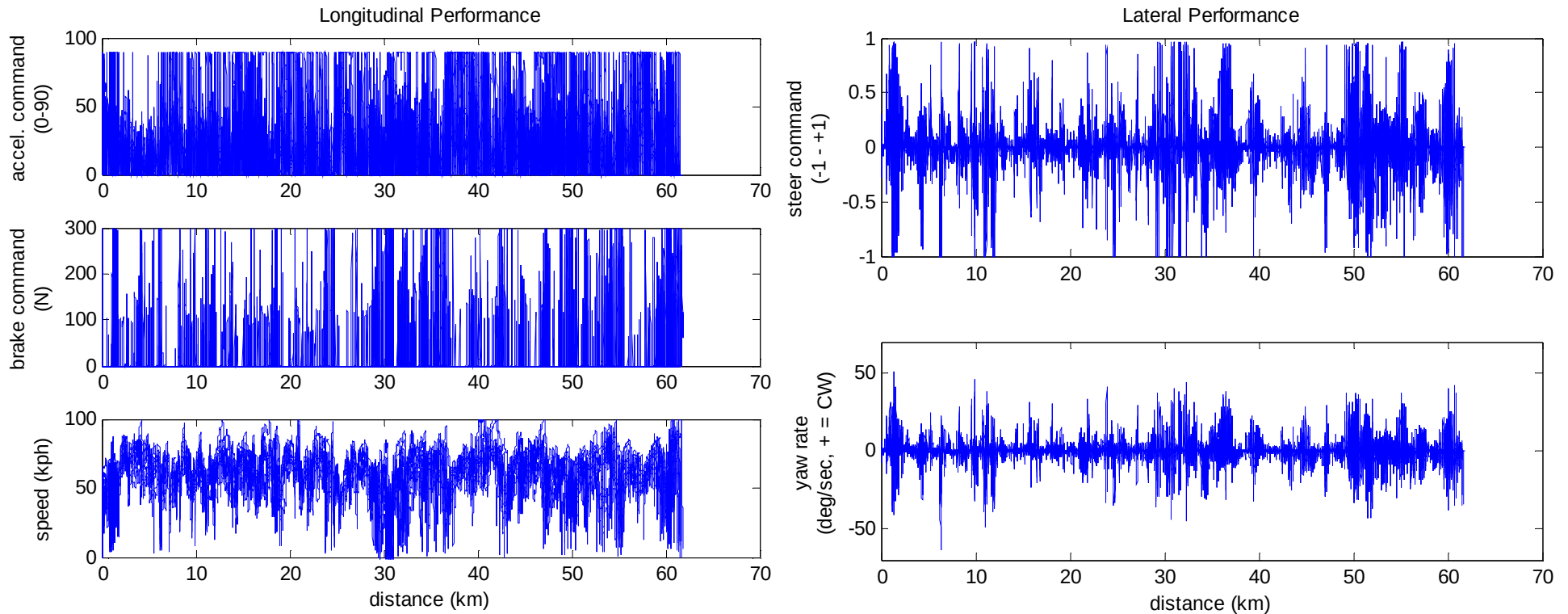


Results: Elevation & Grade

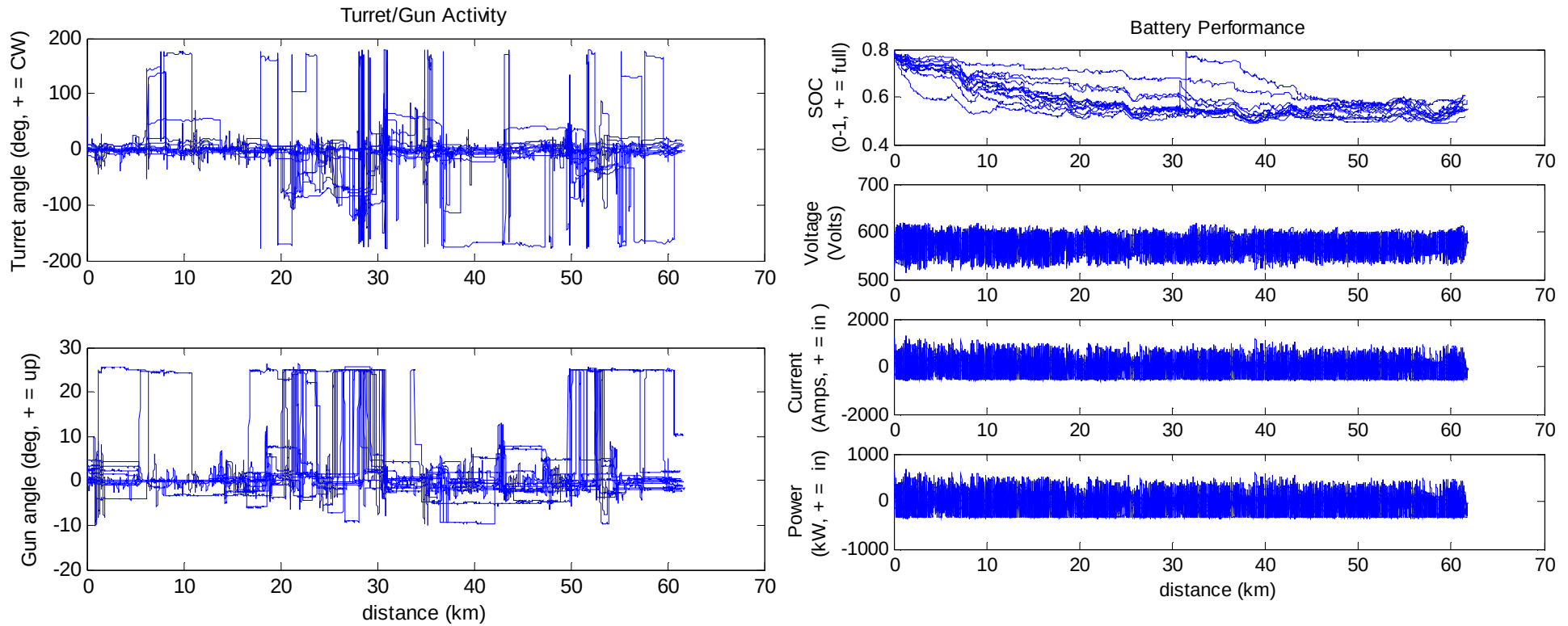
Approximate Elevation and Grade Performance (measured from vehicle global position)



Results: Driver Commands



Results: Turret/Gun & Battery



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.