



**Investigation of Control Algorithms
for Tracked Vehicle Mobility Load
Emulation for a Combat Hybrid Electric
Power System**

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GVSETS

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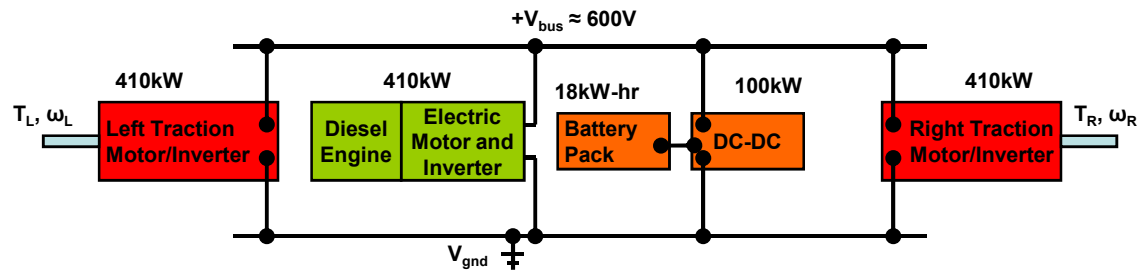
Agenda

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MODELING AND SIMULATION, TESTING AND VALIDATION

- Power & Energy SIL overview
- Mobility Load Emulation Definition
- Control System Layout
- Control Algorithm Candidates
- Experimental Results
- Conclusions and Future Work

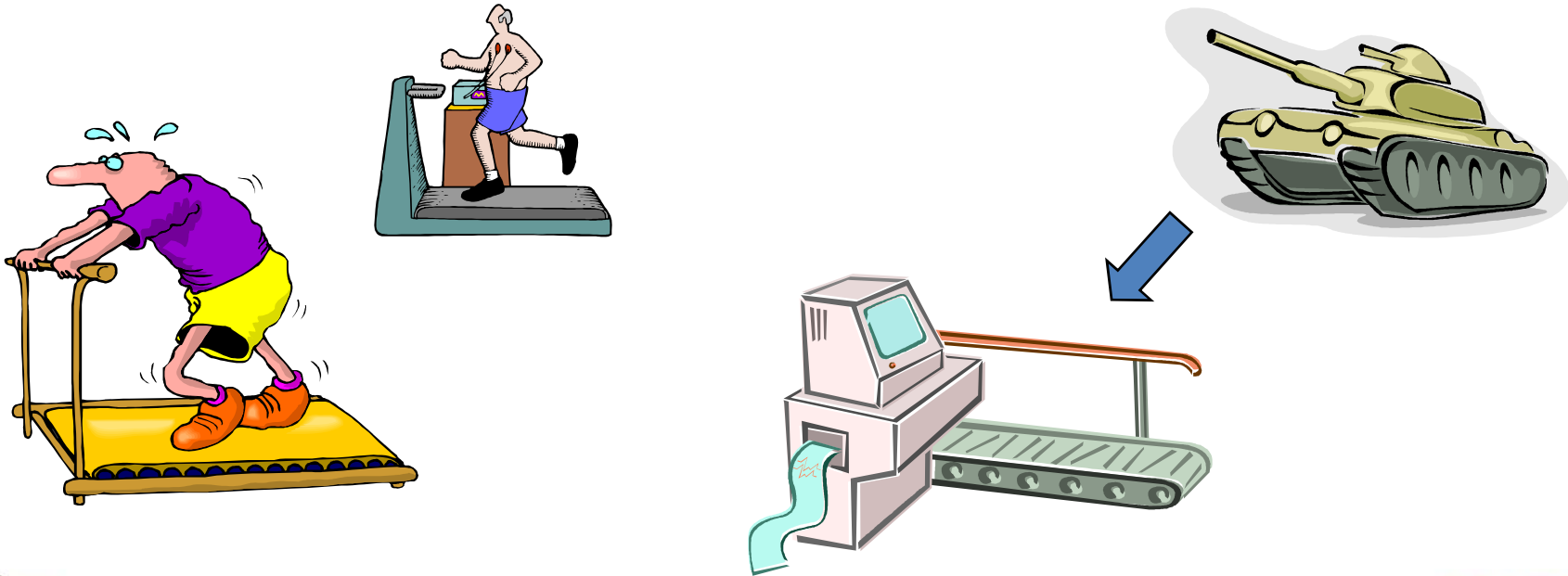
- Hybrid electric power system for ~ 22 ton tracked vehicle
- Tested and Developed:
 - Motors, Generators, Batteries, Inverters, DC-DC Converters, Thermal Management, Pulse Power Components, etc
 - Mathematical models of components and of system



How do we test the HERMIT?

