# HPCMP CREATE™

# Mercury Overview

**26 OCT 2020**

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# Outline

- **CREATE-GV Project**
  - Mercury
  - MAT
  - GVI
- **Mercury**
  - Organization
  - Capabilities
  - Components
  - Usage
- **GVI demo**
  - Vehicle model example

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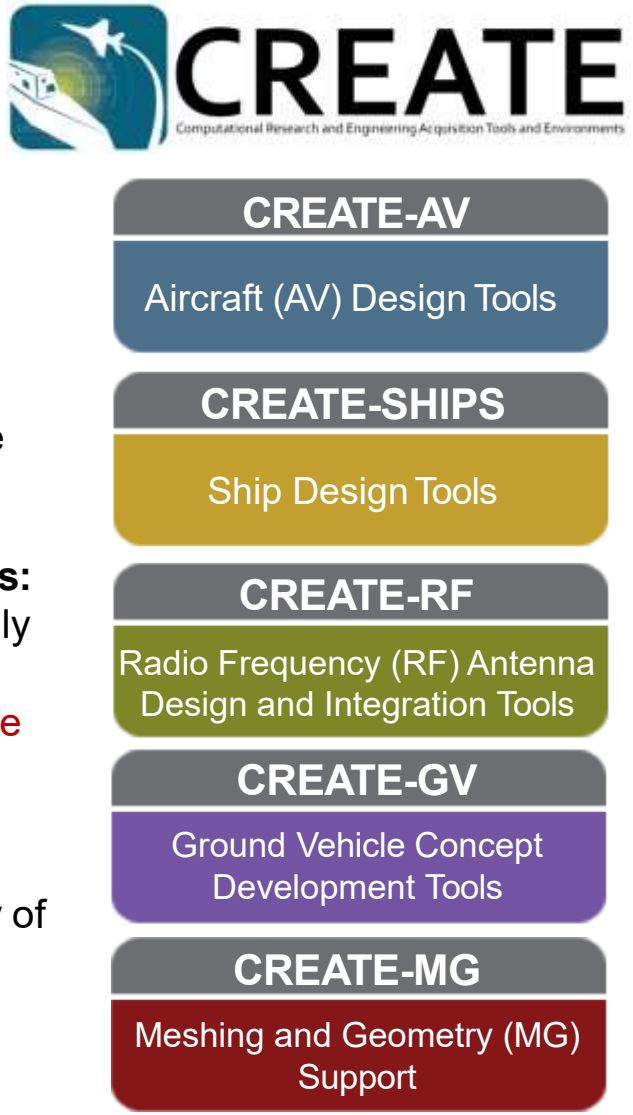
# Computational Research and Engineering Acquisition Tools and Environments (CREATE)

**CREATE is a multi-phase program that started in 2008, to develop and deploy four (now five) computational engineering tool sets for acquisition engineers**

- **Aircraft (AV) Design Tools:** Fixed-wing aircraft, rotorcraft, conceptual design, trade-space exploration and operational testing and transition
- **Ship Design Tools:** Shock/damage, hydrodynamics, early-stage design & trade-space exploration, and operational testing and transition
- **Radio Frequency (RF) Antenna Design and Integration Tools:** Conceptual design and detailed analysis tools relevant to virtually all DOD platforms
- **Ground Vehicles (GV) Tools:** End-to-end mobility solver, provide rapid, physics-based data for concept and requirements development and trade-space analysis
- **Meshing and Geometry (MG) Support:** The geometry and meshing project improves the ease, speed, flexibility, and quality of geometry and mesh generation, and enables the generation of CAD-neutral digital representations and product models of weapons systems & platforms and operational terrains and environments



# CREATE-GV Development Team

DOD HPC MODERNIZATION PROGRAM

ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER

DEVCOM GROUND VEHICLE SYSTEMS CENTER

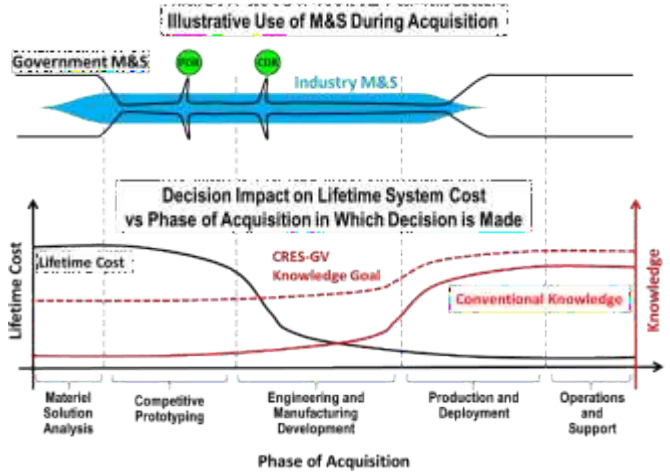
MISSISSIPPI STATE UNIVERSITY

WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

# Program Direction for CREATE-GV

## Enduring Key Program Goals:

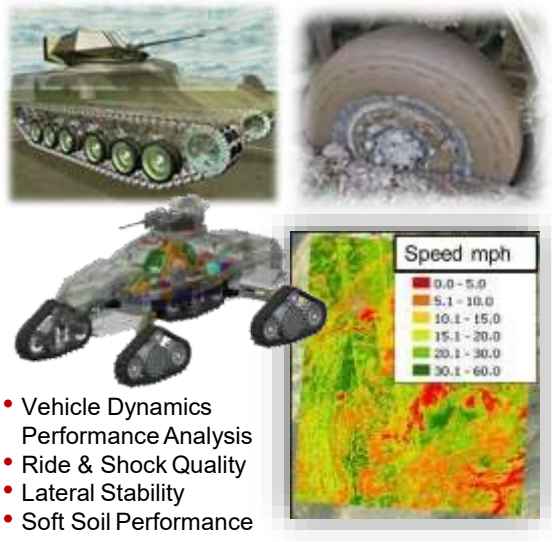
- Enable greater and earlier physics informed performance assessments for analysis of trades in ground vehicle system development
- Enable a new ground vehicle acquisition paradigm by making sound performance data available for use in tradespace analysis
- Achieve via software tools tailored for HPCMP major shared HPC resources with unlimited government use and distribution rights *(unrestricted rights for redistribution and use in source and binary forms, with or without modification)*




