Autonomie
Large Scale Deployment

2011 DOE Hydrogen Program and Vehicle Technologies
Annual Merit Review
May 10, 2011

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Argonne National Laboratory

Sponsored by David Anderson

Project ID #VSS009

U.S. Department of Energy
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 2011
- 90% Complete

Barriers Addressed

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

Budget

- Four Year Project
  - First 3 years (50% DOE/50% GM)
  - Fourth year (26% DOE/74% GM)
- Funding (cash)
  - FY08 $ 500k
  - FY09 $ 500k
  - FY10 $ 500k + $400k (legacy transition)
  - FY11 $ 500K (DOE) + $ 300K (GM)

Partners

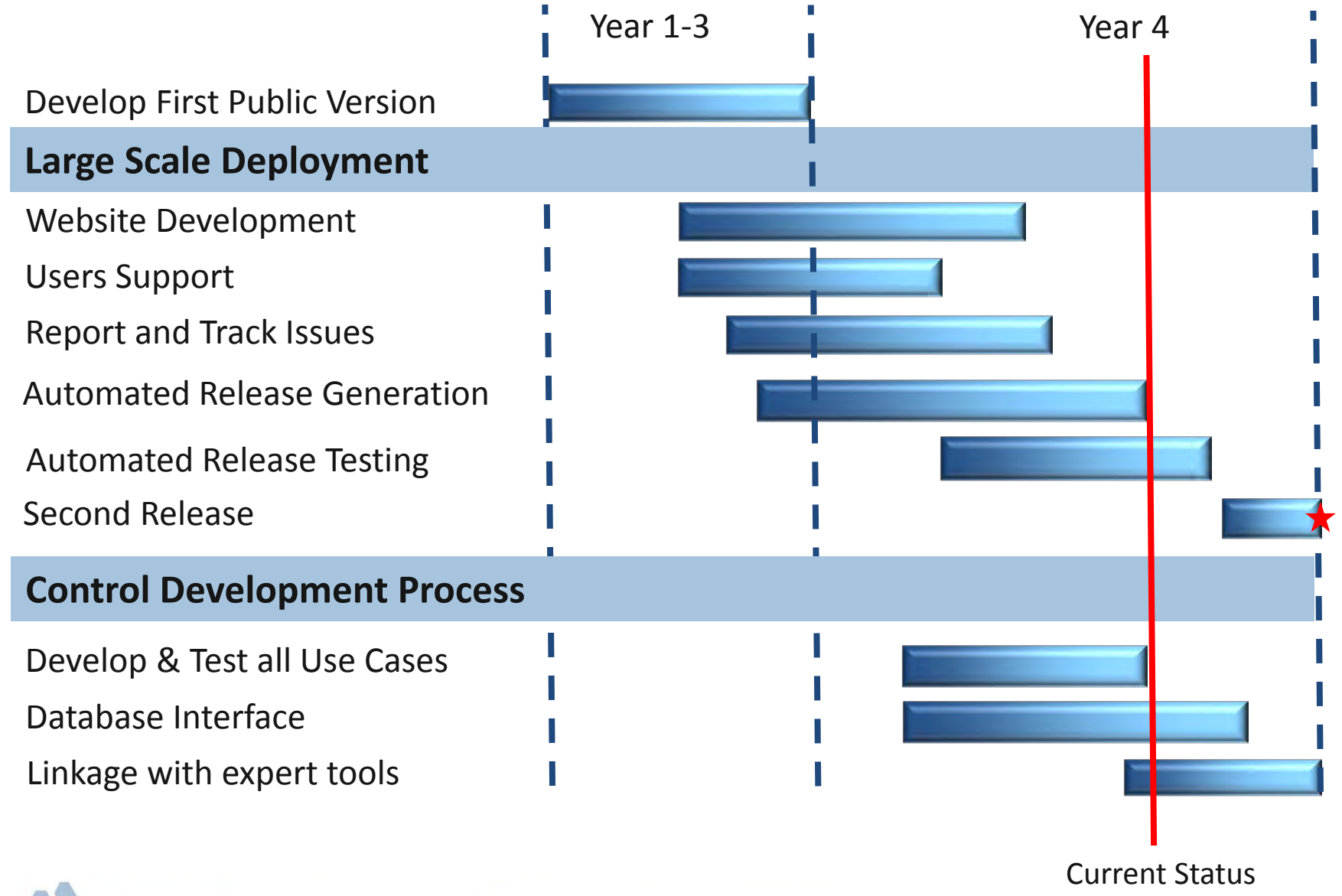
- General Motors
- MathWorks
- Gamma Technology (GTPower)
- LMS (AMESim)
- Mechanical Simulation (CarSim)