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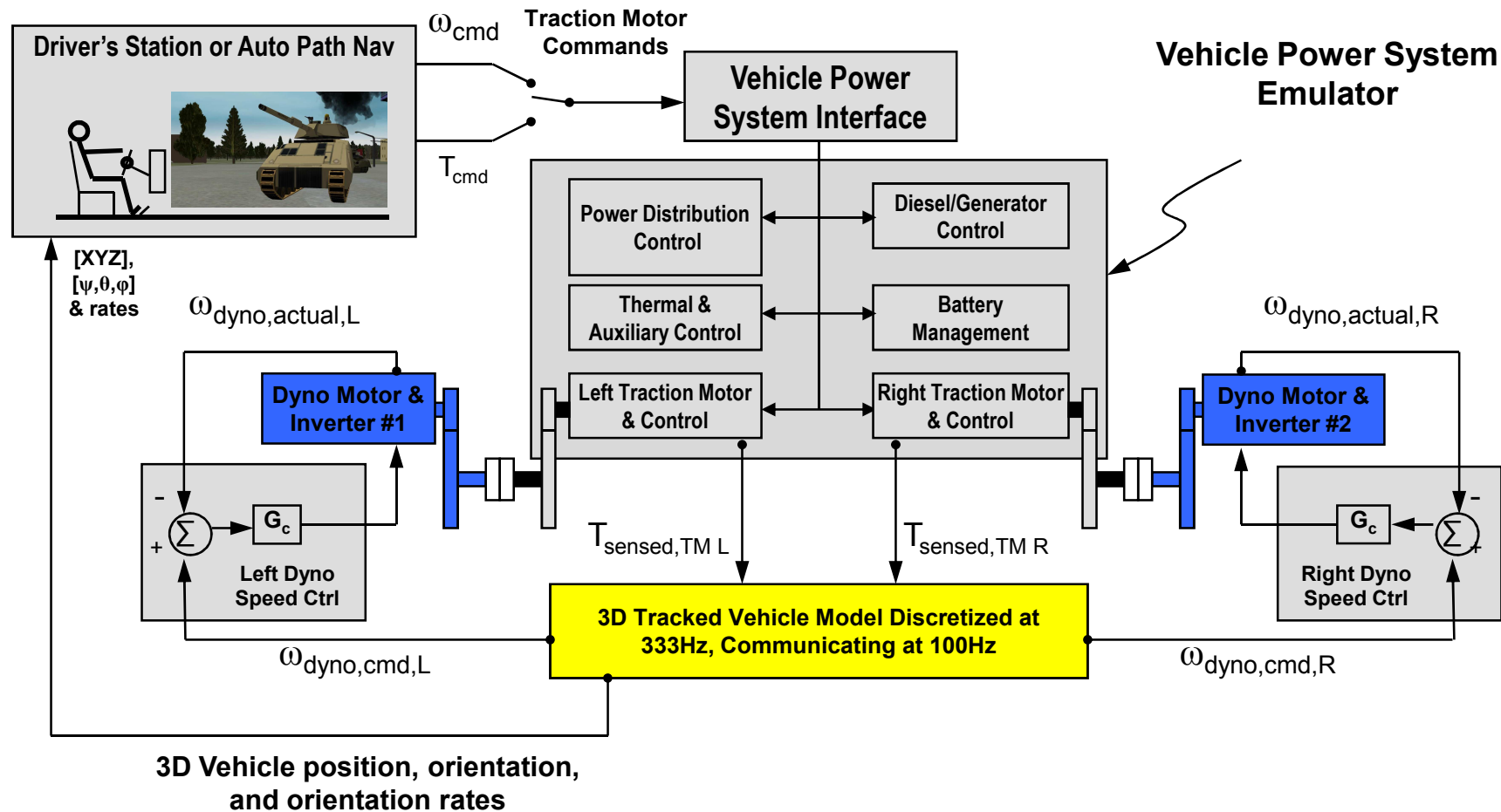
- Mobility Load Emulation
 - Dynamometers
 - Vehicle Model
 - Control Algorithms



