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# *Autonomie Plug&Play Software Architecture*

Project ID # vss_11_rousseau

**2009 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review**

May 19, 2009

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*Argonne National Laboratory*

Sponsored by Lee Slezak

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Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

# Project Overview

## Timeline

- Start – July 2007
- End – September 2010
- 60% Complete

## Budget

- Three year Project
  - 50% DOE
  - 50% GM
- DOE
  - FY08 $ 500k
  - FY09 $ 500k
  - FY10 $ 500k

## Barriers

- Bring technologies to market faster
- Support requirements definition
- Support technology evaluation

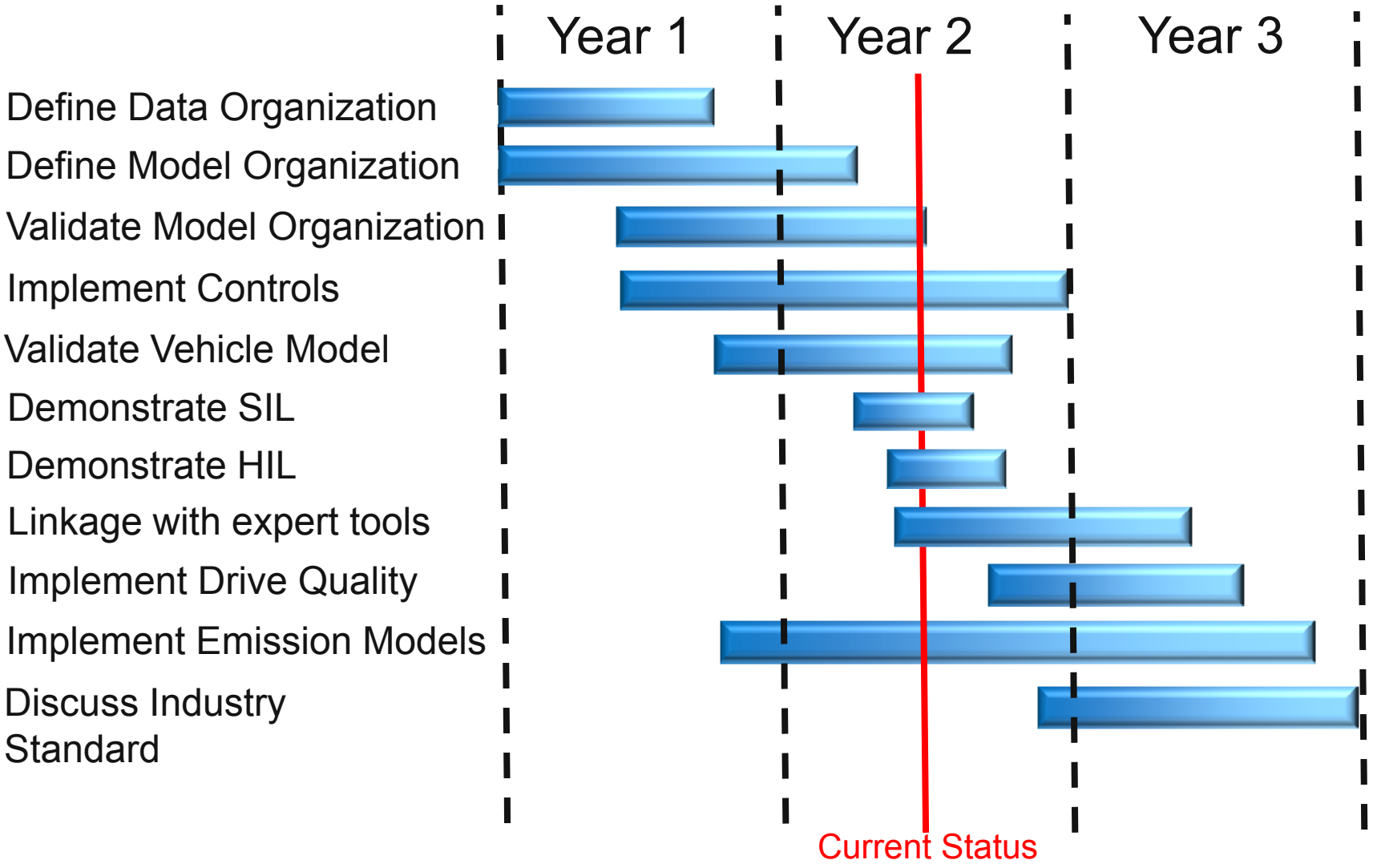
## Partners

- General Motors
- MathWorks
- Mechanical Simulation

# Main Objectives

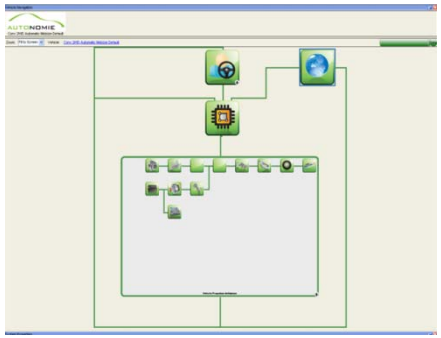
- Provide a software environment and standard framework to unify the entire engineering organization, enterprise-wide, for efficient operation
- Facilitate simulation of subsystems, systems, collections or combinations of systems and subsystems (e. g. powertains), or entire vehicles.
- Integrate models, rapidly and easily, with varying levels of detail/abstraction from simple steady-state to highly detailed physics models through a plug-and-play architecture
- Use one tool throughout the entire development process from modeling (e.g. MIL, SIL), to hardware evaluation (e.g. HIL), to control development (e.g. RCP), and finally through to production
- Include configuration and database management for controlling, storing, and archiving of models, calibration, simulation, analysis, test data and any results or report from these activities

# Milestones

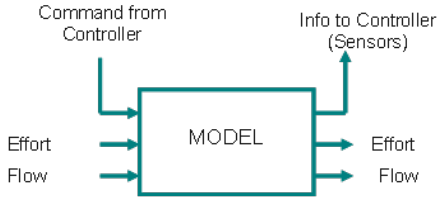

Year 1
Year 2
Year 3
Define Data Organization
Define Model Organization
Validate Model Organization
Implement Controls
Validate Vehicle Model
Demonstrate SIL
Demonstrate HIL
Linkage with expert tools
Implement Drive Quality
Implement Emission Models
Discuss Industry Standard
Current Status