## Captured Stakeholder Priorities:

- Mobility performance assessments via improved physics-based modeling and simulation processes
- Rapid physics-based data for use in tradespace analysis methods

### Mobility and Dynamics

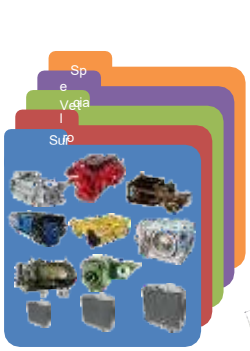


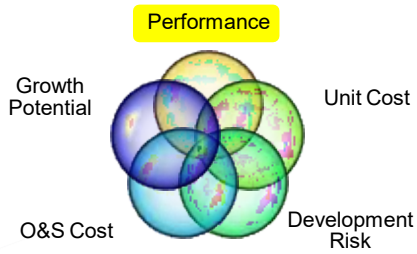

- Vehicle Dynamics Performance Analysis
- Ride & Shock Quality
- Lateral Stability
- Soft Soil Performance

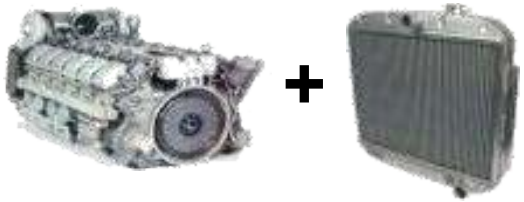
### Vehicle Performance for Trade Space

# CREATE-GV Focus is on <u>Performance</u>

Finding the sweet-spot among competing objectives (**<u>performance</u>**, unit cost, O&S costs, development risk, and growth potential) is a non-trivial task.





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Ground vehicles are complex systems with many interrelated subsystems.

**<u>Early decisions</u>** have the largest impact on lifecycle cost and are made when knowledge is at a minimum.

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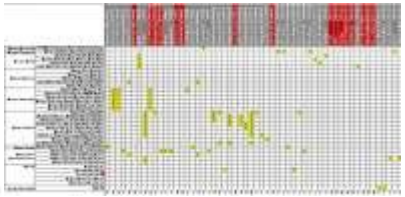
# Targeted Impact to Trades Analysis

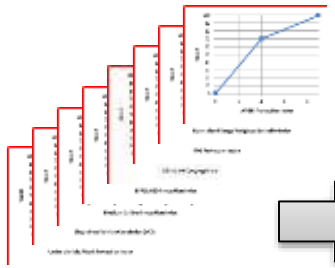
## Concepts from PEO-GCS briefing on WSTAT

Requirements

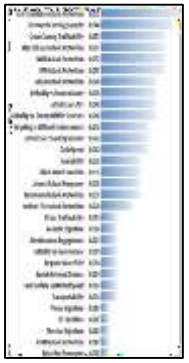
Functional Objective to Requirements Mapping



Value Functions

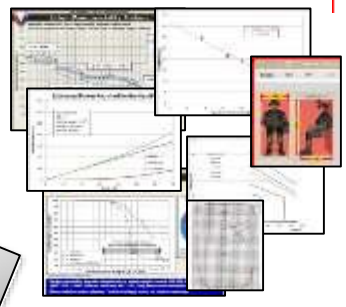


Priority Weightings



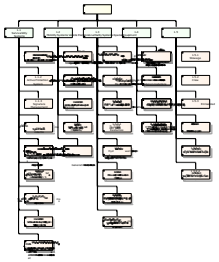
Functional Objectives


Metrics

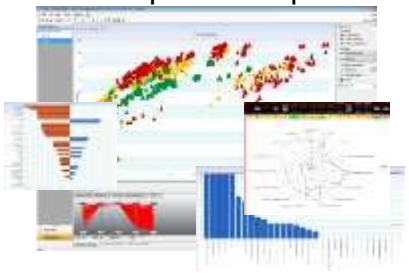


Product Structure to Functional Objective Mapping

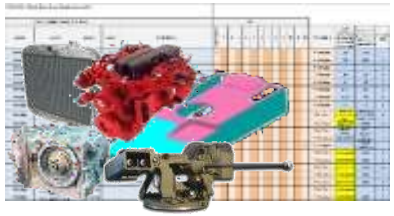
Product Structure



Graphical Output



Technology Options

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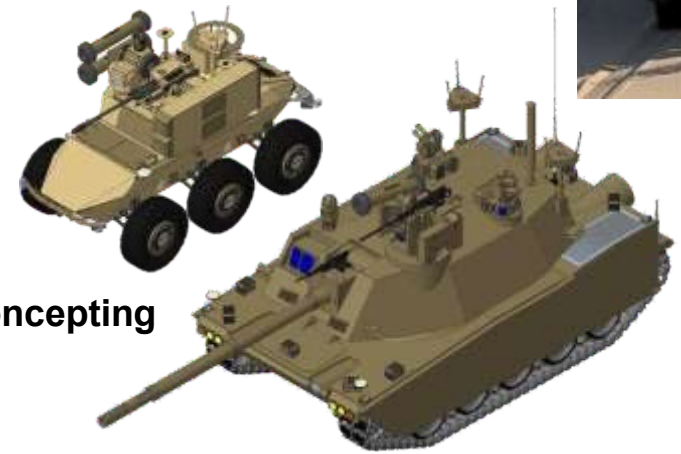
# User Orgs & Supported Programs

- **Currently gaining use in AFC CCDC-GVSC**
  - Used for design concepts for requirements/specs
  - Used on Army NGCV-OMFV Program
  - Used on USMC ARV Program
  - Used on Army LRV Program
- **Expecting usage to expand to new Orgs with V3.0-4.0**
  - Targeting AFC CCDC-DAC (Analysis for AoAs)
  - Targeting USMC MARCORSYSCOM (USMC design requirements/specs)
  - Targeting Navy ONR/NRL (Navy S&T purposes)
  - Targeting ERDC (Operation suitability assessments)
- **Expecting usage to impact more Programs with V3.0-4.0**
  - Army NGCV-OMFV (continuing use)
  - Army NGCV-OMT
  - Army NGCV-RCV-Light
  - Army NGCV-RCV-Medium
  - Army NGCV-RCV-Heavy
  - USMC ARV (continuing use)
  - Army MPF
  - Army GMV1.0
  - USMC ACV
  - Army AMPV

