Advancing Energy Analysis at GM with the New VERDE Toolchain





Anamitra Bhattacharyya, GM

- Vehicle energy model co-simulation specialist
- Analysis tool development and co-simulation tool and method development
- Previous experience at Cummins and FEV
- M.S. in mechanical engineering from Wayne State University and a B.S. in mechanical engineering from VNIT India.

Nate Wilmot, GM



- Engineering manager of the Energy Model and Toolchain Development Team
- Advance GM's virtual capability in the vehicle energy and performance domain.
- 25+ years of automotive industry experience
- M.S. in mechanical engineering from the University of Michigan, a B.S. in mechanical engineering from Cornell University, and a B.A. in physics from Ithaca College.

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(he/him/his)

Anamitra Bhattacharyya Vehicle Energy Co-sim Specialist



(he/him/his)



Agenda





VERDE	Tool Details and	VERDE Features	What's Next
Introduction	Execution	and Use Cases	

zero crashes

zero emissions





ero congestion

Energy Model and Toolchain Development Team

zero emissions

- Provide the analytical tools, virtual infrastructure, and user support to engineer efficient, capable, and exciting vehicles.
- Manage and advance the suite of tools used to predict, analyze, develop, validate core vehicle performance attributes such as:



GM Vehicle Energy Modeling Journey





Biggest Challenges & Opportunities





Co-Simulation – Leverage other tools; collaborate with other domains

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VERDE Introduction





Why an In-House tool?



Why **NOT** use a pre-packaged COTS tool for this analysis?

- Not difficult to develop these models at the highest level
- Many people/teams do this, and do it well...



Strategic Advantages:





Tool Details and Execution

Advancing Energy Analysis at GM with the new VERDE Tool Chain

VERDE GUI



Legacy GUI: based on GM custom MATLAB toolbox

- Needs Simulink model to be loaded
- Complex and layered navigation
- Difficult to onboard new users
- Difficult to add advanced features

VERDE GUI: based on MATLAB App Designer

- GUI can function independent of the model
- GUI is easy to navigate
- GUI is Intuitive and integrates many help features
- Supports several advanced features related to data import, tools integration etc.

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VERDE GUI Features

Provides several user-friendly features

- Ribbon with buttons
- Intuitive navigation
 - Multilayer Tabs
 - Dynamic tree options
 - Interactive system graphics
- Dynamic model configuration
 - Right click tree node options

MATLAB[®] App Designer

Parameter selection from GUI



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VERDE Model



VERDE GUI interacts with Simulink models to set up and run the simulations

- Simulink variants
- Reference subsystems and models
- Bus architecture
- Simscape toolbox
- Auto configurable from GUI
- Complexity
 - More than 2000 parameters

Simscap

- Around 100 variants
- Over 200,000 blocks

SIMULINK

and more ..



Supporting Tools, Pre-Processing



Energy Tool-Chain features following pre-processing capability

- Compare and edit one or more models
- Set up and run DOE using a seed model
- Manage input data from Database
- Submit and retrieve jobs from HPC (with / without DOE)

MATLAB[®] App Designer

etc.



Supporting Tools, Post-Processing



Energy Tool-Chain features following post-processing capability

- Model results post-processing
 - Plot time history
 - Export model results
 - Use various post processing tools, ex. perform Energy
 Balance Analysis
- Automated model correlation tool
 - Common logic is used between test data and simulation

MATLAB[®] App Designer

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etc..



Executing a VERDE Model

Supported architectures and Standard Process





Model Prediction Standalone Use





Model Prediction, Tool Connection







VERDE Features and Use Cases

Advancing Energy Analysis at GM with the new VERDE Tool Chain

VERDE Features





Semi Coupled GUI and Tool





Co-Simulation Framework and COTS Tools



- Supports direct co-simulation
 - Thermal systems model for EV
 - Lap time Simulation
 - Vehicle and driveline dynamics
 - ICE thermal performance and emissions
- Supports Virtual HIL
 - Enables co-simulation with production control
- Supports FMI 2.0
 - ➢ GT Thermal, AMESIM, HV Battery etc.
- Modular design and extracted subsystems
 - Standalone module can be integrated with
 - Vehicle dynamics simulation
 - Lap time simulation / CarSim
- Supports Driver In Loop, can run real time



VERDE and Database

- VERDE input data can be accessed from a database
- VERDE simulation result metrics are stored in a database for further analytics and reporting



VERDE Tool Use, Flexibility Example





VERDE Tool Use, Fidelity Example





VERDE Tool Use, AMESIM Co-sim Example







VERDE Tool Use, NVH Co-sim Example

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VERDE Model Closed Loop Learning







- Main goals:
 - Assess the ability of the tool to accurately generate METRICS AND BEHAVIORS
 - Ensure generation of this information is easy and repeatable
 - Use feedback to highlight model improvement needs and ACT on the learning



Model

VERDE Transition Impact?







VERDE Tool Management Learnings





Conclusions and Future Work

- Enhance controls integration at varying fidelity levels
- Full database integration
 - Automated data updates and model construction
 - Data Mining inputs and outputs
- Model Accuracy & Precision Improvements
 - Driven by closed loop learning
- Co-Simulation
 - Keep updated with COTS tools (updates & new tools)
 - Reduce simulation build & run time
- Drive cross-enterprise alignment
 - Inputs/outputs, connections, workflows, data processing
- Integrate new functionality into VERDE ecosystem
 - Durability Modeling, Fast/Backwards Looking Models







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GM Team







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Purvi Limaye



Nishant Singh



Andrew Kim



Paul Mrozek

Jaesoo Lee



William Seldon



Jinbiao Li



Caelan Purnama



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Anamitra Bhattacharyya Vehicle Energy Co-sim Specialist



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