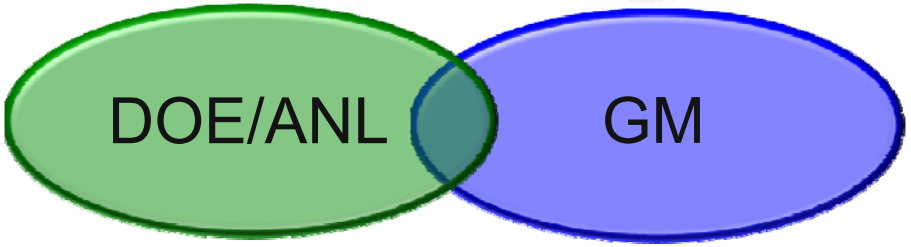
# Approach

## Graphical User Interface



## Component Organization



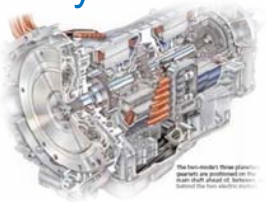

## Hardware Modeling & Analysis Requirements

Engine

Transmission

Vehicle

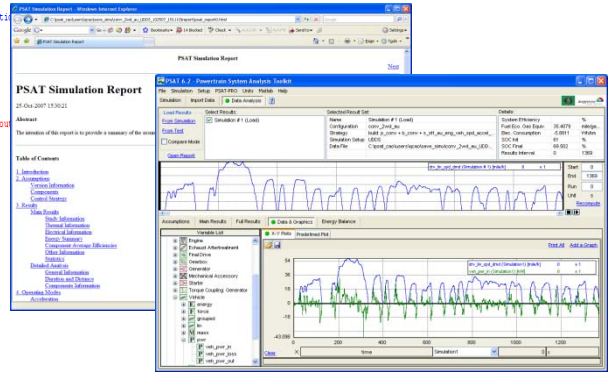
Hybrid



## Data Organization

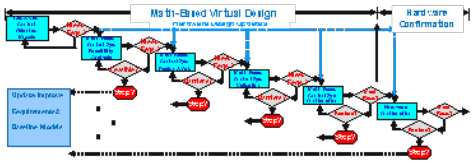
```
<?xml version="1.0" standalone="yes"?>
<ConfigurationDS xmlns="http://tempuri.org/Configuration.xsd">
  <Powertrain name="Conventional">
    <Axle name="2 wheel drive">
      <Transmission name="dm">
        <Position1 name="N/A">
          <Position2 name="N/A">
            <Config name="conv_2wd_dm" type="build" description="2 wheel-drive conventi
              <Component name="dry" row="-2" col="1">
                <Model name="conv_dm_equation" />
                <Model name="conv_dm_f0f1f2" />
              </Component>
              <Component name="str" row="1" col="2" default_transient="lib_trs_str">
                <Model name="map" />
                <Link compo_name="eng" effort_in="2" effort_out="2" flow_in="3" flow_ou
                <Transient model="lib_trs_str" />
              </Component>
```

## Post-processing Tools




## Control Algorithm Design & Analysis Requirements

Process




Control

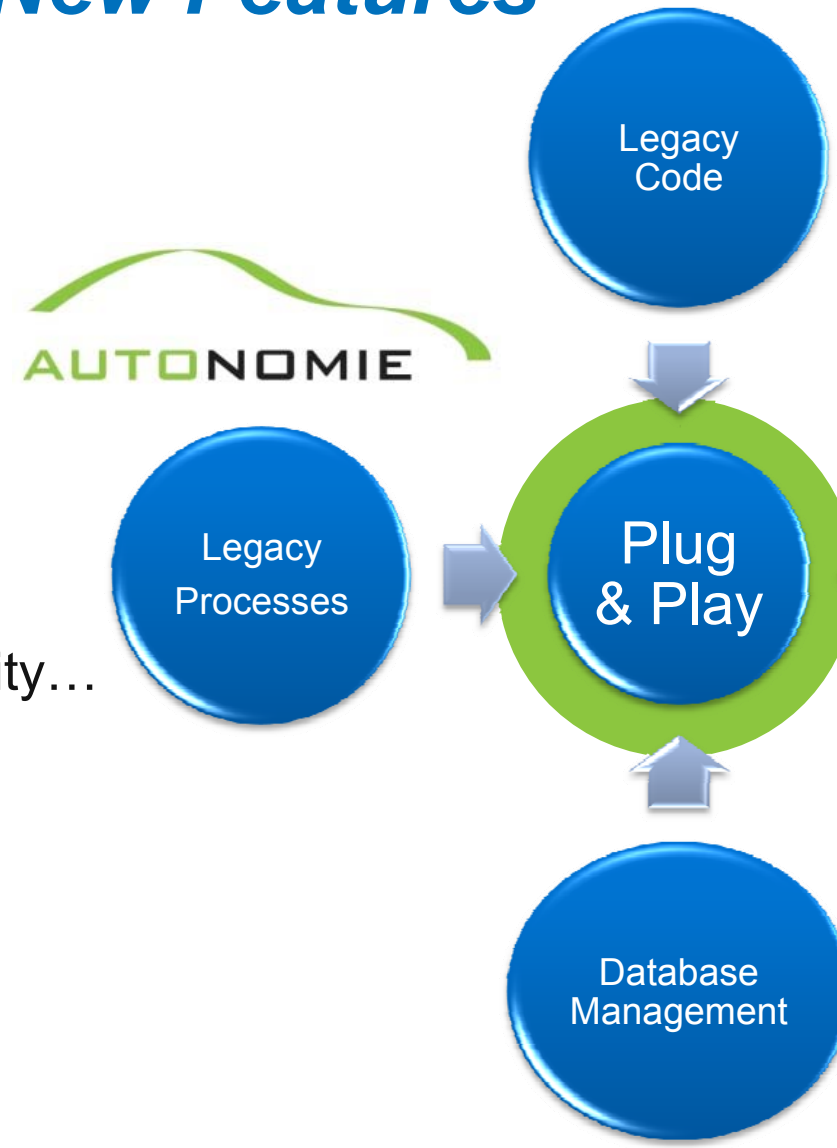
# Key Benefits


- Flexibility & Reusability
- Customizable architectures
- Common Nomenclature
- Code Neutral