Mobility Load Emulation Layout

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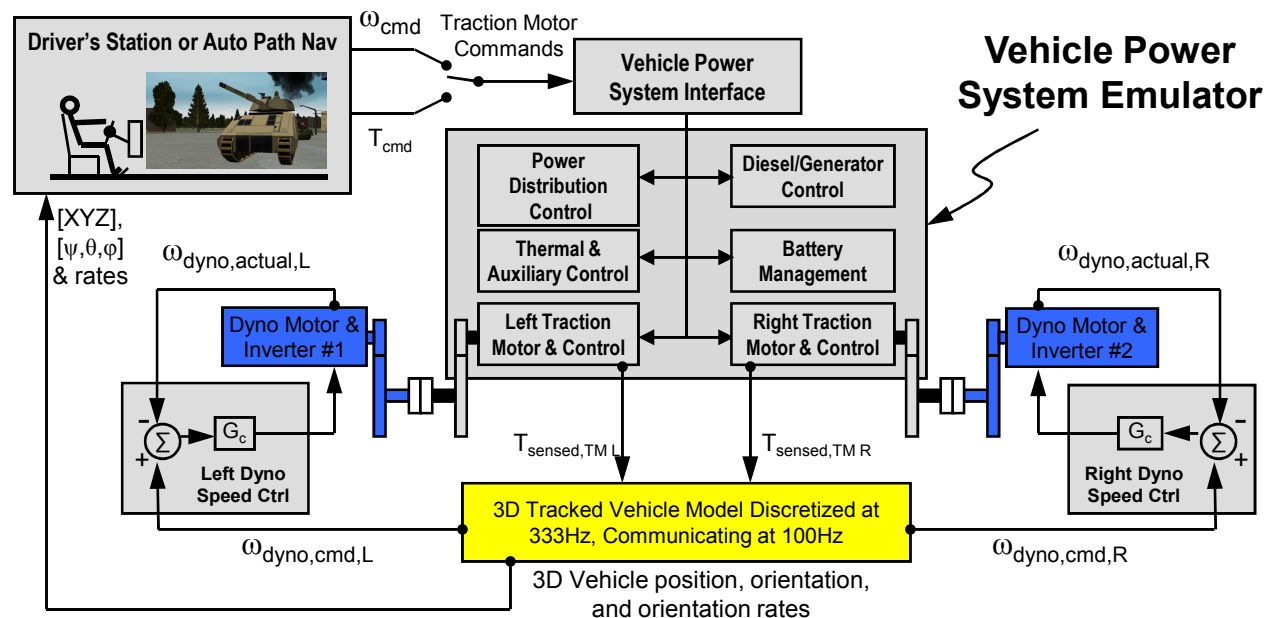
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Mobility Load Emulation Signal Flow

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- Driver commands to power system
- Left/right sensed torques to vehicle model
- Virtual sprockets' motion becomes dyno setpoints



