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# Warfighter-in-the-Loop Experiments with GT-DRIVE and SimCreator

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# Report Documentation Page

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## OUTLINE

- Motivation - Hybrid Electric Vehicle Evaluation and Assessment Program
- TARDEC Duty Cycle Experiment Process (DCE-TOP)
  - Warfighter-in-the-Loop
- TARDEC GT-Drive Conv. & Hybrid HMMWV Models
- SimCreator Vehicle Dynamics Model
- GT-DRIVE / SimCreator Integration
- DCE-TOP Results
- Conclusion

## MOTIVATION

- Develop HEV Test Operating Procedure (TOP) for Military Vehicles
- Determine the fuel economy benefits of hybrid electric vehicles using quantifiable test data
- Provides Test Data to Validate TARDEC DCE-TOP Simulations

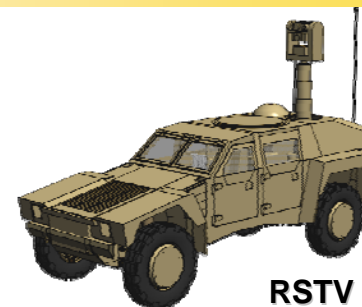
### HEVEA Testing:

#### Conventional:

- 2 - HMMWVs,
- 2 - 21/2T LMTVs
- 1 - 5T MTV
- 1 - FMTV CVT
- 2 - HEMTTs
- 1 - AM GEN UV

#### Hybrid Electric:

- 1 - HMMWV
- 1 - RSTV
- 1 - IMG UV
- 1 - LM UV
- 1 - AH/SS MSV
- 1 - BAE FMTV
- 1 - OSHKOSH HEMTT "A3"



**RSTV Series HE**

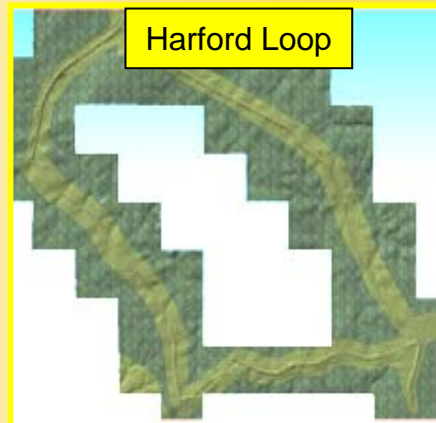


**Parallel Hybrid MSV**



**2-Parallel hybrid UV's**

- Purpose
  - Replicate Field Tested Fuel Economy Measurements
  - Driver-in-the-Loop, Digitized Test Courses
  - Vehicle Models, Motion Platform
- HMMWV Vehicles
  - M1113 Conventional
  - XM1124 Hybrid
- Participants
  - 2 APG Test Drivers
- Aberdeen Terrains
  - Harford Loop
  - Munson SFC
  - Churchville B
  - Perryman Paved
- Variables
  - Terrain
  - Vehicle Speed
  - Driver
  - Initial SOC (Hybrid)



### M1113 Conventional:

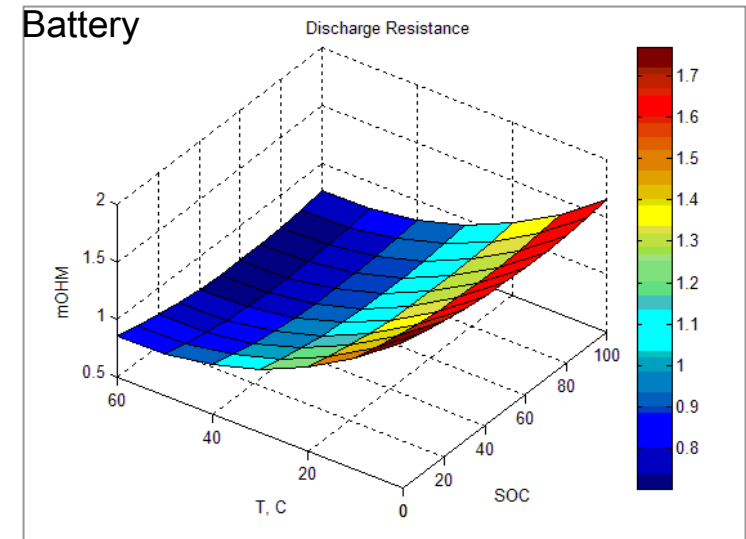
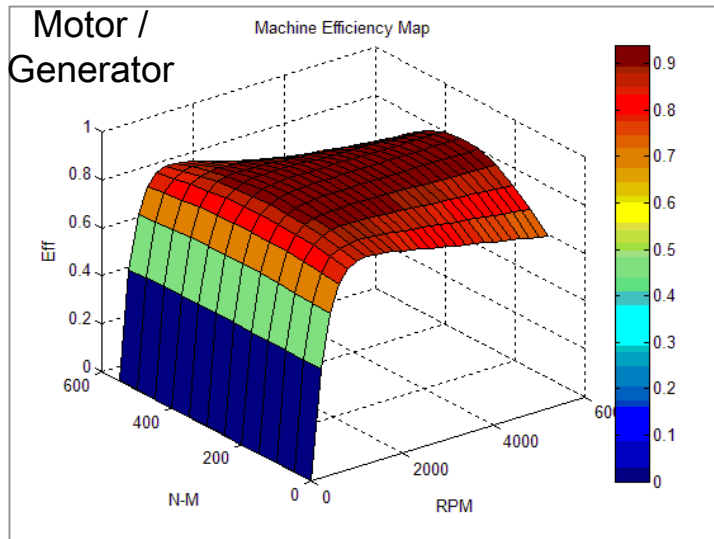
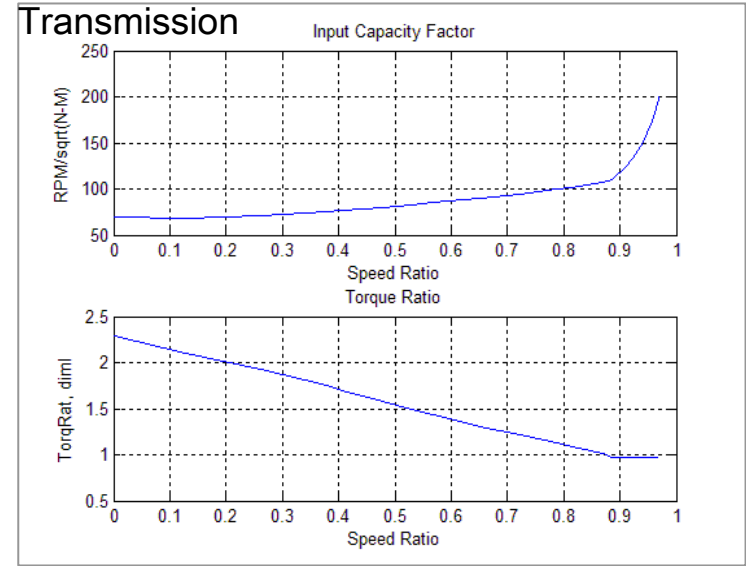
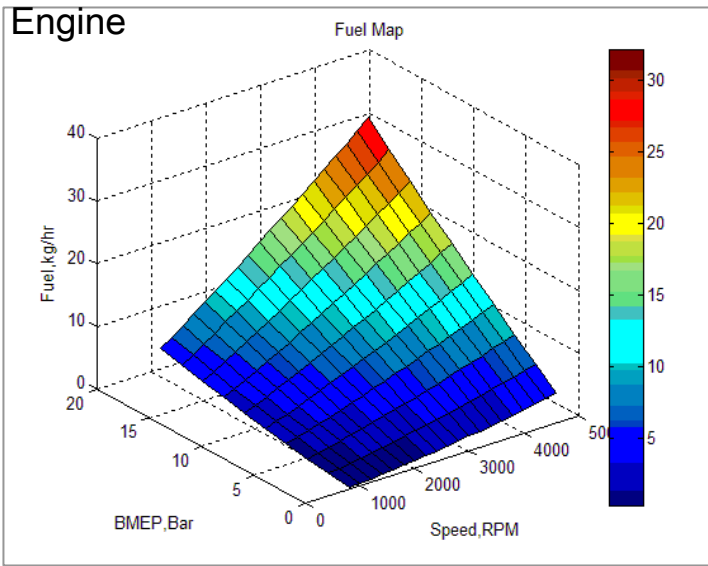
- GM / GEP 6.5 L Turbo-Diesel
  - 145 kW @ 3200 rpm
- GM 4L80-E Automatic Trans.
  - 4 Spd. Overdrive
  - Conv. Lockup 3<sup>rd</sup> & 4<sup>th</sup>
- 2-Spd. Transfer-Case