- Sorts technologies quickly to reduce hardware build iterations
- Reduces/eliminates duplicate modeling and analysis work
- Delivers designs that balance Fuel Economy, Emissions and Drivability (FEED) requirements

- Database Management
- Provides common methods and tools for comparing/evaluating technologies

# Key New Features



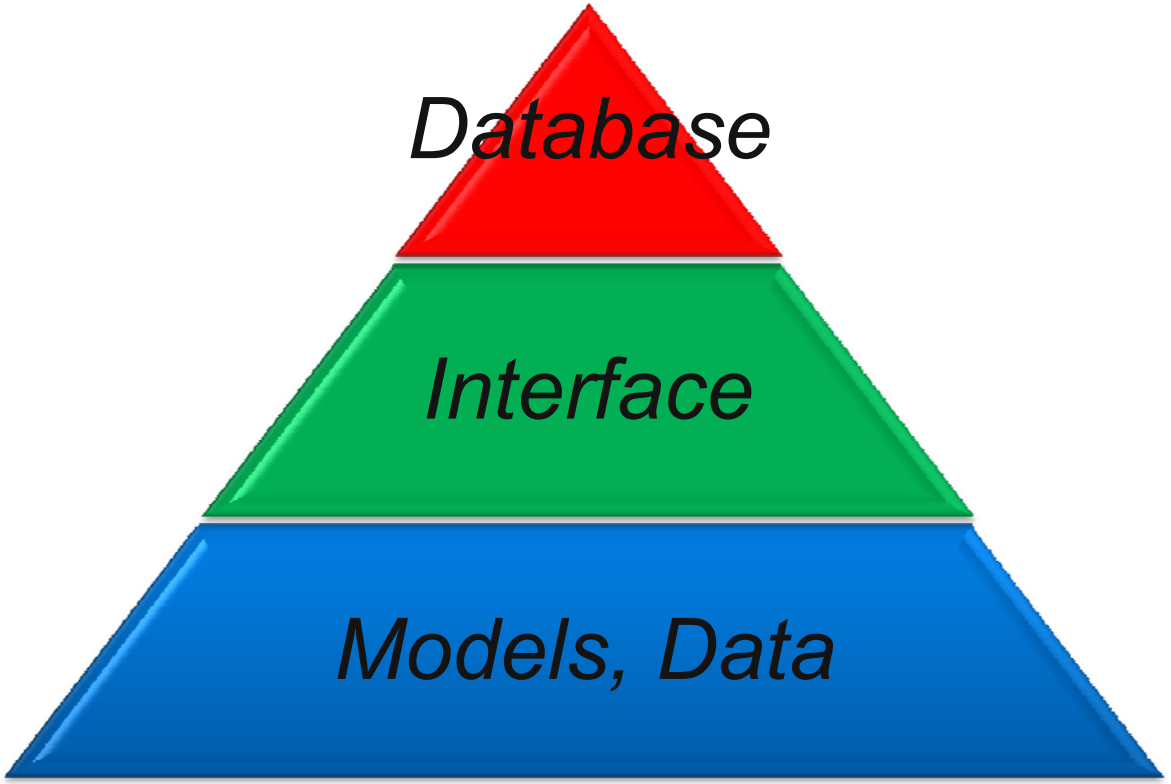

Implement any language
Automated process to import legacy code (data, model, control, process)…

Calibration
Validation
Tuning
Drive Quality…

CarSim
GTPower
Amesim
AVL Drive…

Version Control
Database Search

# AUTONOMIE




- Maximum Reusability
- Maximum Flexibility
- Selectable Complexity
- Code Neutrality

**Models, Data**

- User Access Control
- Enterprise Wide Solution
- Version Control
- Database Search

**Database**

**Graphical User Interface**

- Setup Simulation
- Generic Processes
- Results Visualization
- Linkage with Other Tools