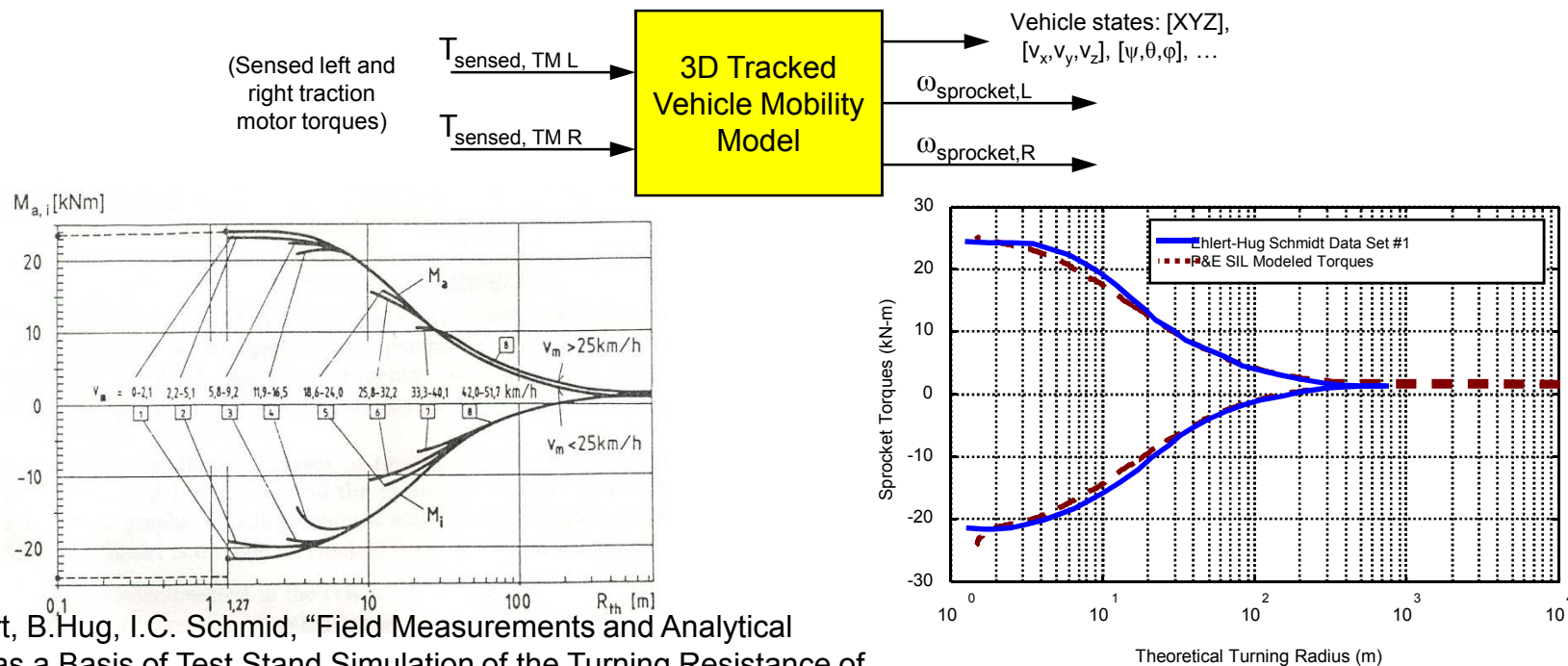
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-
- dyno shaft speed commands come from vehicle model
- vehicle hybrid power system
- $T_{TM,actual}$
- GR_v
- disturbance $\equiv T_{TM,sprocket}$
- $\omega_{dyno,cmd}$
- $\omega_{dyno,err}$
- $\sum$
- $k_p + \frac{k_i}{s}$
- Controller
- $T_{dyno,cmd}$
- $\frac{1}{\tau_{dyno}s + 1}$
- $\tau_{dyno} \approx 1ms$
- $T_{dyno,actual}$
- GR_d
- final drive gear ratio
- $T_{dyno,sprocket}$
- $\sum$
- Plant
- $\sum$
- $1/J_{eff}$
- $\omega_{sprocket}$
- $\frac{1}{s}$
- b_{eff}
- $\omega_{dyno,actual}$

Tracked Vehicle Model

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- Model features
 - 6 DOF skid-steered model with lumped left/right track inertias
 - Soil compression, bulldozing, shear



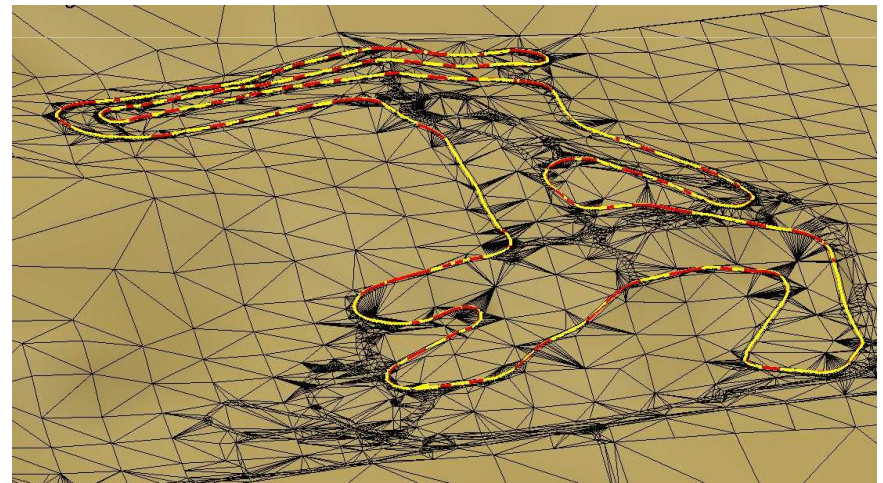
W. Ehlert, B.Hug, I.C. Schmid, "Field Measurements and Analytical Models as a Basis of Test Stand Simulation of the Turning Resistance of Tracked Vehicles," Journal of Terramechanics, v.29, no.1, pp.57-69,1992