LRV Concept

ACV Prototype



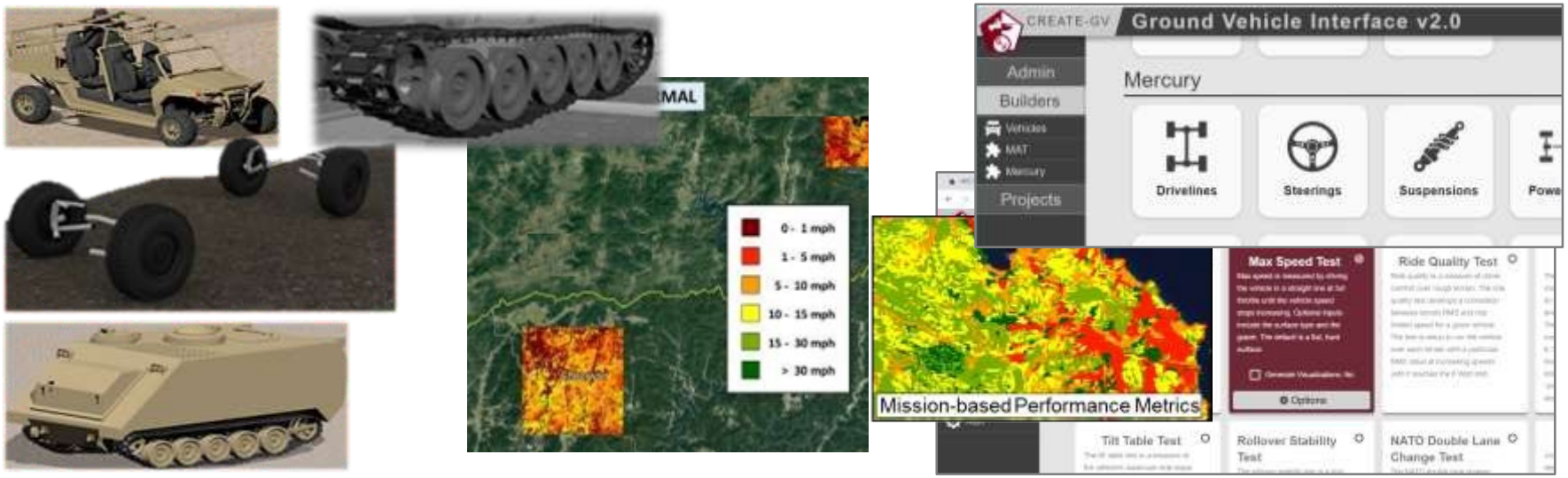
Concepting

# CREATE-GV Tool Set Description

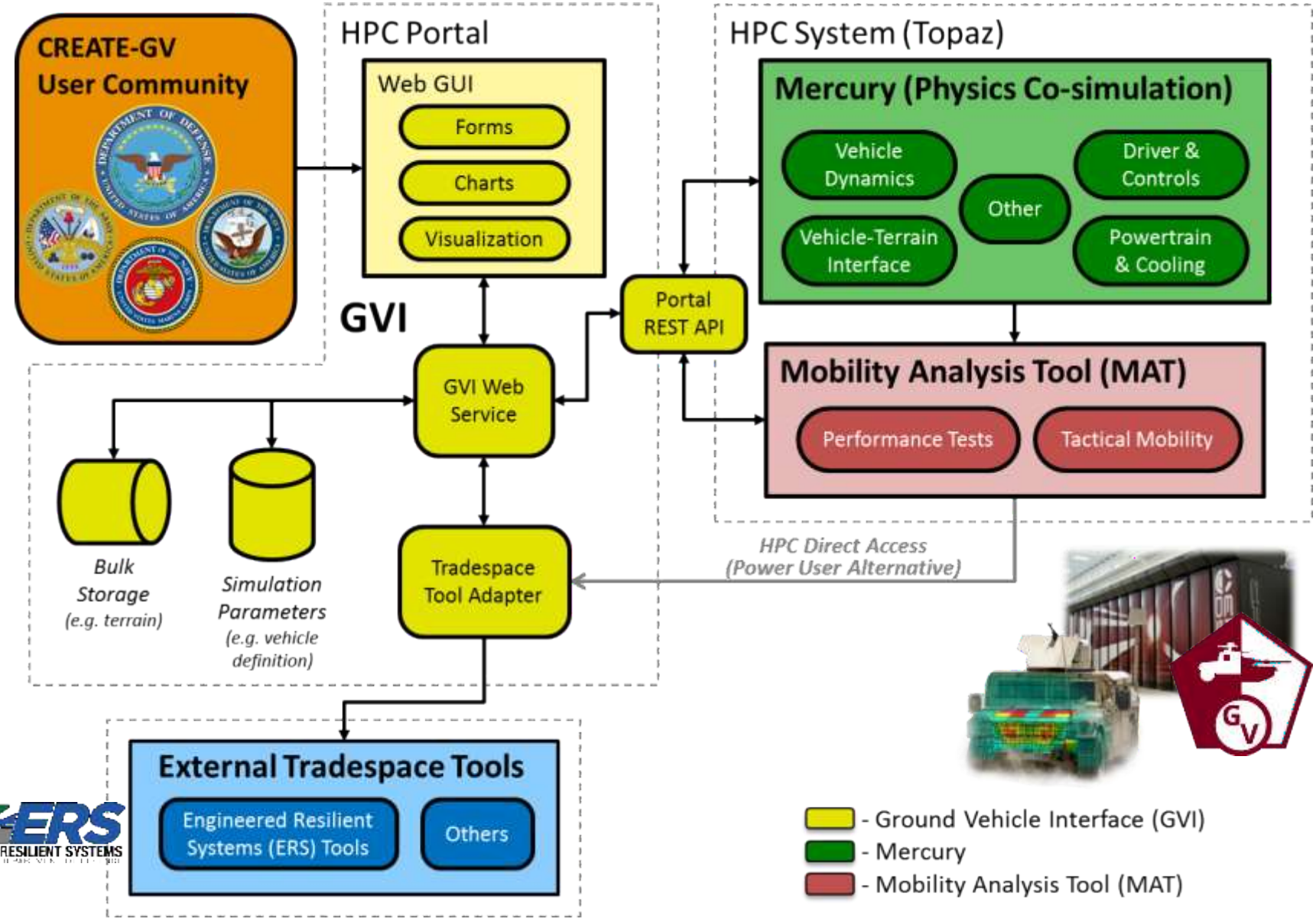
## *Mercury (Flagship Product) & Expansion Tools:*

The CREATE-GV program is developing high-fidelity, physics-based software tools for analyzing ground vehicle concept designs and the mobility performance of wheeled and tracked ground vehicles, covering manned and unmanned vehicle applications.