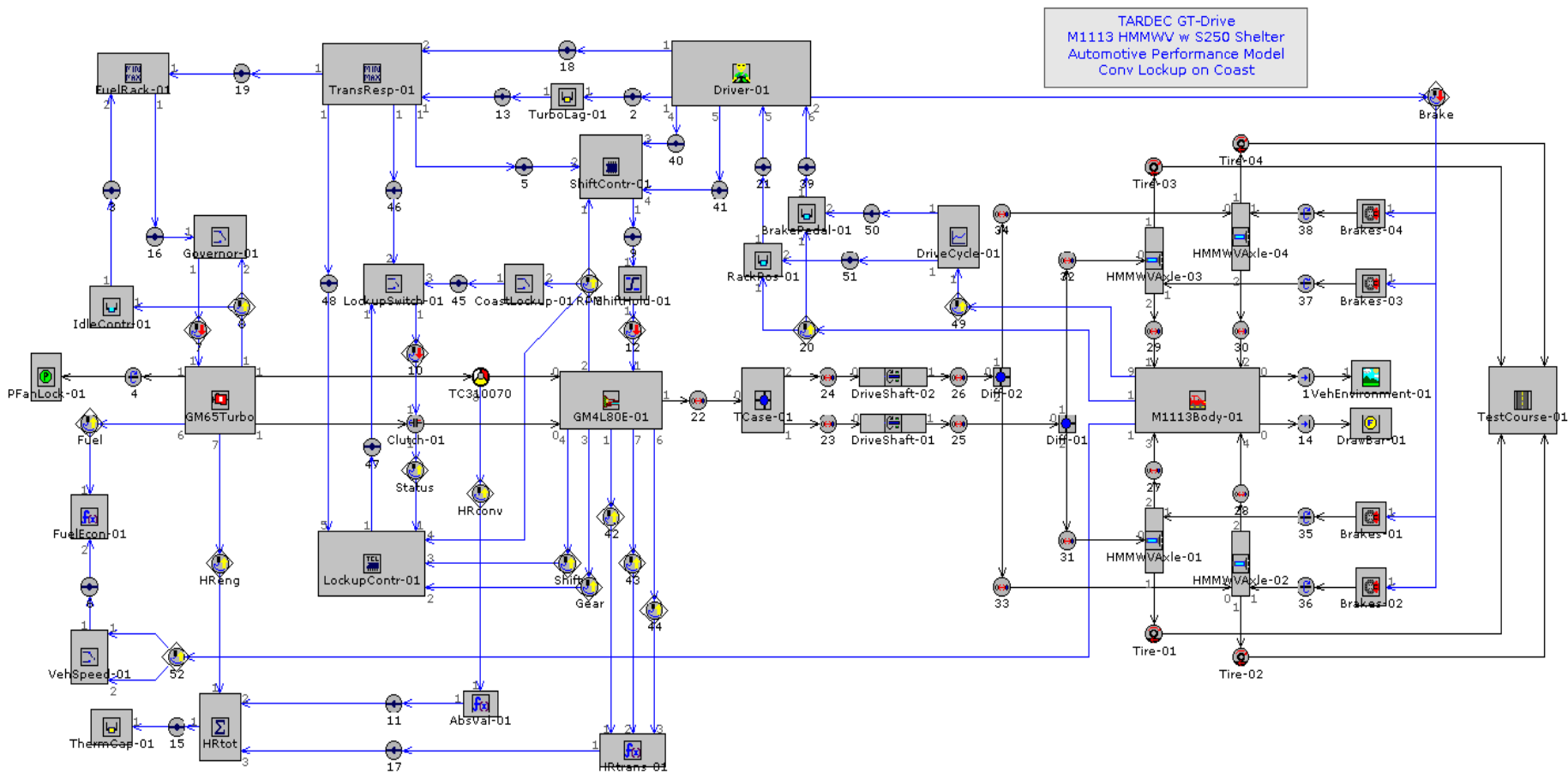
### XM1124 Series Hybrid:

- Peugeot 2.2 L Turbo-Diesel
  - 100 kW @ 4000 rpm
- UQM SR-286 PM Generator
  - 85 kW Cont Output
- Saft VL30P LiOn Battery Pack
  - 300 V, 60Amp-Hr
- UQM SR-286 Traction Motors
  - 550 N-M Peak Torque