Objective

Autonomie's objective is to accelerate the development and introduction of advanced technologies through a Plug&Play architecture that will be adopted by the entire industry and research community.

- Reduce cost and time to production by minimizing hardware iterations through virtual environment
- Enterprise wide solution through database management maximize model and process reusability

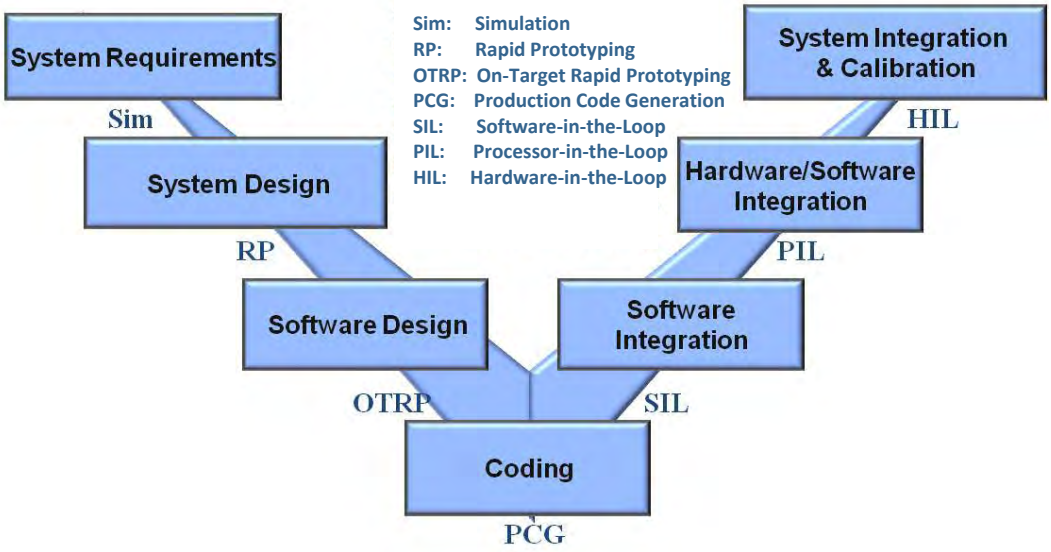
Milestones


Year 1-3
Year 4
Develop First Public Version
Large Scale Deployment
Website Development
Users Support
Report and Track Issues
Automated Release Generation
Automated Release Testing
Second Release
Control Development Process
Develop & Test all Use Cases
Database Interface
Linkage with expert tools
Current Status

Approach

Use Virtual Engineering Approach to Accelerate the Vehicle Development Process

Virtual Engineering Process



Problem:

- Heavy reliance on hardware leads to high cost and longer development time
- Integration of new technologies in a system lowers its expected benefit

Result:

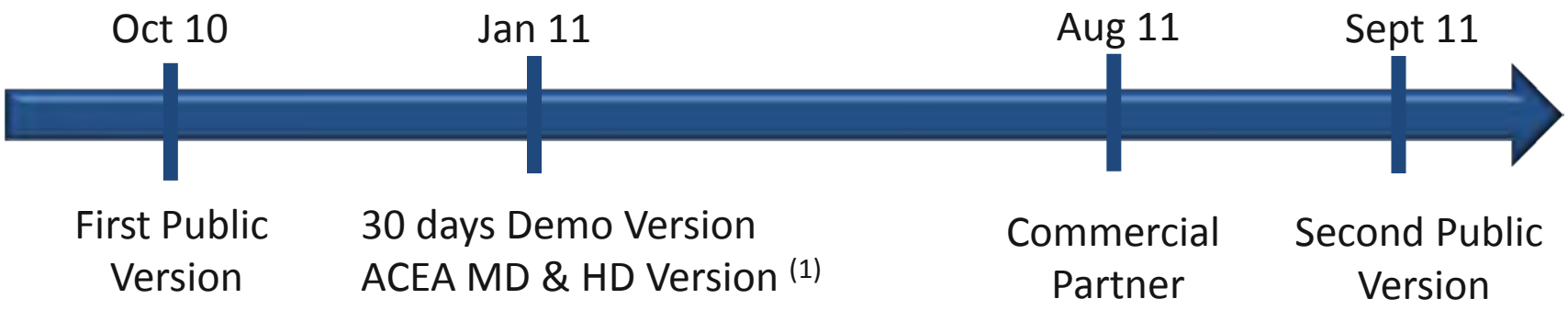
Wasted Opportunities, Time, and Resources (People & $)

Solution:

OEMs are moving towards an increasing reliance on modeling to accelerate the introduction of advanced technologies

DOE is leading the way with the development of Autonomie

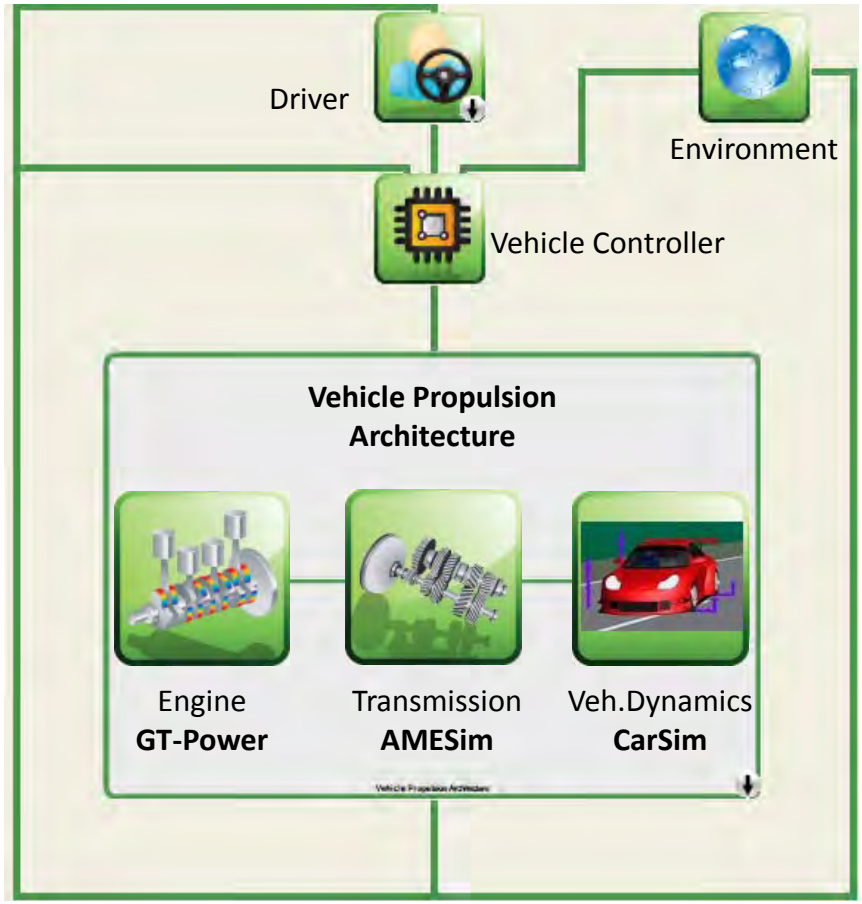
Development Status



- PSAT users are able to acquire Autonomie at no cost
- More than 65 companies are using Autonomie (as of 03/11/11)
- Numerous new companies have licensed Autonomie or purchased additional licenses based on the new features