Simulated Terrain Navigation

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- Digitized terrain triangle data
- Manual driving or waypoint-based path navigation





Mobility Load Emulation Control Algorithms

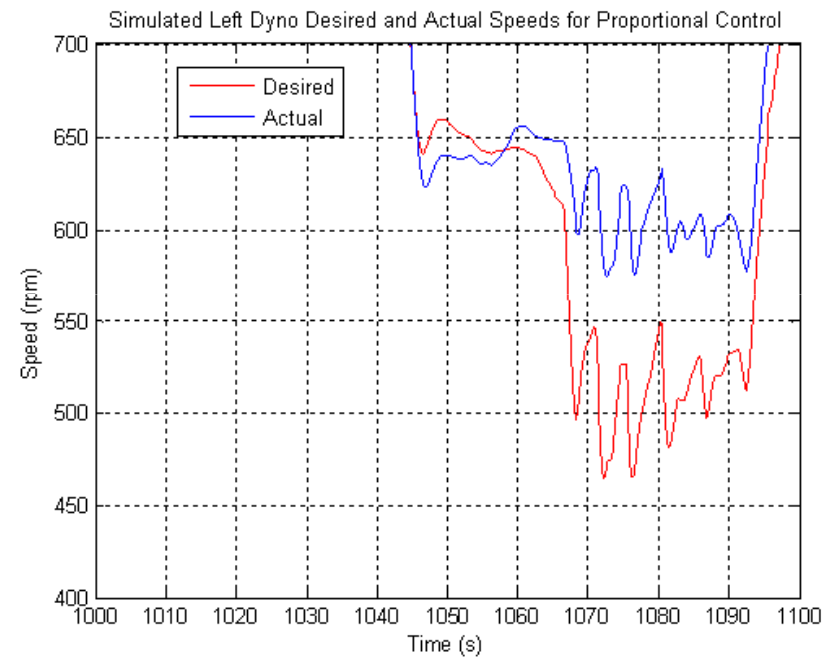
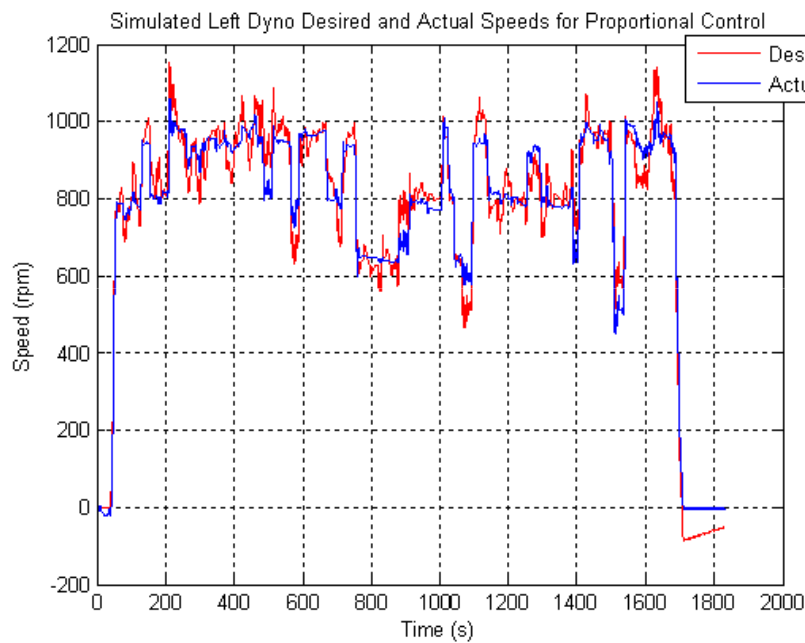
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- Tested algorithms
 - Proportional Control
 - Proportional Integral Control
 - Proportional Feed-forward Control
- Initial tests in simulation environment
- Then proceed to hardware-in-the-loop experiment