- Mercury: Physics-based co-simulation tool for simulating proving-ground performance tests used as acquisition requirements.
- Mobility Analysis Tool (MAT): Computational tool for predicting mission-level mobility performance metrics used as requirements.
- Ground Vehicle Interface (GVI): Portal-accessible user interface providing a simplified, intuitive process to launch HPC simulations using Mercury and MAT and produce performance data required for robust tradespace analysis.



# CREATE-GV Architecture

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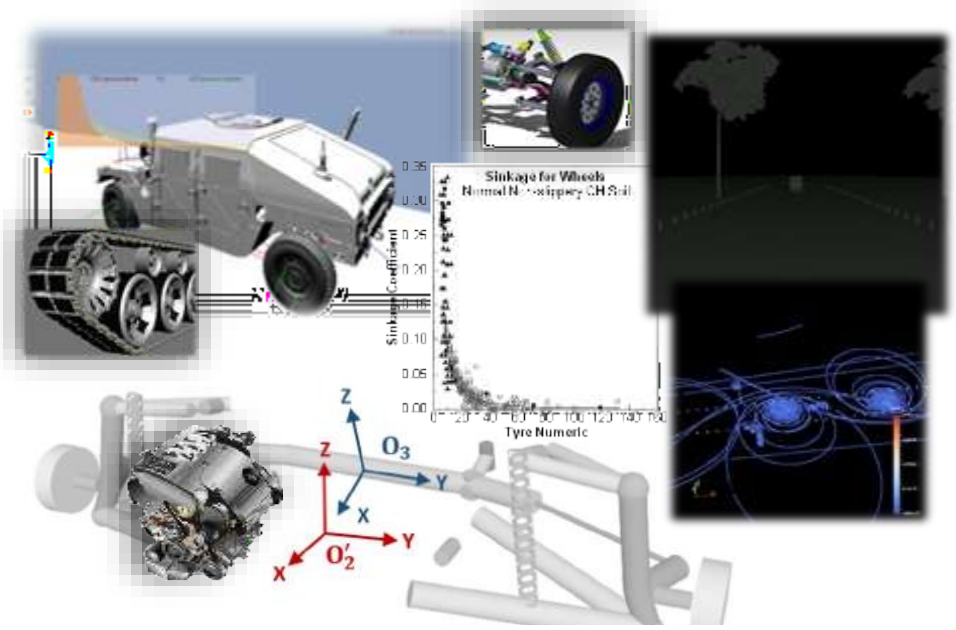
# GV HPC Computational Tools

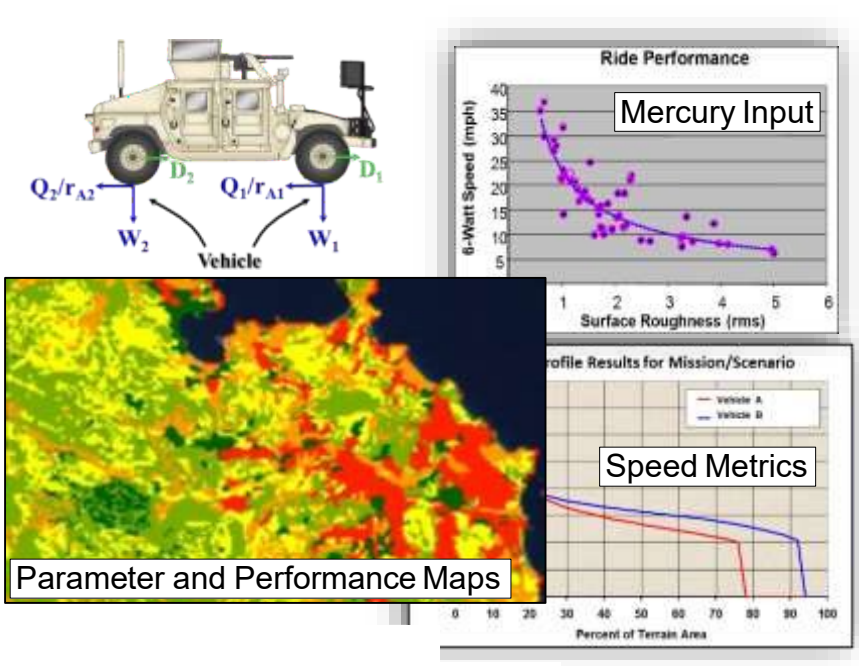
## Mercury

- Simulates engineering performance tests of wheeled and tracked ground vehicles for proving-ground type developmental testing.
- Co-simulation framework for integrating physics domains.
  - Powertrain
  - Vehicle Dynamics (wheels and tracks)
  - Tire-soil & track-soil interaction
  - Sensor-environment interaction
  - Flexibility for others, as needed