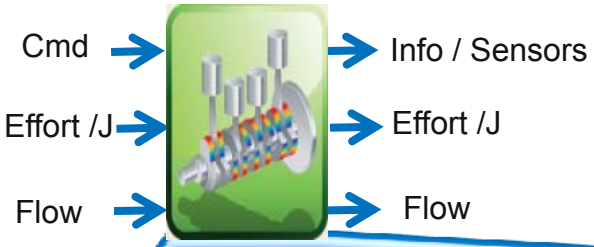
# Model & Data Requirements

| | |
|---|---|
| Maximum Reusability | ■ Automated integration of existing models / controls / data<br>■ All models for a specific area of expertise in a single location<br>■ Systems duplicated using Matlab API |
| Maximum Flexibility | ■ Any system can be built automatically<br>■ User can add their own configurations<br>■ Single components or entire vehicles can be simulated |
| Selectable Complexity | ■ Common nomenclature (i.e., naming, I/O…)<br>■ Common model organization (i.e, CAPS)<br>■ Model compatibility checked |
| Code Neutrality | ■ Matlab / Simulink main environment<br>■ Use S-functions<br>■ Co-simulation (i.e., CoSimate) |

# Model & Data Requirements

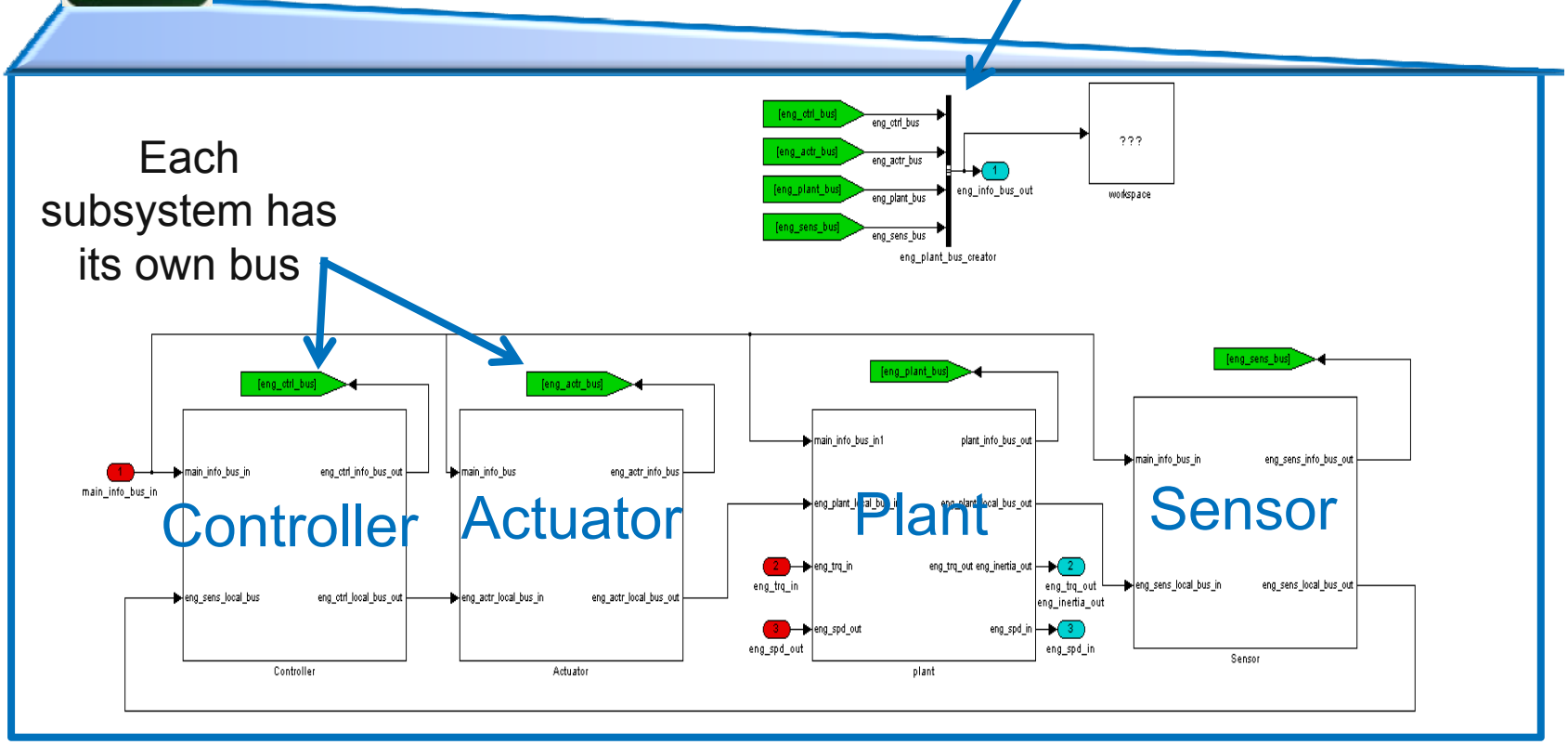
## Common Model Organization

All Systems have 3I/3O




Subsystem buses aggregated so that other systems can access information

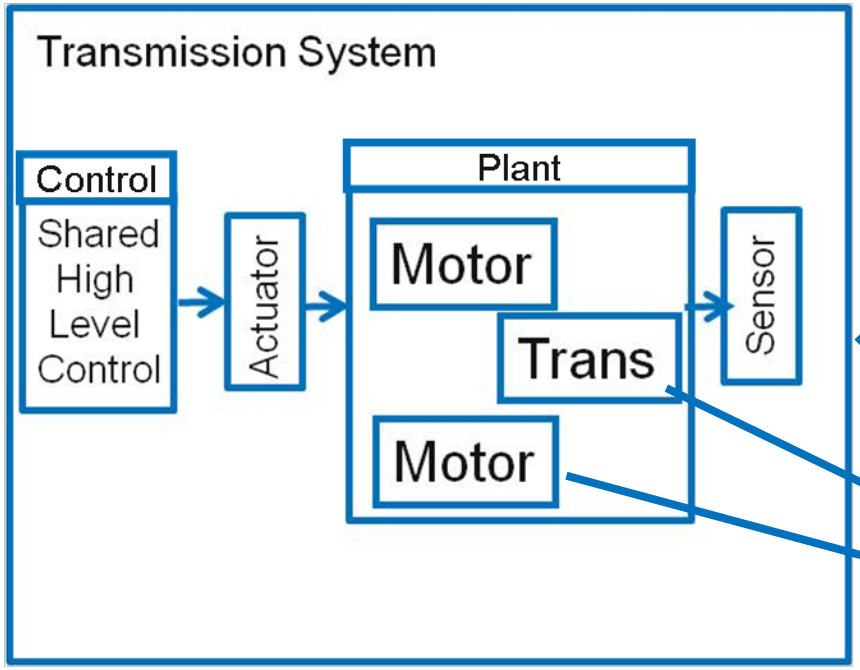
Each subsystem has its own bus



# Model & Data Requirements

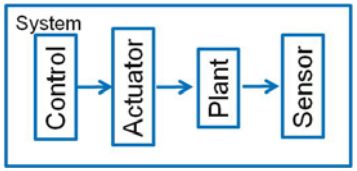
## *Maximum Flexibility*

- Users can create any new configurations by adding a new file (which can be automatically created from existing Simulink Model)
- Users can design their model to represent a hardware setup




Example: Systems that share a controller should be located under the same subsystem

Each subsystem can have its own control (CAPS)