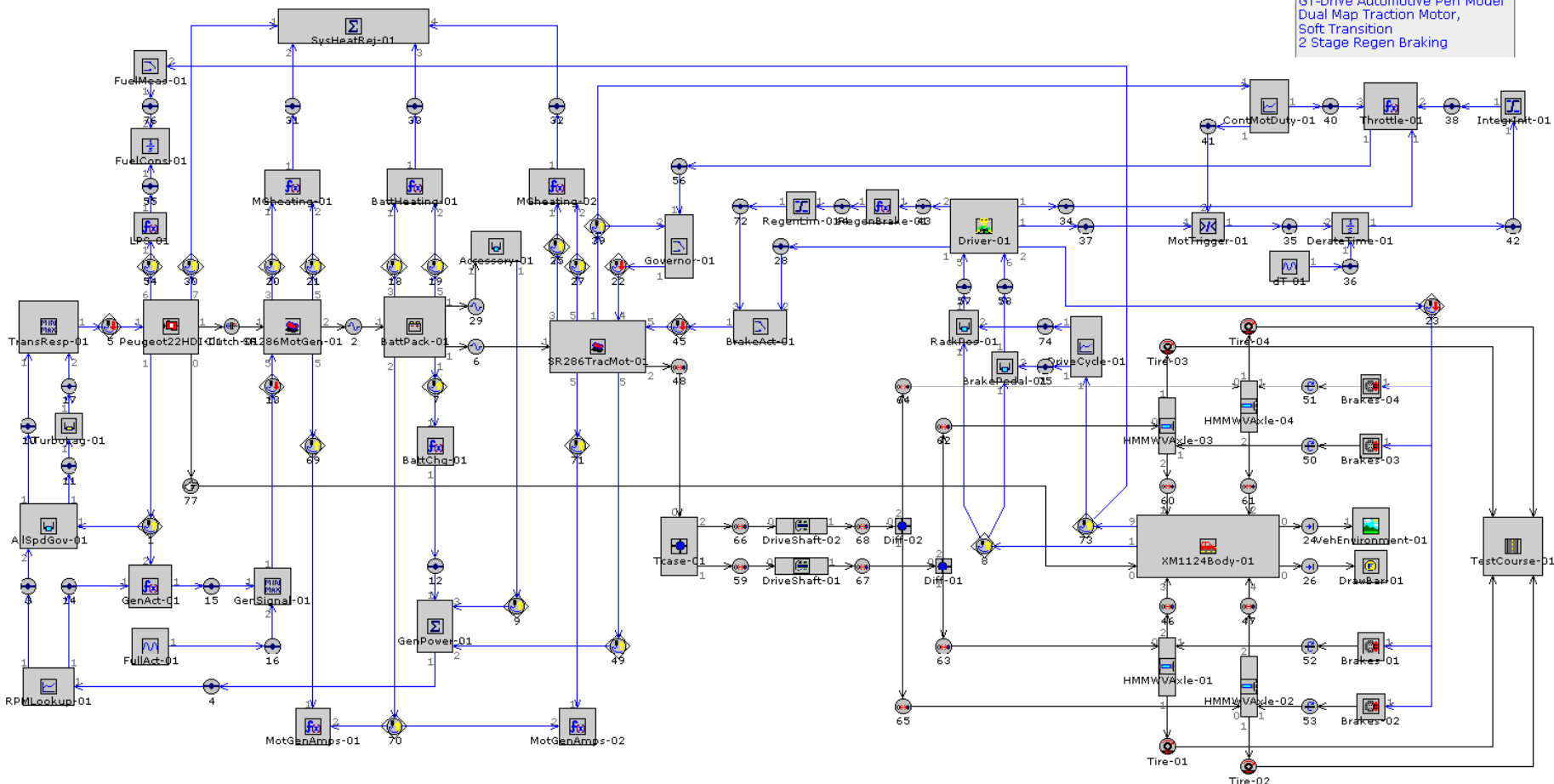
### Common Components:

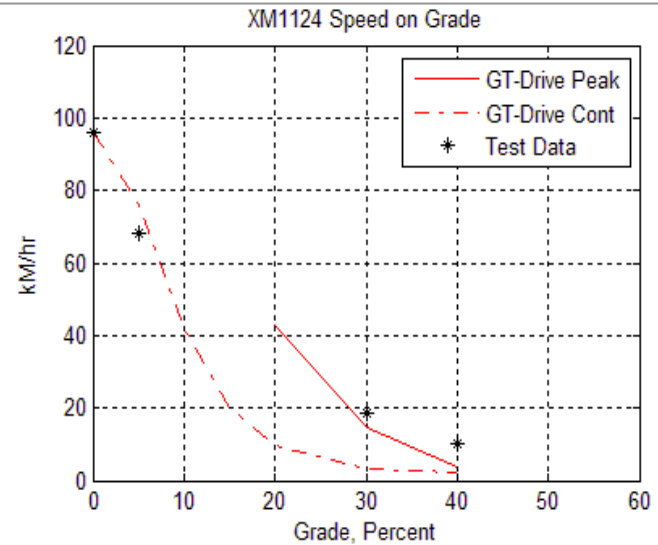
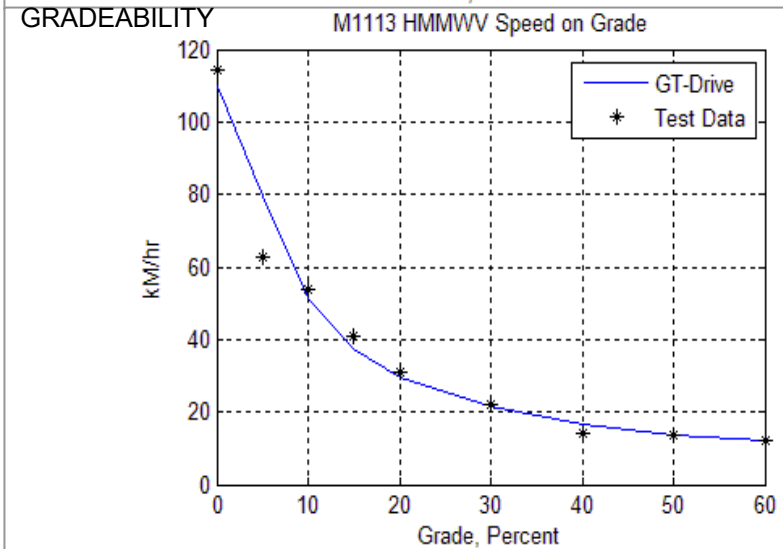
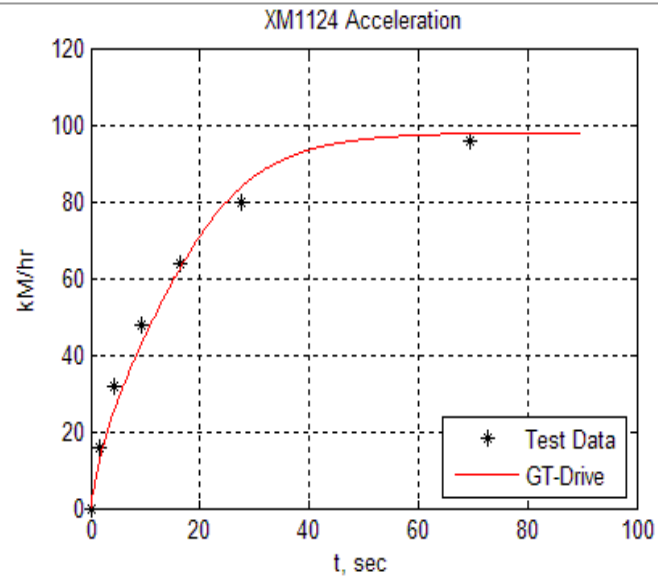
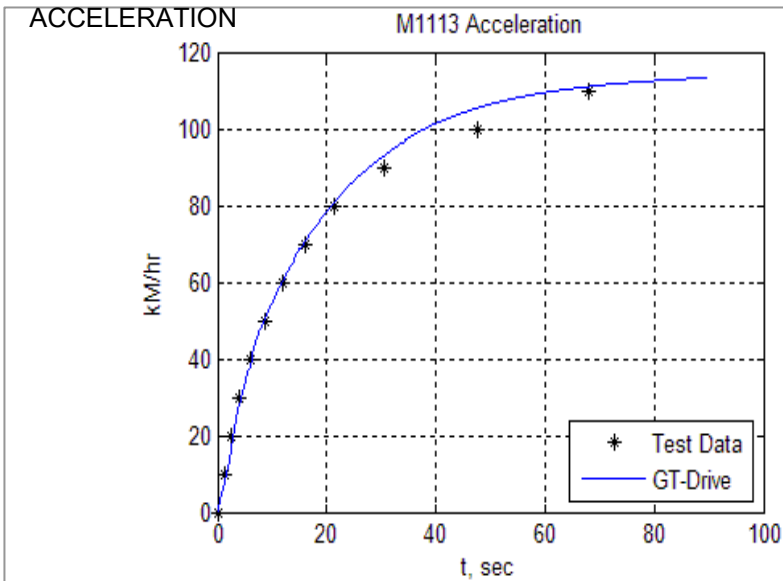
- Torsen Differentials
- Reduction Hubs (1.92:1)