## Mobility Analysis Tool (MAT)

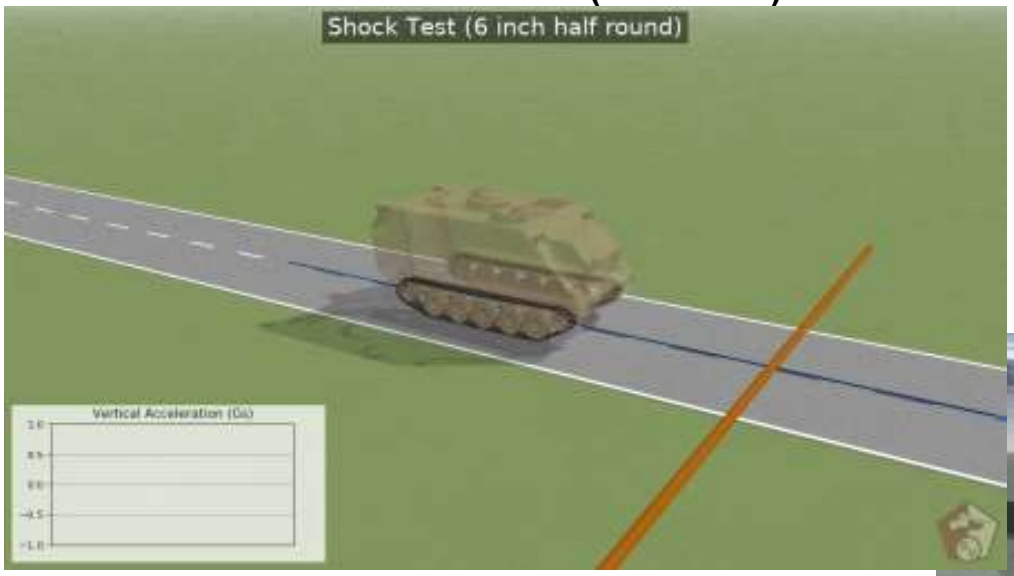
- Converts vehicle performance metrics and terrain information into mission-based analysis of performance over large areas of terrain.
- Predicts multiple metrics currently used in acquisition processes.
  - % NOGO
  - Mission rating speeds
  - Off-road speed ratings
  - $VCI_1$



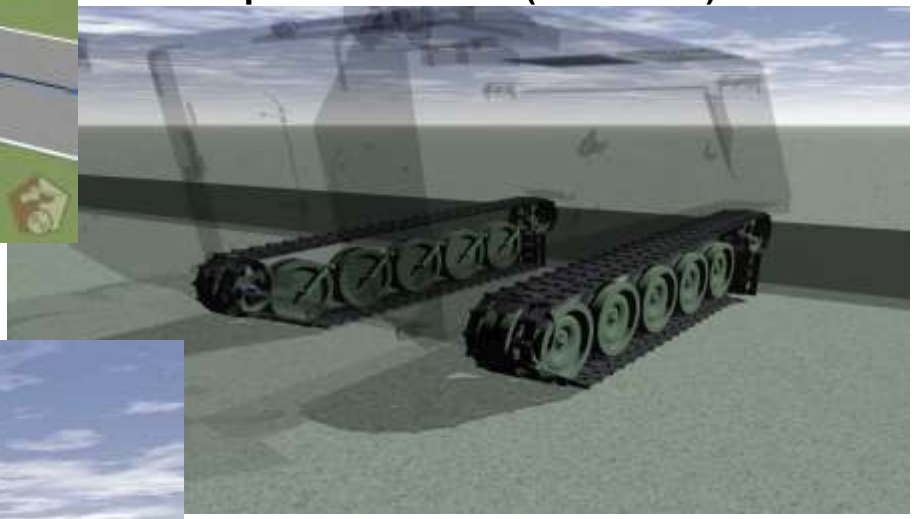



# Mercury Simulated Test Examples

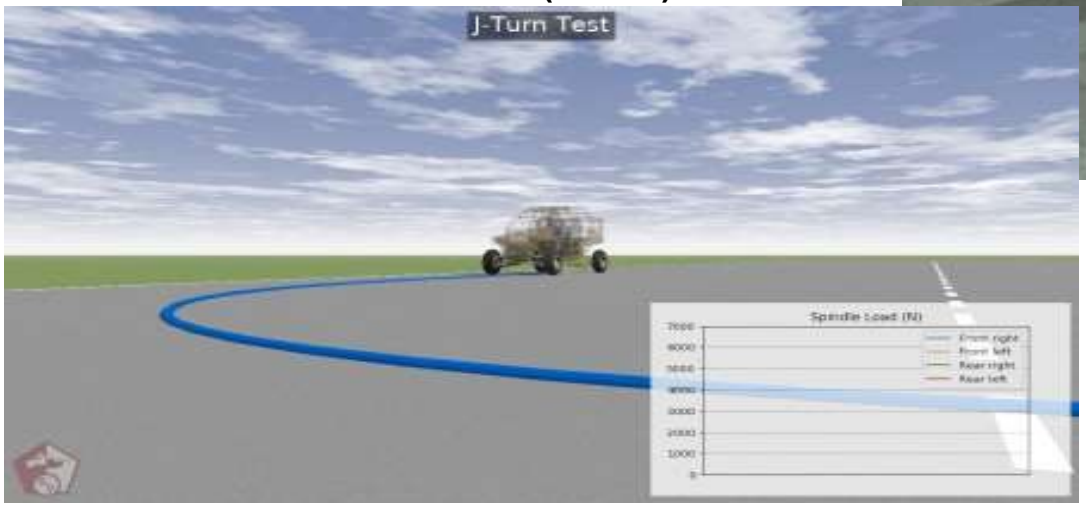
### Shock Obstacle Test (M113APC)




### Step Obstacle Test (M113APC)



### J-Turn Test (MRZR)



# GV Tool Set Status at V3.0

- **Key Capability Highlights**
  - Model both wheeled and tracked vehicles with various suspension types
    - Legacy and modern vehicle component technologies
  - Automatically simulate/compute about half of the primary mobility test performance metrics used as acquisition requirements/specs
    - Developmental testing and mission-level requirements/specs
  - Deployed for primary usage on DSRC HPCs
    - Onyx HPC (ERDC DSRC)
    - HPC Portal Appliance (app access)

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# GV Tool Set Access and Users at V3.0

- **Modern user access via user-friendly web-based interface**
  - Includes access to legacy benchmark terrain sets
  - Provides secure access for new terrain sets
  - Allows use of legacy vehicle models via import feature
  - Provides instant in-app access to guidance on modeling parameters
  - Enables built-in knowledge sharing for SME-based modeling standards that predict metrics well (i.e., acquisition requirements/specs)
    - Requires more than just capable modeling tools
    - Requires SME awareness on modeling methods and simulation setup
    - Requires in-depth understanding of performance test standards (e.g.,ATEC TOPs)
- **User base growth is just starting**
  - Approximately 75 total individual license holders
  - Onboarding is continuing
    - Expected/traditional user orgs (targeted used cases)
    - Unexpected/new user orgs (coming with new use cases)