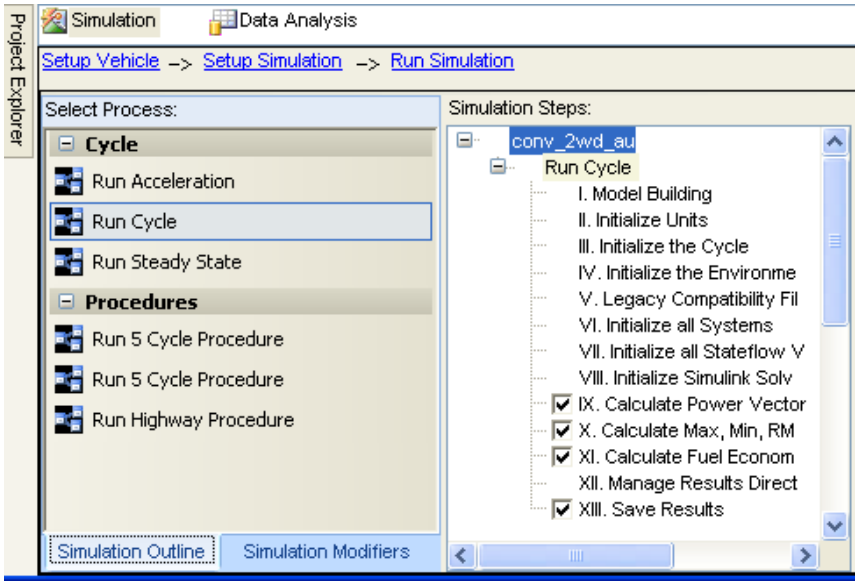
# Graphical User Interface Requirements

| | |
|---|---|
| Setup Simulation | ■ Predefined or user defined architectures<br>■ Select existing / Add legacy model and data<br>■ Check compatibilities<br>■ Select simulation type (i.e., fuel efficiency, performance…) |
| Generic Processes | ■ Calibration, Validation, Tuning<br>■ Parametric study, including Monte Carlo analysis<br>■ Optimization algorithms<br>■ Predefined or user defined processes & report |
| Results Visualization | ■ Predefined or user defined calculations (i.e., fuel economy…)<br>■ Predefined or user defined plots<br>■ Energy balance<br>■ Specific plots available for different models (experts defined) |
| Linkage with Other Tools | ■ Co-simulation (i.e., CoSimate)<br>■ Specialty Tools (i.e, GT-Power, CarSim, AMESIM, AVL Drive…)<br>■ Database Management (i.e., SourceSafe…)<br>■ Well-to-Wheel (i.e., GREET) |

# Graphical User Interface Requirements

## *Integrate Any Processes*

- Each process is defined by a file listing the pre-processing, simulation and post-processing files.
- Legacy/New processes can be automatically added in GUI
- Users have options to combine processes




Processes:

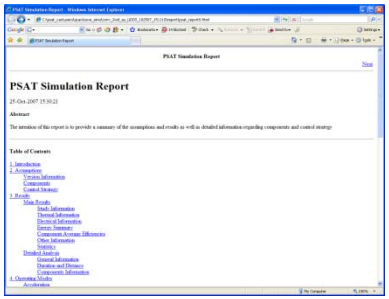
Fuel Economy
Performance
Validation
Tuning
Calibration
Drive Quality
Sizing…

SOC correction
Parametric Study
Optimization
MonteCarlo…

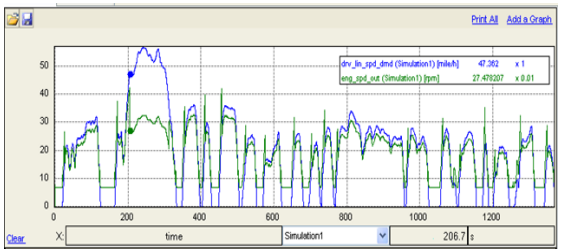
# Graphical User Interface Requirements
## *Results Visualization*