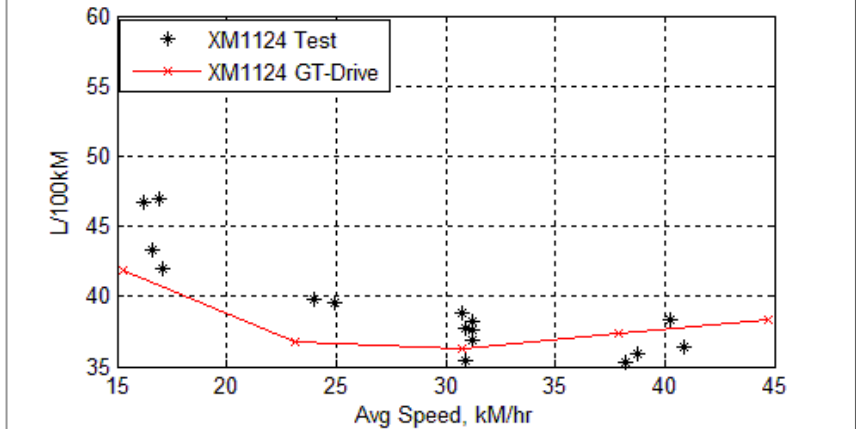
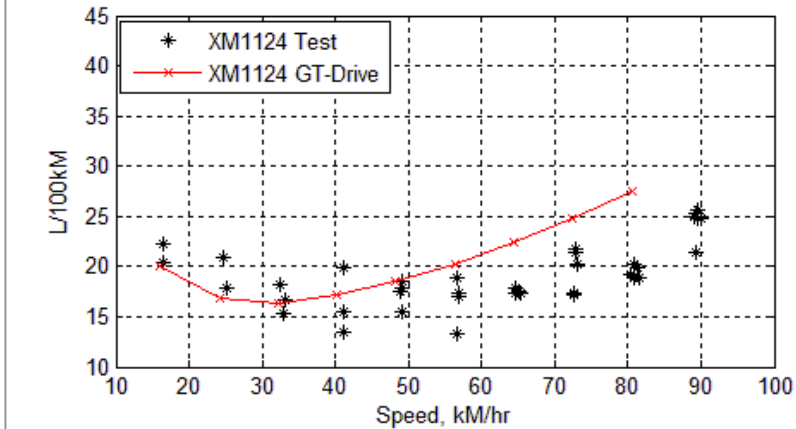
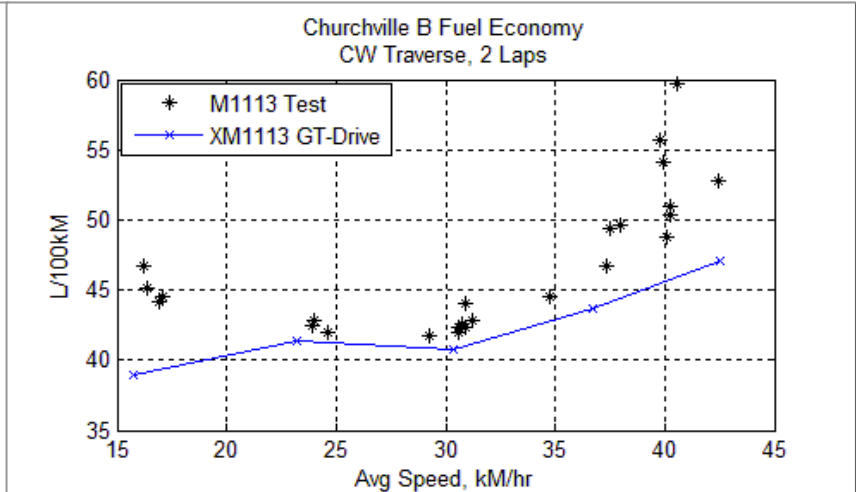
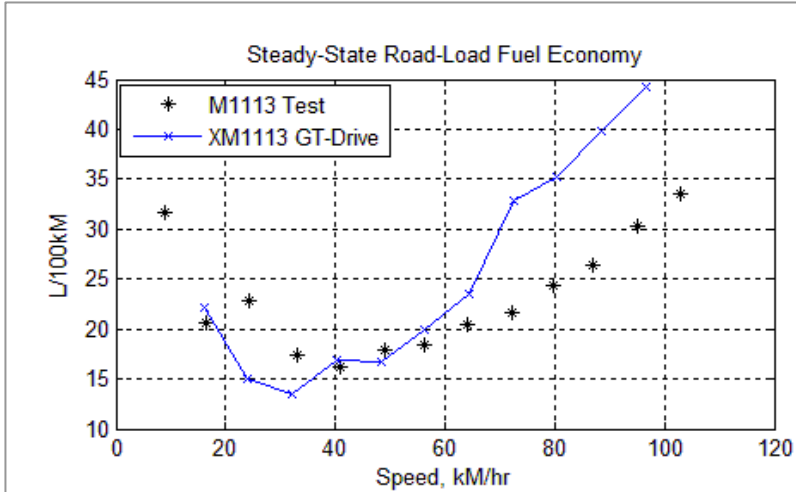




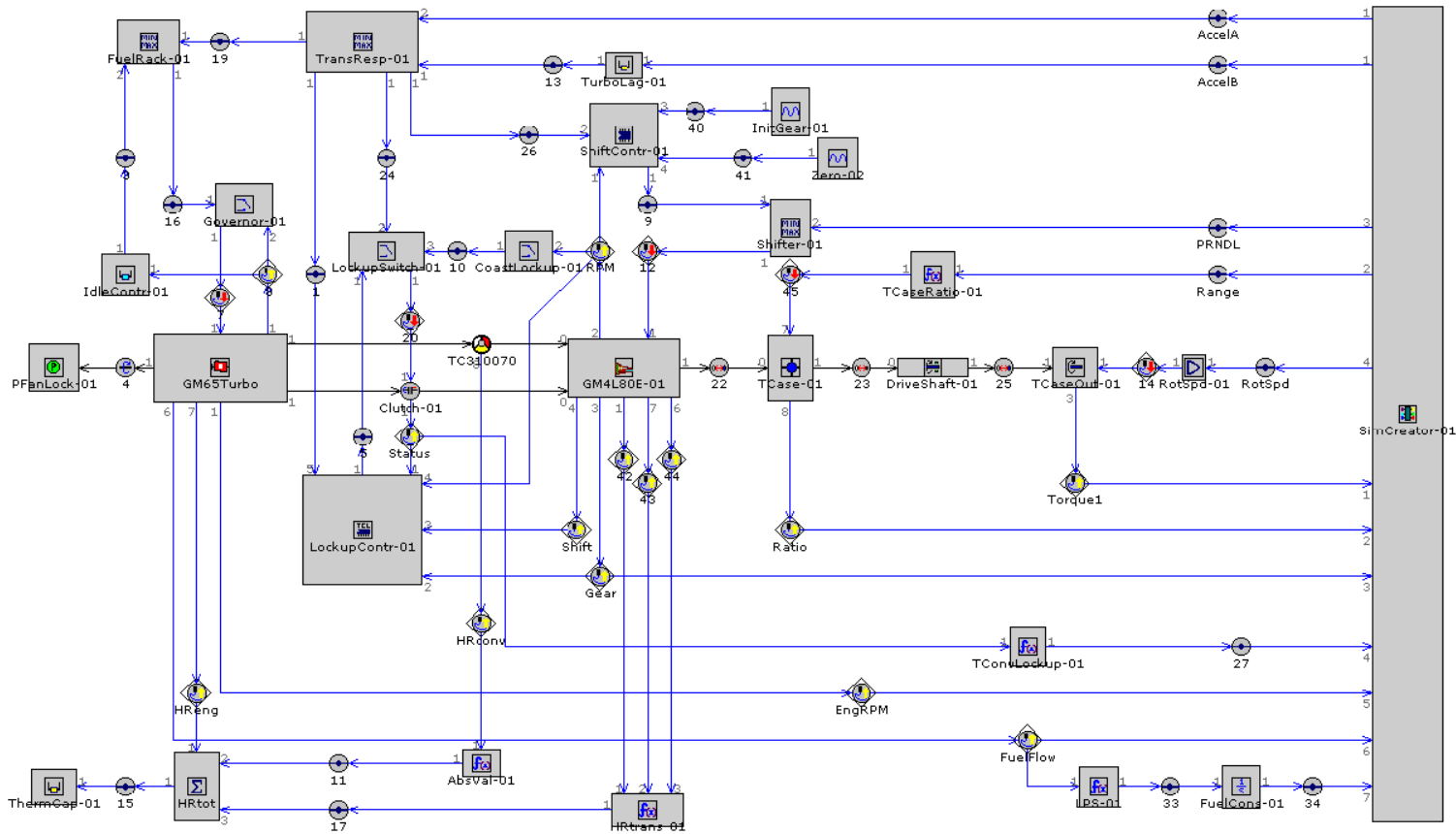
TARDEC XM-1124 HE-HMMWV  
 GT-Drive Automotive Perf Model  
 Dual Map Traction Motor,  
 Soft Transition  
 2 Stage Regen Braking