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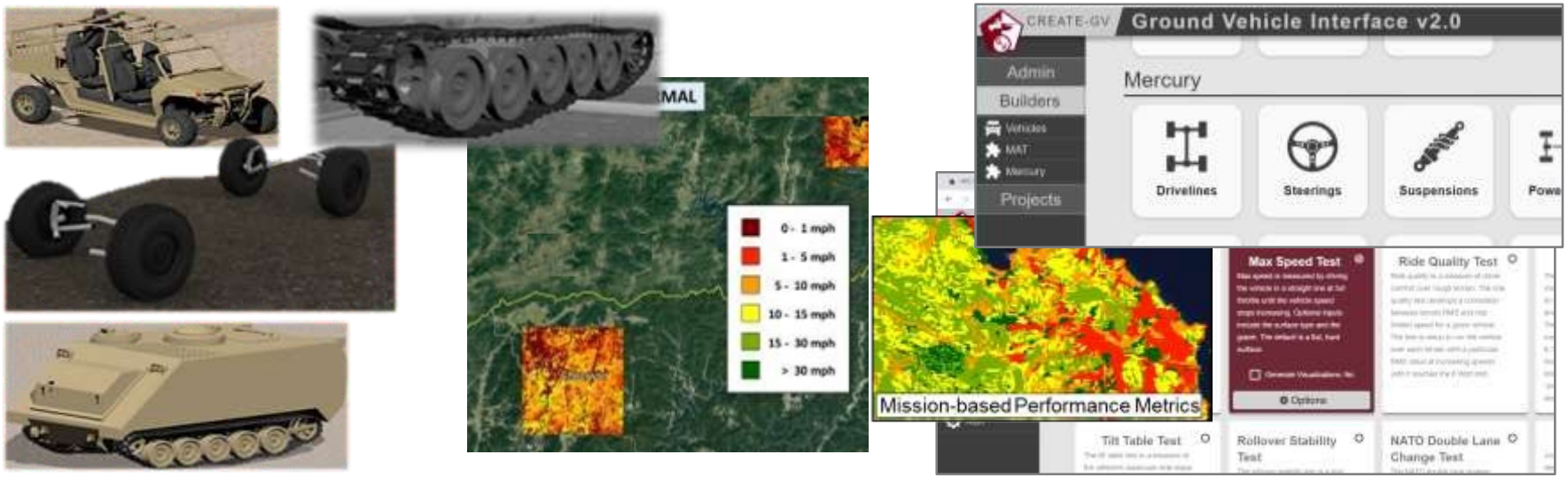
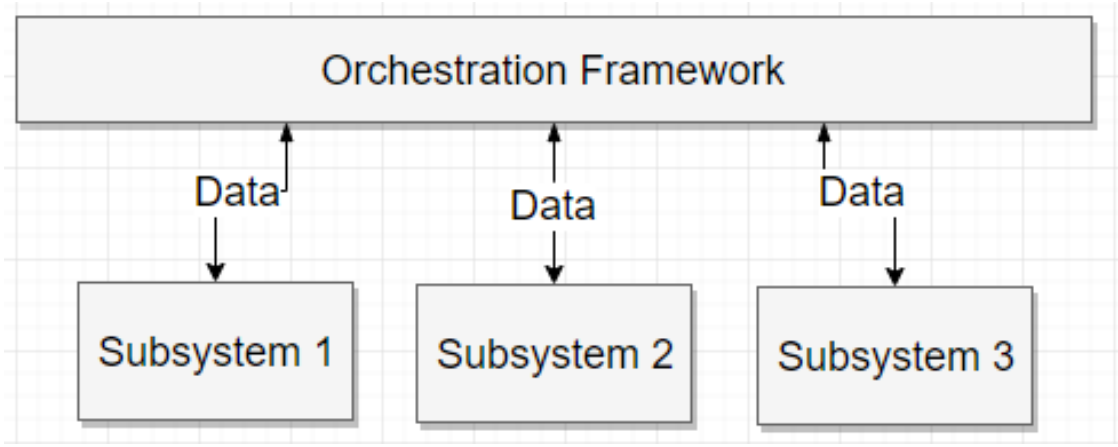


# Mercury Overview

- **High-fidelity Co-simulation**
  - Detailed vehicle models
    - Suspension, driveline, steering, powertrain, chassis, tires/tracks, driver models, etc.
  - Detailed vehicle/terrain interaction modeling
    - Terrain characterization, tire/track details
  - Defined simulation procedure
  - Extensive logging and metric calculations
  - Flexible architecture to enable rapid simulation development and testing

# Mercury Overview

- **Co-simulation:**
  - Synchronized execution of multiple context-specific simulations
  - Allows for the use of “specialized” systems within a larger framework
  - Combine domain expertise from disparate areas

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# Capabilities

- **Mobility Tests**
  - Specifically defined simulation procedure and associated metric
  - Generally modeled after physical vehicle tests
  - Currently implemented / tested:

| | | |
|---|---|---|
| **Ride quality (RMS course)** | Drawbar Pull | Tilt Table |
| Shock (Half-rounds) | Maximum Speed | Vehicle Cone Index (VCI) |
| Steady-state circular turn | Spindle Load | Wall-to-wall turn |
| NATO double lane change | Sand Slope Climb | Steady-state wheel angle |

- **Designed to allow for arbitrary modeling and simulation tasks**
  - Opportunities beyond mobility testing