- Numerous standard plots provided

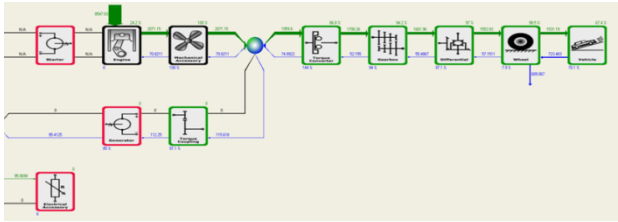
HTML Report




Replay Simulation




Energy balance

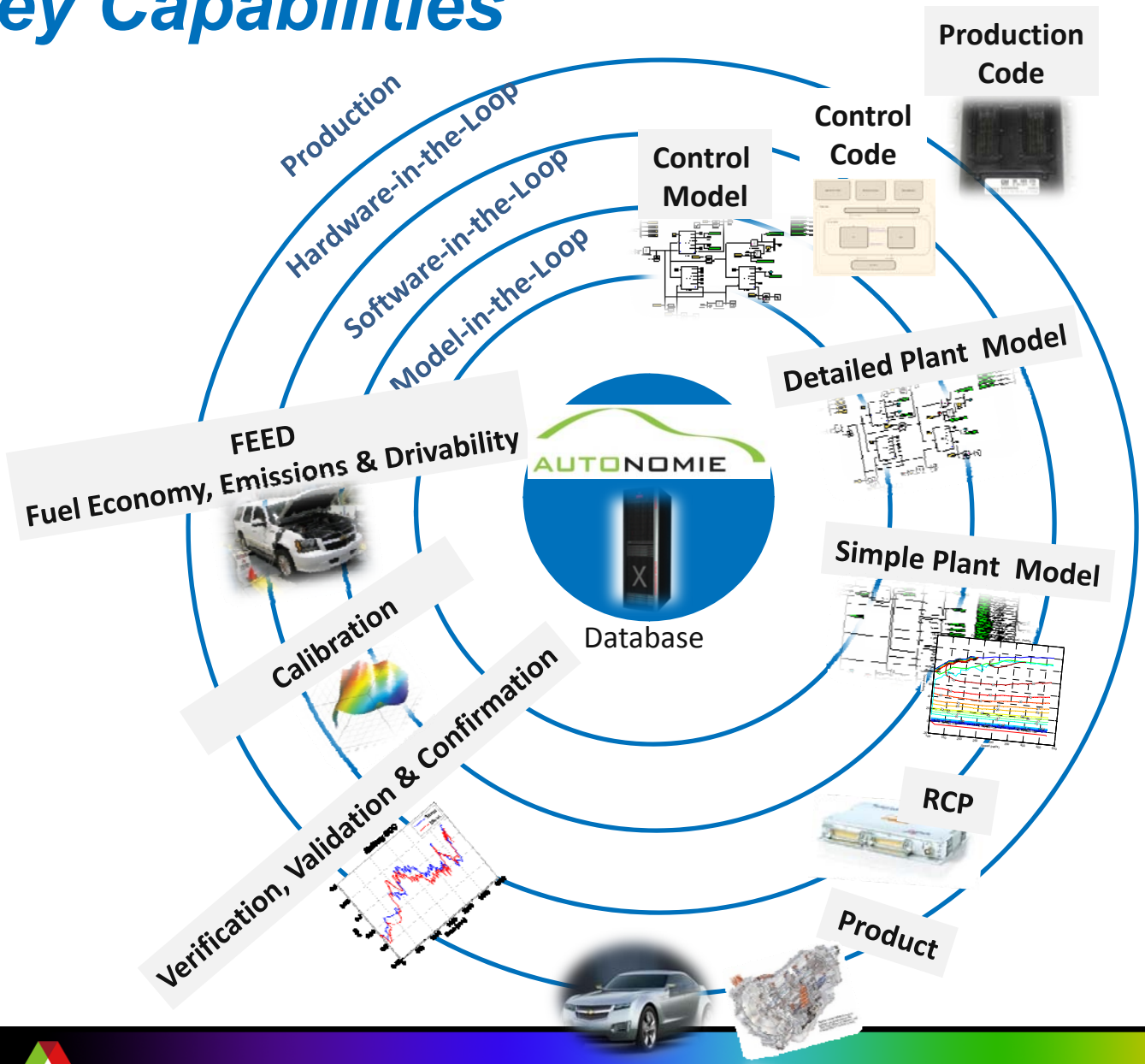


- Users can define their own plots
  - Each model has an associated list of plots
  - Each process has an associated list of post-processing files (calculations, plots)
- GUI can launch legacy tools

# Database Requirements

| | |
|---|---|
| User Access Control | ■ Prevent unauthorized users from accessing restricted or proprietary data<br>■ Allow authorized users to download all necessary files<br>■ Ensure model is documented before integration into database |
| Enterprise Wide Solution | ■ Allow users to collaborate (i.e. share models)<br>■ Main database accessible anywhere<br>■ Consistent process for interacting with files |
| Version Control | ■ Maintain traceability of all changes<br>■ Keep linked files together through entire vehicle process (i.e. design, simulation and test) |
| Database Search | ■ Use keywords to search data, models, controls related to specific projects<br>■ Quickly find the correct model with the correct fidelity of modeling and all related files |

# Key Capabilities



# *Future Activities*

- Complete first version of Autonomie (Sept 2009)
  - Demonstrate MIL, SIL, HIL, RCP…
  - Complete integration of processes
  - Complete linkages with specialty tools
- Continue discussion with OEMs, suppliers…
- Initiate definition of standard for automotive industry (SAE)
- Implement feedback from OEMs, suppliers… into second version of Autonomie
- Complete standard


A software environment and standard framework

# *Summary*

- Establishes tool and framework for enterprise-wide collaboration
- Reduces costs and time to production, which will benefit both companies and government partnerships (e.g., FreedomCAR and 21CTP)
- Provides complete user customization by an open architecture
- Simulates from single components, subsystems to entire vehicles
- Manages models, data, processes, results and control code from research to production by configuration and database management