- Remove GT-Drive Vehicle Components:
  - Vehicle Body, Axles, etc.
  - Road, Environment
  - PID Driver
- Add Components
  - “SpeedBoundaryRot” at T-Case Output
    - Imposes Rotational Speed from SimCreator drive-line
    - Applies Reaction Torque to drive-line
  - SimuLink Wiring Harness
    - Driver Interface
    - Vehicle / Power-Train Model Interface
    - Information Channels
- Create Real-Time .dat file



TARDEC GT-Drive M1113 HMMWV  
Power-Train Only Model for  
SimCreator Vehicle Dynamics Model  
Improved Engine Braking through  
Conv-Lockup in Coast-Down

**Harness Inputs:**

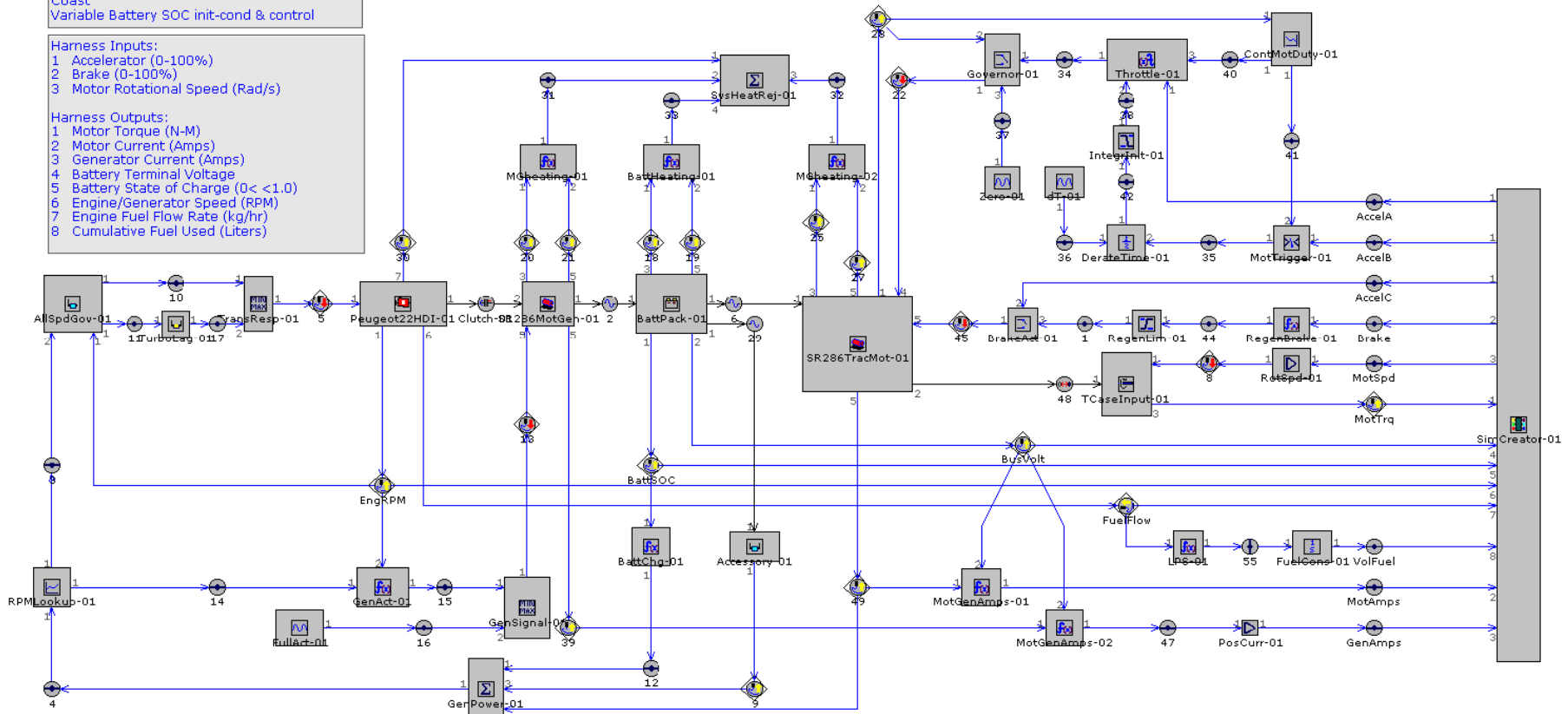
- 1 Accelerator (0-100%)
- 2 T-Case Range (0=Low, 1=High)
- 3 PRNDL (1 - 4)
- 4 T-Case Output Speed (Rad/s)