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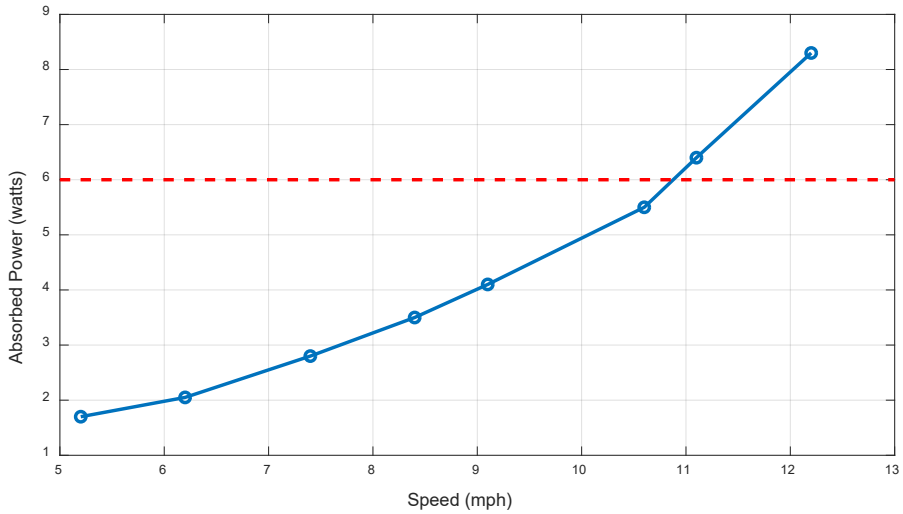
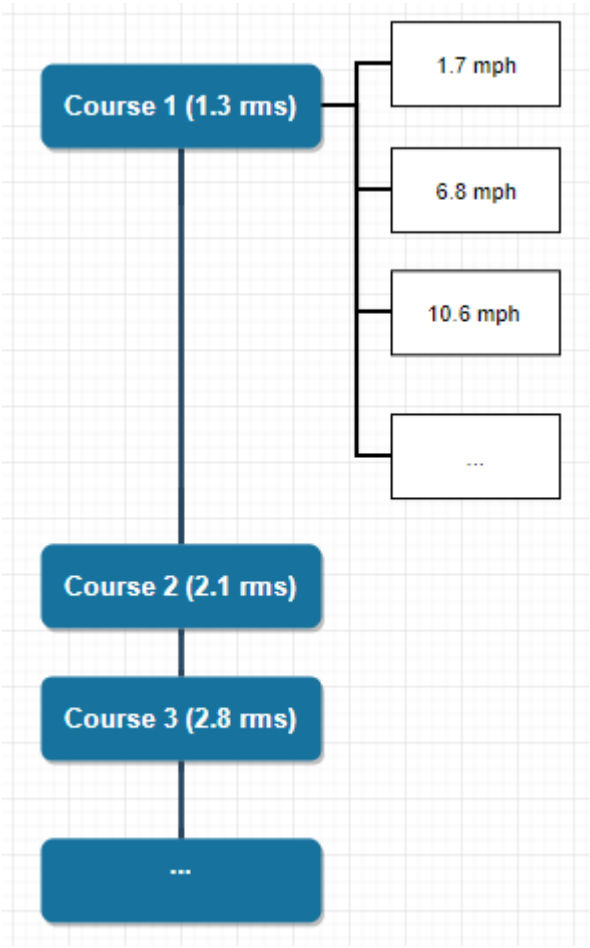
# Capabilities

- **Example: Ride Test (RMS courses)**
  - Multiple simulated courses
    - Most modeled after existing physical courses
  - Multiple speeds for each course
  - Produces a ride-limited speed curve
  - All transparent to the user

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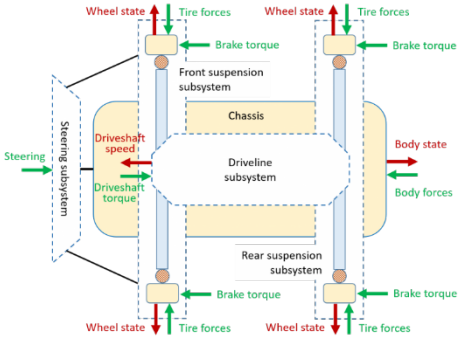
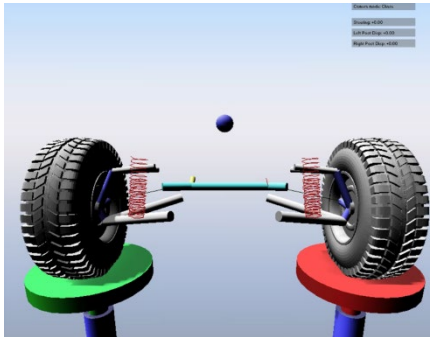
# Components / Tools

- **Four current major components**
  - Vehicle Dynamics
    - Chrono (open-source multi-physics simulation engine)
  - Vehicle / terrain interaction
    - Ground Contact Element (GCE)
    - Fiala tire model
    - Pacejka tire model
    - Others in development / testing
  - **Powertrain**
    - **Powertrain Analysis Computational Environment (PACE)**
    - **Several other powertrain models**
  - Driver models
- **Modular architecture to allow for adding or swapping of components**

# Components / Tools

- **Chrono**
  - Open-source “physics-based modeling and simulation infrastructure”
  - Developed by the University of Wisconsin - Madison
  - Handles the basic mathematical calculations for multi-body dynamics modeling and simulation
    - Bodies, joints, constraints, motors, actuators, springs, dampers, forces, torques, etc.
  - Specially-designed components for vehicle modeling