Simulated Results for Proportional Control

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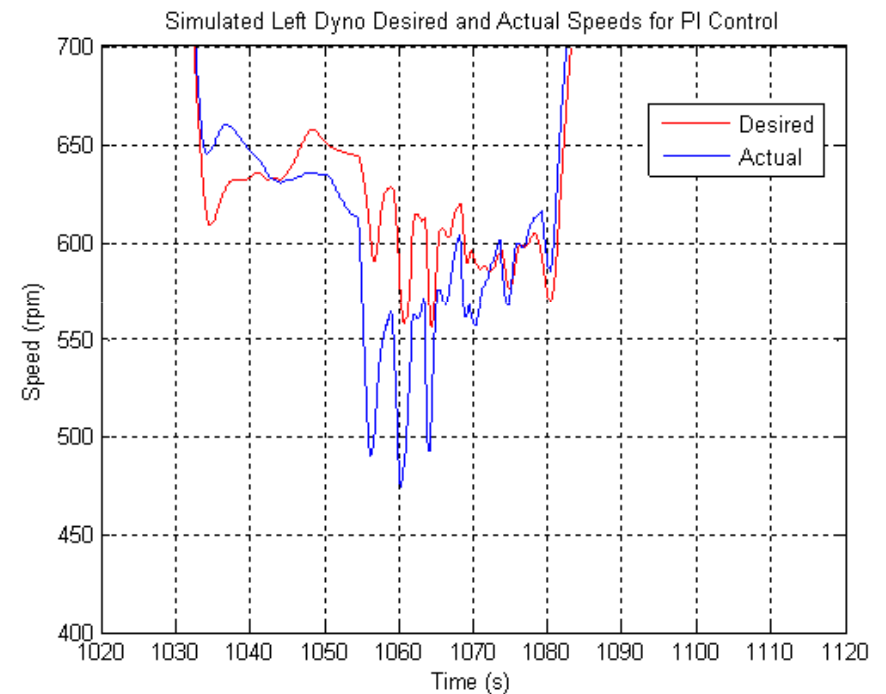
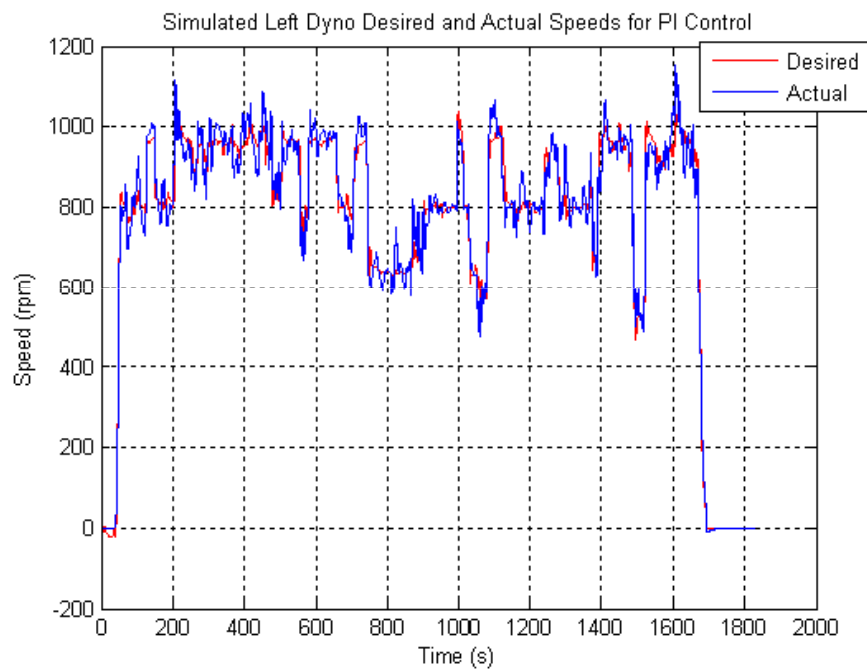
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Simulated Results for PI Control