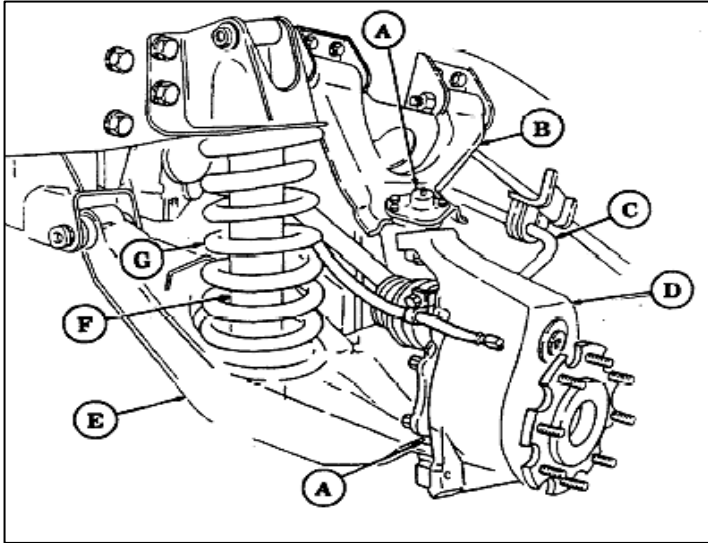
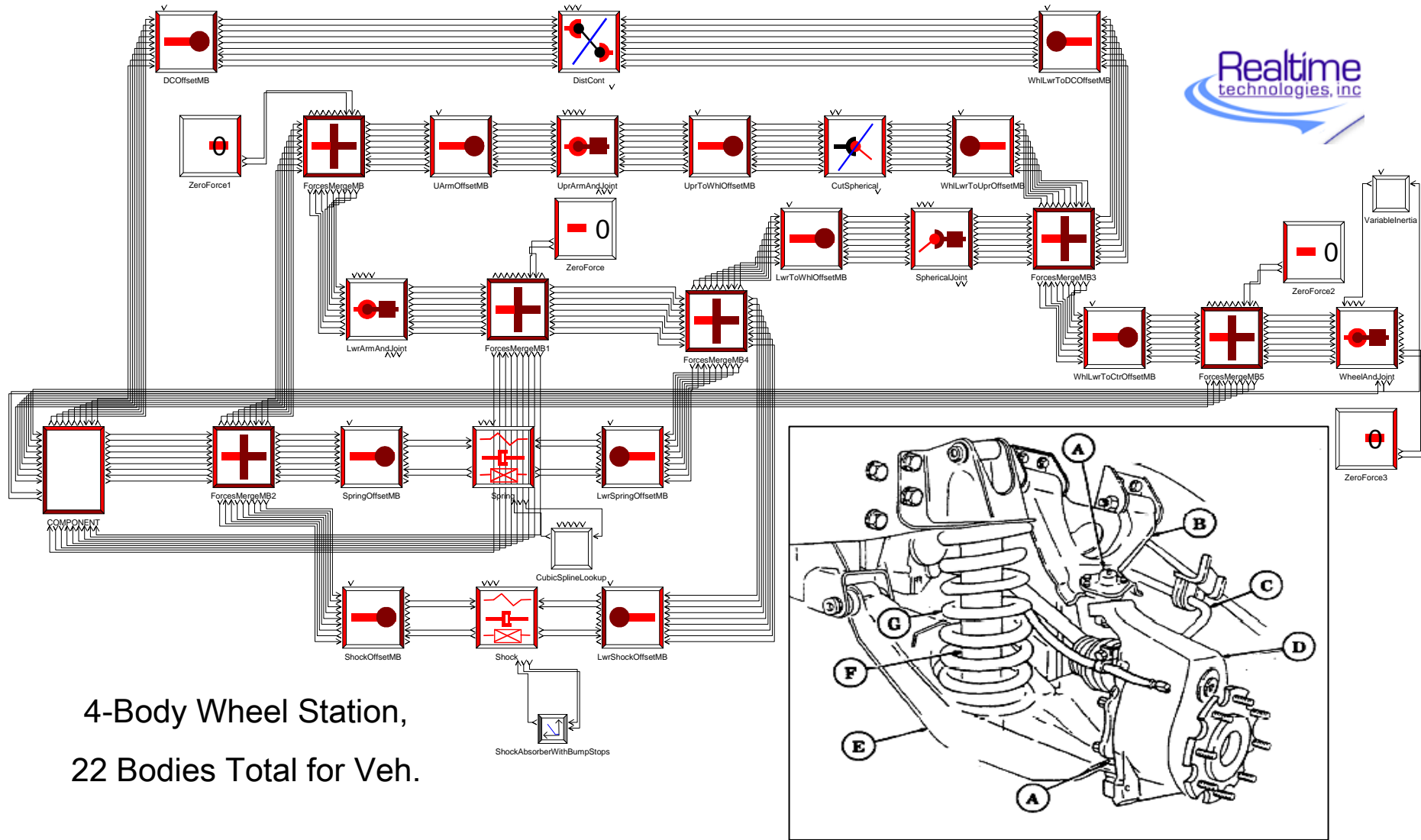
**Harness Outputs:**

- 1 Driveline Torque (N-M)
- 2 T-Case ratio
- 3 Transmission Gear
- 4 Converter Lockup Status
- 5 Engine/Generator Speed (RPM)
- 6 Engine Fuel Flow Rate (kg/hr)
- 7 Cumulative Fuel Used (Liters)

TARDEC XM-1124 HE-HMMWV GT-Drive Power-Train Only Model for SimCreator Veh.  
 Dual Map Traction Motor, Soft Transition  
 2 Stage Regen Braking w/ 10% Regen on Coast  
 Variable Battery SOC init-cond & control

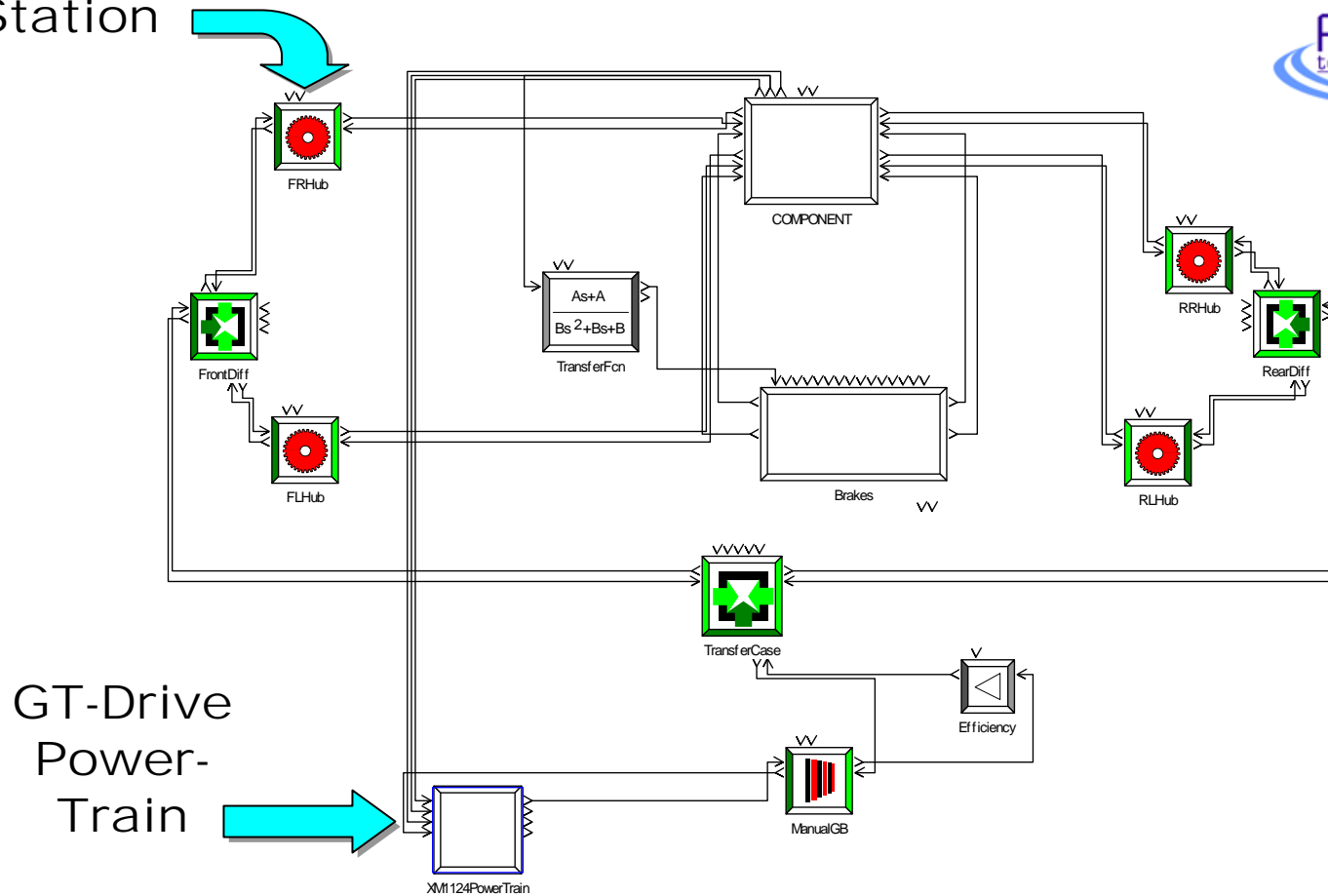
- Harness Inputs:**
- 1 Accelerator (0-100%)
  - 2 Brake (0-100%)
  - 3 Motor Rotational Speed (Rad/s)
- Harness Outputs:**
- 1 Motor Torque (N-M)
  - 2 Motor Current (Amps)
  - 3 Generator Current (Amps)
  - 4 Battery Terminal Voltage
  - 5 Battery State of Charge ( $0 < SOC < 1.0$ )
  - 6 Engine/Generator Speed (RPM)
  - 7 Engine Fuel Flow Rate (kg/hr)
  - 8 Cumulative Fuel Used (Liters)