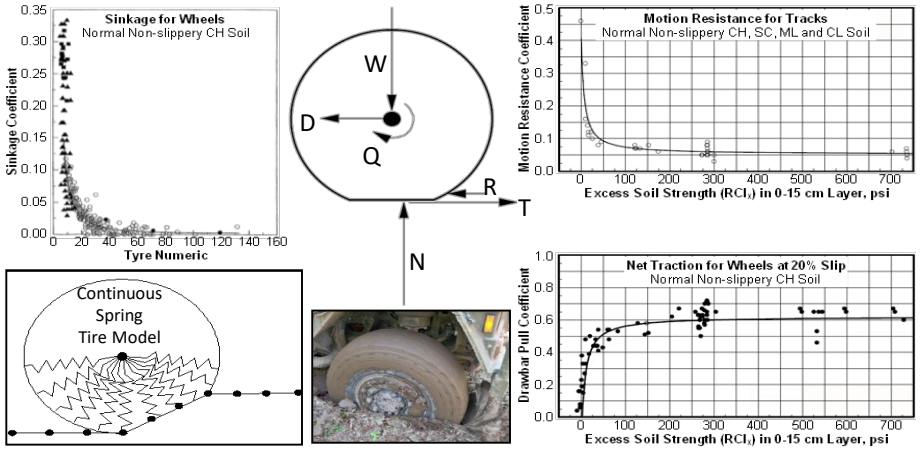



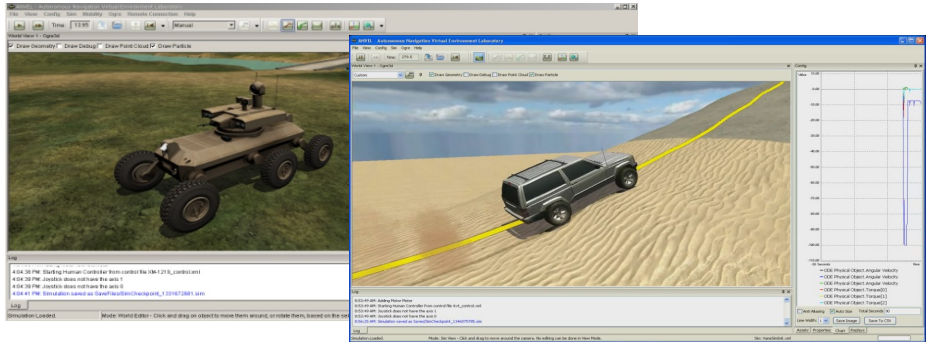
http://projectchrono.org/

# Components / Tools

## Ground Contact Element (GCE)

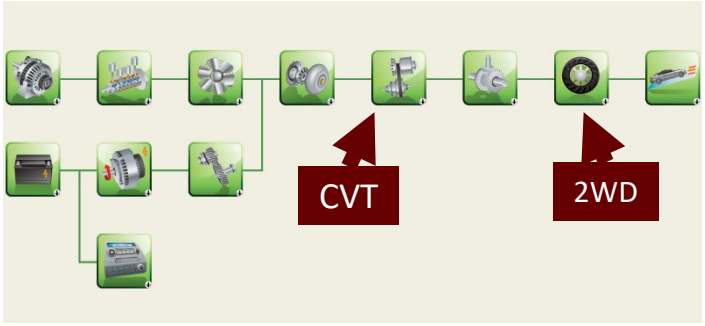
- **Deformable terrain mechanics for 3-D vehicle dynamics simulation**
  - Physics basis → predicts normalized resultant force coefficients parallel to ground
  - Data driven → extensive database for vehicles and single tire/track dynamometers
  - Includes soil type, soil moisture/strength, and surface slipperiness effects
  - Provides ground forces, slip, and sinkage for vehicle dynamics calculations
- **Comprehensive global terrain coverage for M&S predictions**



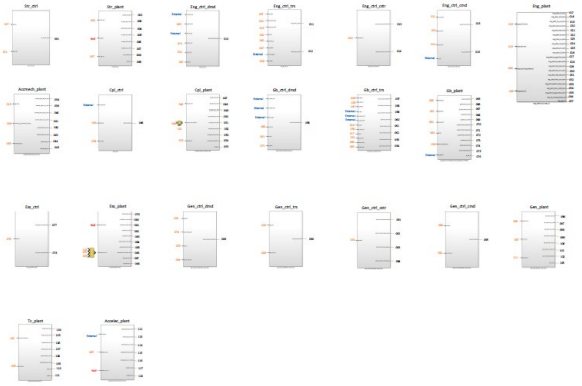



# Components / Tools

- **Powertrain Analysis Computational Environment (PACE)**
  - Architecture to support detailed modeling and simulation of various powertrain architectures
  - Developed by Mississippi State University
  - Allows for accurate modeling of newer powertrain features (e.g. electric and hybrid architectures)
  - Used for vehicle simulations with significant powertrain interactions
  - Transitioning away from specific tool requirements to support a broader range of users

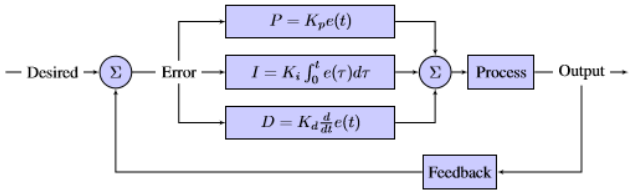


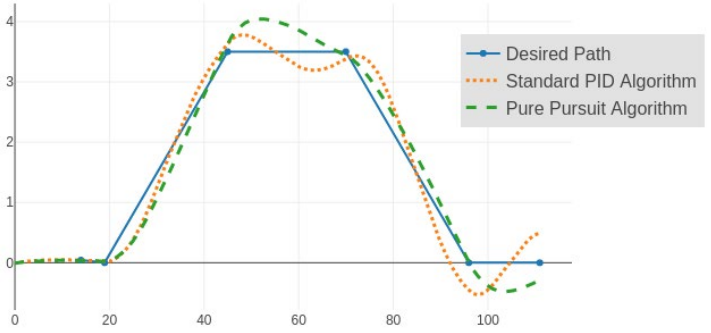

Simulink Model



# Components / Tools

- **Driver Models**
  - Automated control of vehicle through defined simulation procedure
  - Provides for consistent results for a given mobility test (no human factors)
  - Several algorithms have been implemented and compared for various tests



# Usage

- **Detailed vehicle model**
  - Series of JSON files defining all subsystems
- **Test specification**
  - Pre-defined simulation procedure, applicable parameters
  - May require significant HPC computation (e.g. ride/shock)
- **Parameterized vehicle options**
  - Can define a large tradespace of potential vehicles
  - Again may involve significant HPC computation

- **Setup, execution, results through GVI (most users) or command line ("power users")**

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# Mercury 4.0 General Focus Areas

- **PACE – New powertrain capabilities**
- **Ground Contact Element**
  - Additional capabilities for wheeled simulations in soft soil
  - Full tracked support for soft soil in multiple conditions
- **Autonomy support**
  - Additional sensor integration leveraging VANE
  - Autonomous test implementations
- **Ease of use**
  - GVI workflow improvements
  - Additional integration between Mercury and MAT

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