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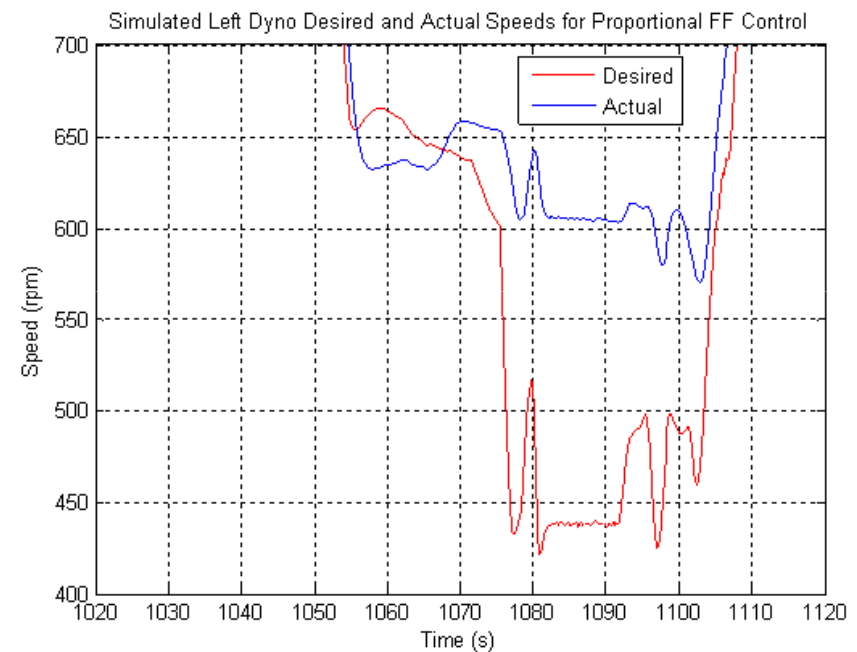
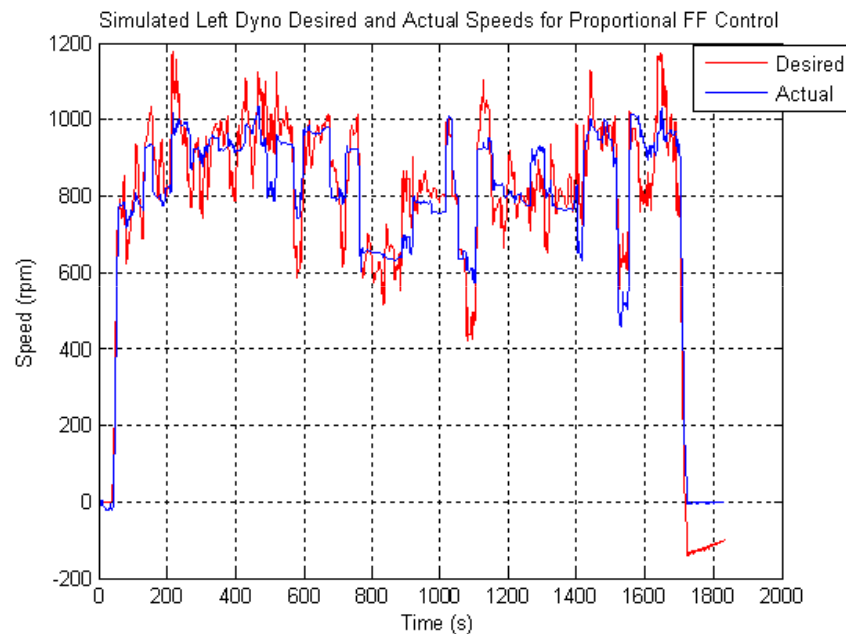
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Simulated Results for Proportional/FF Control