(1) Different funding source

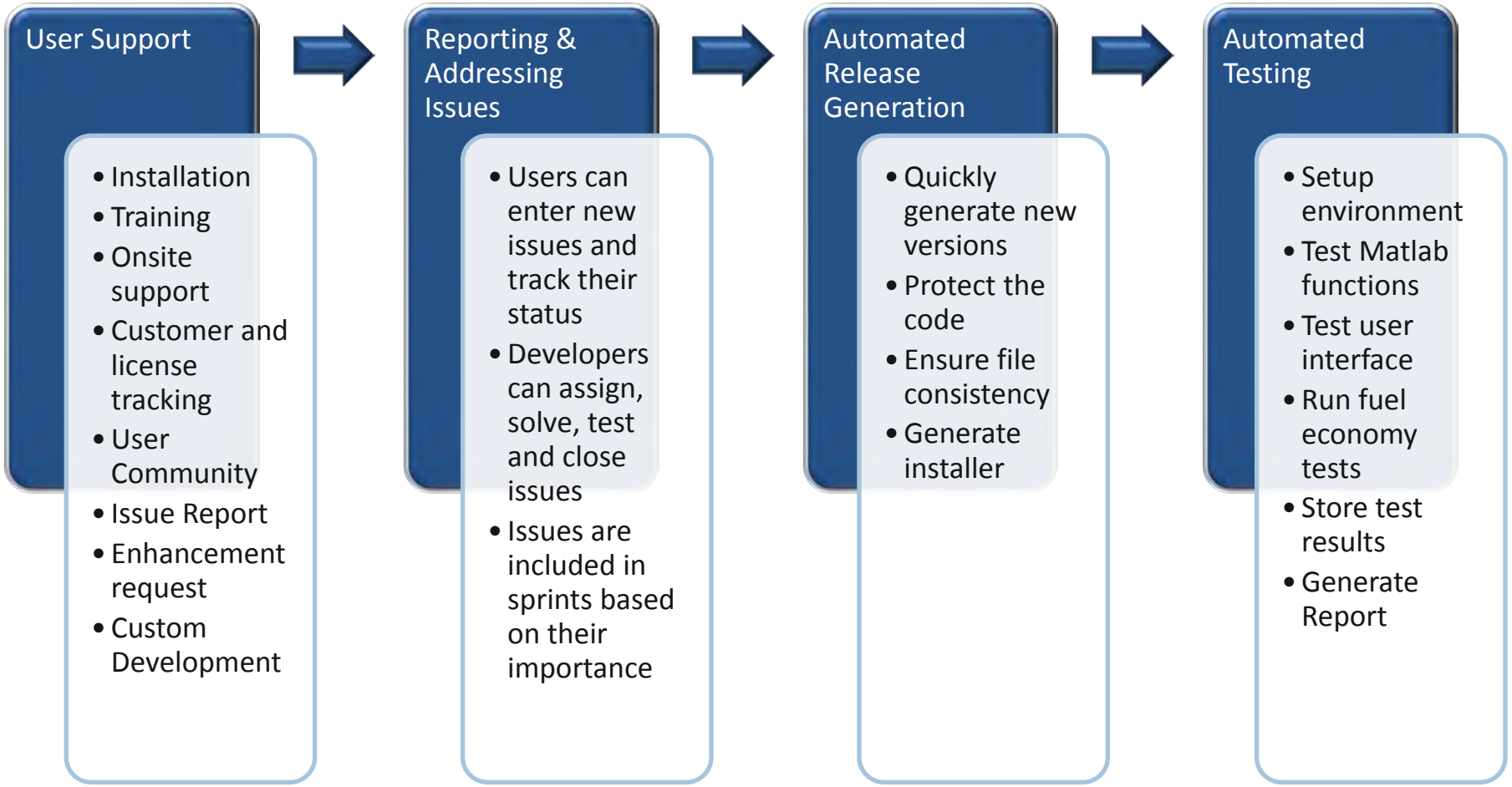
Technical Accomplishments
Multi-Controller Simulation



