Autonomie
Plug&Play Software Architecture

Project ID # vss_11_rousseau

2009 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review
May 19, 2009

Aymeric Rousseau, Shane Halbach, Phil Sharer, Sylvain Pagerit, Charles Folkerts, Ram Vijayagopal
Argonne National Laboratory
Sponsored by Lee Slezak

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Project Overview

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

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

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

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**
- 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

**Year 2**
- 

**Year 3**
- 

**Current Status**
Approach

Component Organization

Graphical User Interface

Data Organization

Post-processing Tools

Hardware Modeling & Analysis Requirements

Vehicle

Hybrid

Control Algorithm Design & Analysis Requirements

Process

Control
Key Benefits

- Plug & Play
  - Reduces Cost & Time to Production

- Enterprise Wide Solution
  - Flexibility & Reusability
  - Customizable architectures
  - Common Nomenclature
  - Code Neutral

- Reduces Cost & Time to Production
  - 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…

Legacy Code

Plug & Play

Legacy Processes

Specialty Software

CarSim
GTPower
Amesim
AVL Drive…

Database Management

Version Control
Database Search
Math-based, Plug-and-Play Software for
Automotive System Database Models, Data
Maximum Flexibility Selectable Complexity
Code Neutrality

Database
Interface
Models, Data

Graphical User Interface

User Access Control Enterprise Wide Solution
Version Control Database Search

Models, Data
Setup Simulation Generic Processes Results Visualization Linkage with Other Tools

Database

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Model & Data Requirements

- **Maximum Reusability**
  - Automated integration of existing models / controls / data
  - All models for a specific area of expertise in a single location
  - Systems duplicated using Matlab API

- **Maximum Flexibility**
  - Any system can be built automatically
  - User can add their own configurations
  - Single components or entire vehicles can be simulated

- **Selectable Complexity**
  - Common nomenclature (i.e., naming, I/O…)
  - Common model organization (i.e., CAPS)
  - Model compatibility checked

- **Code Neutrality**
  - Matlab / Simulink main environment
  - Use S-functions
  - Co-simulation (i.e., CoSimate)
Model & Data Requirements

Common Model Organization

All Systems have 3I/3O

- **Cmd** → Info / Sensors
- **Effort / J** → Effort / J
- **Flow** → Flow

Each subsystem has its own bus

Subsystem buses aggregated so that other systems can access information
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
- Select existing / Add legacy model and data
- Check compatibilities
- Select simulation type (i.e., fuel efficiency, performance…)

Generic Processes
- Calibration, Validation, Tuning
- Parametric study, including Monte Carlo analysis
- Optimization algorithms
- Predefined or user defined processes & report

Results Visualization
- Predefined or user defined calculations (i.e., fuel economy…)
- Predefined or user defined plots
- Energy balance
- Specific plots available for different models (experts defined)

Linkage with Other Tools
- Co-simulation (i.e., CoSimate)
- Specialty Tools (i.e., GT-Power, CarSim, AMESIM, AVL Drive…)
- Database Management (i.e., SourceSafe…)
- 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
  - Energy balance
  - Replay Simulation

- 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
- Allow authorized users to download all necessary files
- Ensure model is documented before integration into database

Enterprise Wide Solution
- Allow users to collaborate (i.e. share models)
- Main database accessible anywhere
- Consistent process for interacting with files

Version Control
- Maintain traceability of all changes
- 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
- Quickly find the correct model with the correct fidelity of modeling and all related files
Key Capabilities

Production
Hardware-in-the-Loop
Software-in-the-Loop
Model-in-the-Loop
Control Model
Control Code
Production Code

FEED
Fuel Economy, Emissions & Drivability
Calibration
Verification, Validation & Confirmation

Database

Simple Plant Model
Detailed Plant Model

RCP
Product

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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