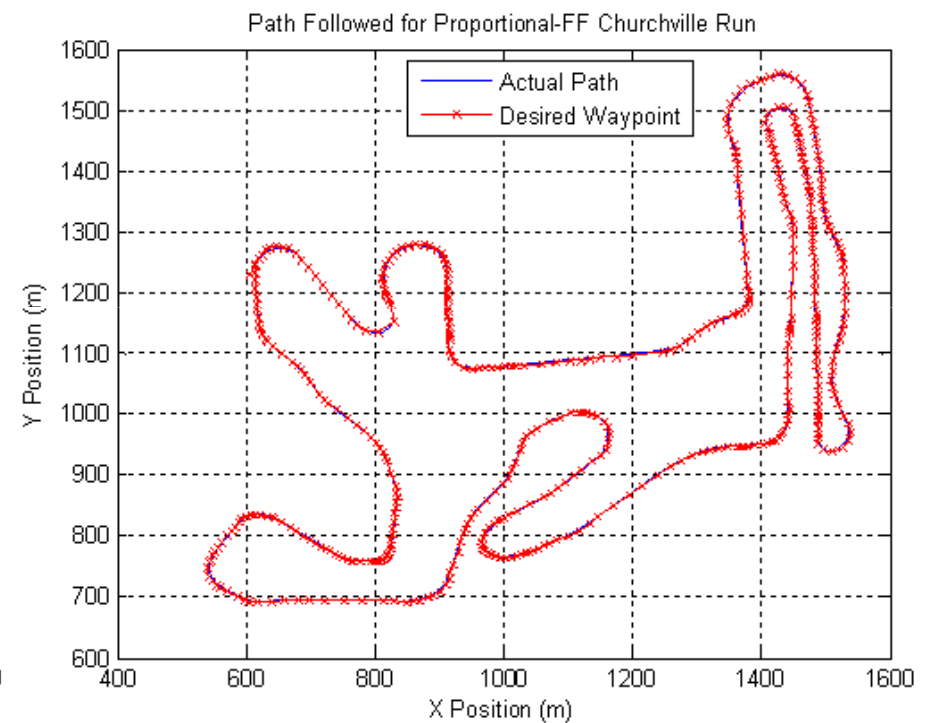
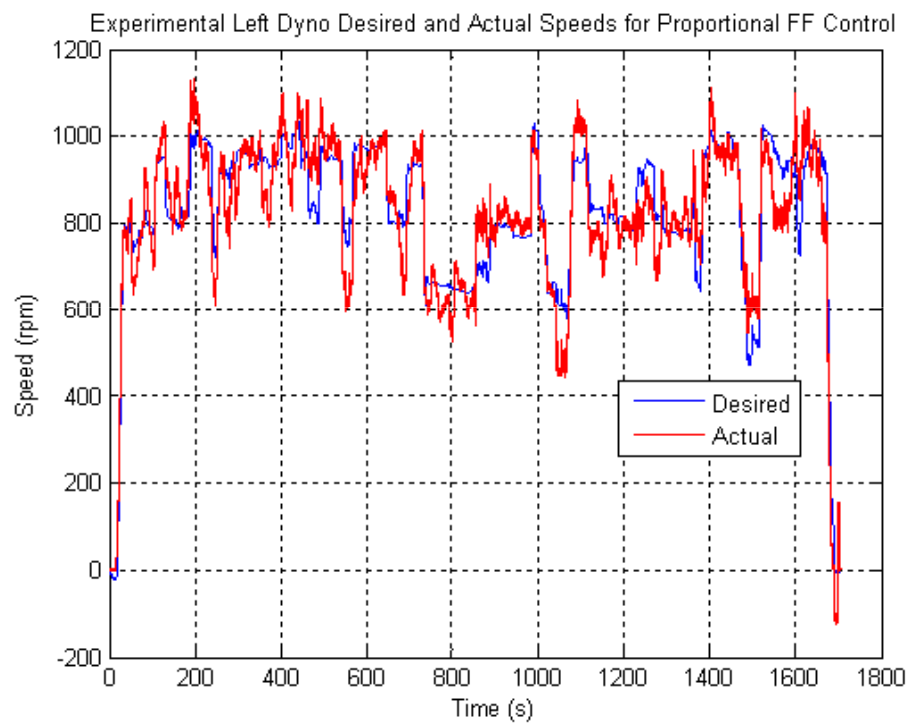
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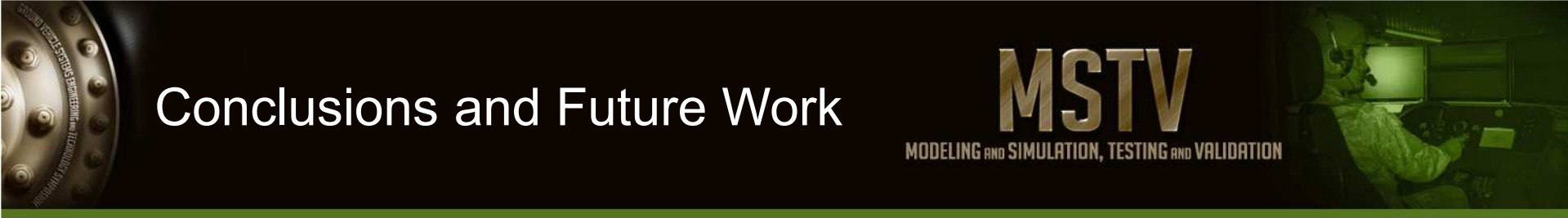
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Experimental Results for Proportional/FF Control

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Conclusions and Future Work

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- Mobility Load Emulation Capability Developed
 - Modularity
 - Repeatability
 - Simulated results match experimental results
- Realistic test environment for hybrid electric components
- Presently interfacing HERMIT with new dynos
- Performance can be improved