4-Body Wheel Station,  
22 Bodies Total for Veh.

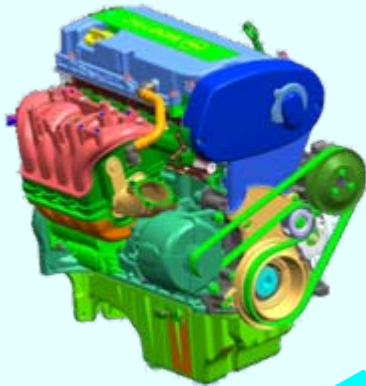
Wheel Station





## GT-DRIVE

MAP BASED or "MEAN-VALUE" ENGINE MODEL



## Virtual Vehicle Simulation

POWERTRAIN CONTROLS



DRIVELINE COMPONENTS



## SimCreator

VEHICLE BODY



ROAD and ENVIRONMENT



DRIVER



## Launch SimCreator



### • Initialization

Initialize SimCreator Model

Initialize GT-Drive Model

### • Runtime

Advance SimCreator Model

Advance GT-Drive Model

Stop  
Button  
Pressed

NO

YES

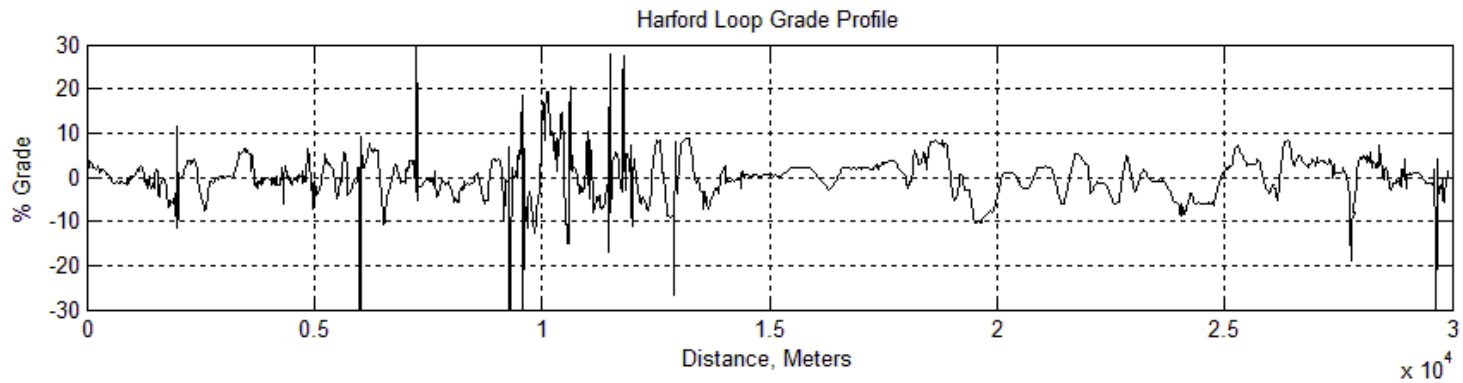
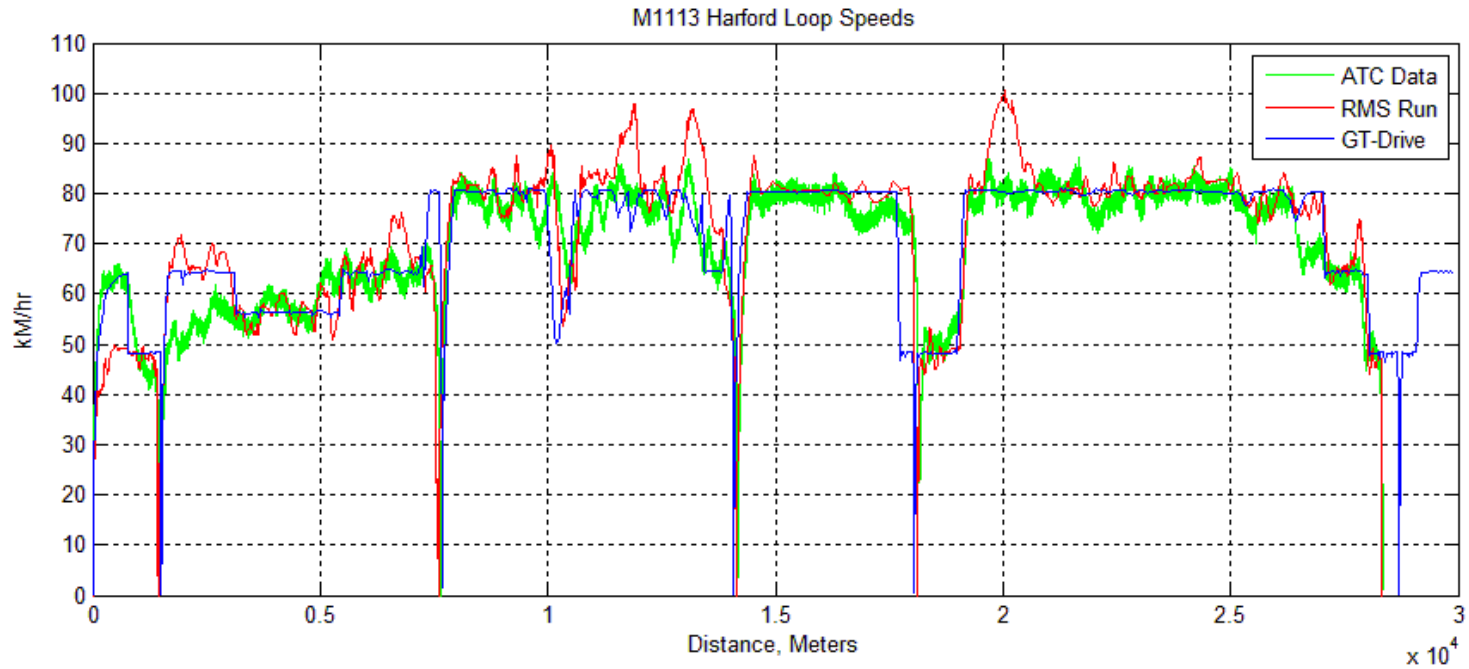
### • Termination

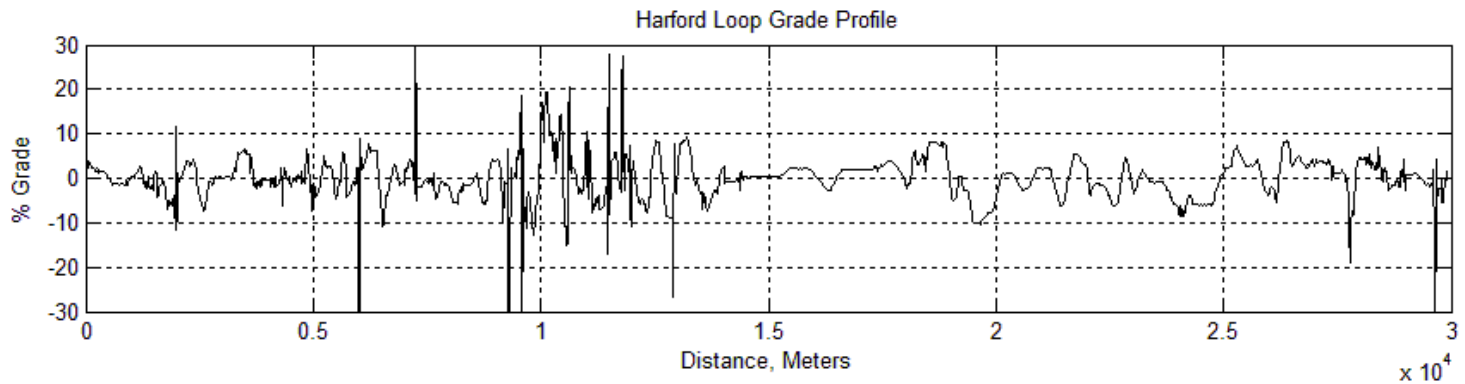
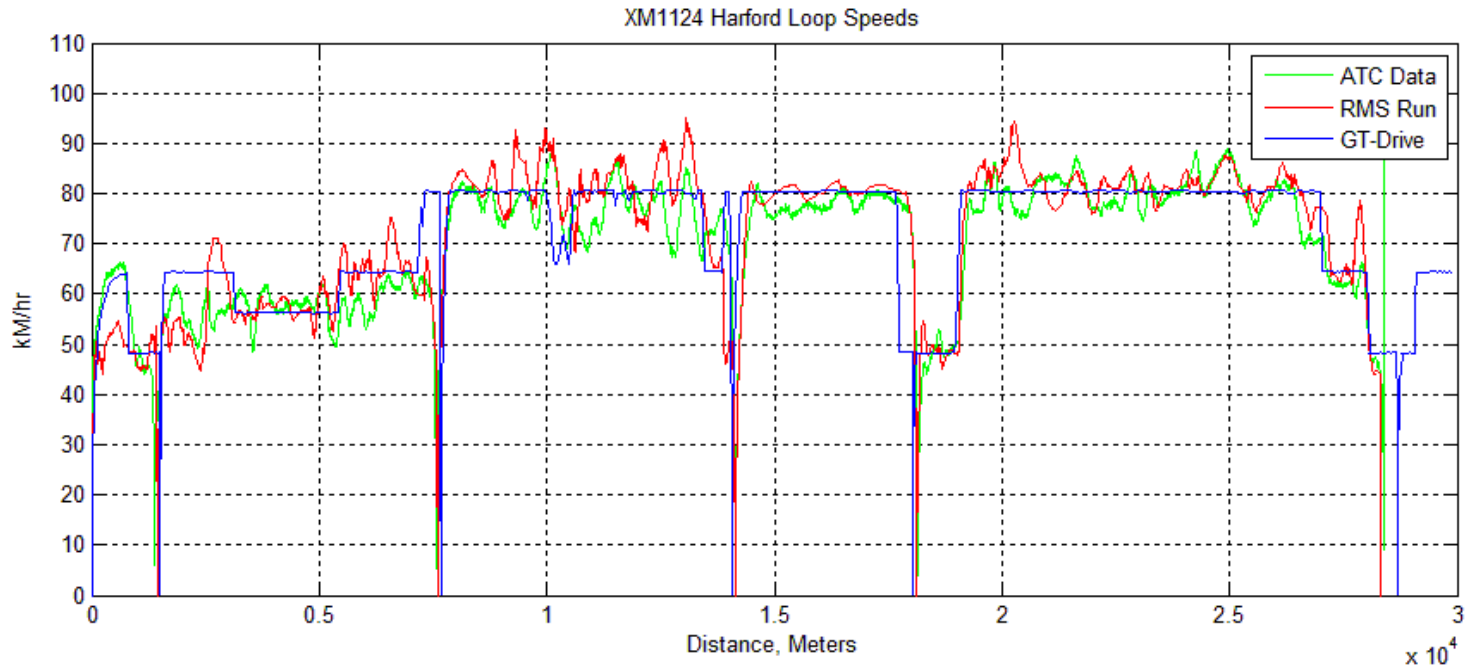
Terminate GT-Drive Model

Terminate SimCreator Model



- Integration achieved in Linux by dynamically linking the GT-SUITE-RT solver library in the model executable.
- RT Capability achieved through:
  - *Euler ODE solver for speedup*
  - *Extra “bulk” in standard solver removed*
  - *No RLT’s, plots or other output stored*





Test Course	HMMWV Variant	Lap Speed Mph (kM/hr)	APG-Test L/100kM	GT-Drive L/100kM	RMS-Simulation L/100kM
Munson Fuel Loop	M1113	10 (16.1)	25.85	18.20	16.01
		15 (24.1)	23.53	19.90	16.97
		20 (32.2)	22.19	20.64	18.57
		25 (40.2)	22.41	23.11	21.19
		30 (48.3)	24.25	25.31	24.04
	XM1124	10 (16.1)	22.41	25.94	20.60
		15 (24.1)	21.78	22.79	18.29
		20 (32.2)	20.82	22.62	19.08
		25 (40.2)	20.46	23.24	20.71
		30 (48.3)	22.62	24.47	23.91
Churchville Hilly X-Country	M1113	10 (16.1)	45.24	38.94	35.11
		15 (24.1)	42.78	41.38	36.53
		20 (32.2)	42.78	40.71	36.56
		25 (40.2)	43.57	43.71	39.74
	XM1124	10 (16.1)	42.78	41.85	30.44
		15 (24.1)	39.21	36.72	28.16
		20 (32.2)	36.76	36.30	27.91
		25 (40.2)	38.57	37.42	30.55
Harford Loop	M1113	Posted Limits	24.76	31.17	22.41
	XM1124		22.19	29.55	18.75

- GT-Drive vehicle models using typical component data accurately predict vehicle full-throttle performance.
- Fuel Economy results more approximate: sensitive to component spin-losses, accessory loads, etc.
- GT-Drive power-trains exportable for use in multi-body vehicle-dynamic and human-in-the-loop co-simulations.
  - Evaluate automotive performance of virtual vehicles
  - Allow pre-prototype user evaluation
  - Collect duty-cycle data for simulated mission scenarios