- Process developed & documented to integrate several expert system models in Autonomie
- New Architecture developed to ensure that the different models run properly
- Opens new doors for control engineers holy grail: multi-controller optimization
- Next challenge: improve execution time (i.e., multiple processors…)

Technical Accomplishments

Large Scale Deployment - Overview



Technical Accomplishments

Support & Training - Overview

Support Types

Installation

Training

Issue fix

Enhancement Request

On-site Support

Custom Development

…

Support Options

FAQ page(1)

Forum(2)

Documentation(1)

Email(1)

Chat Room(2)

Web meeting(1)

Phone Support(1)

Issue Reporting(1)

Paid Contracts(1)

Increased Issue Complexity

(1) Currently available
(2) Planned in Year 4

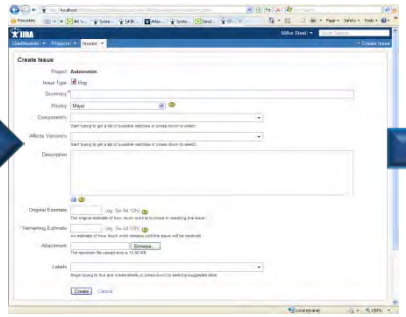
Technical Accomplishments

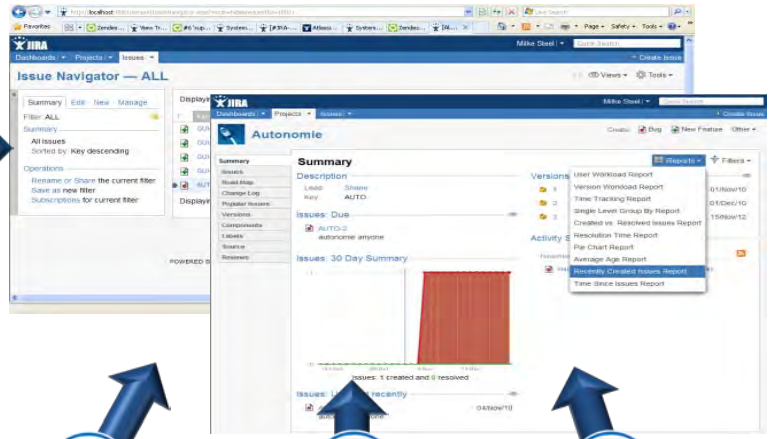
Entering and Tracking Issues

Enter Issue

Access Issue
Status, Statistic, Roadmap…

User





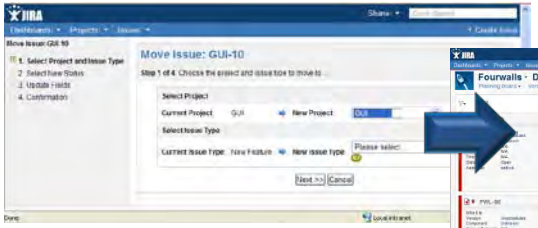
Review Issue
(bug vs. improvements…)

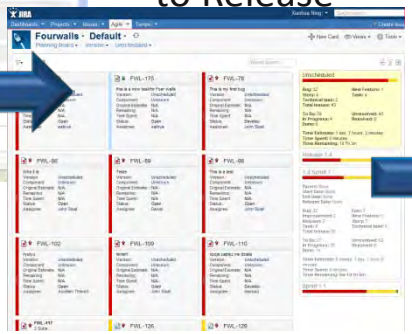
Assign Issue
to Release

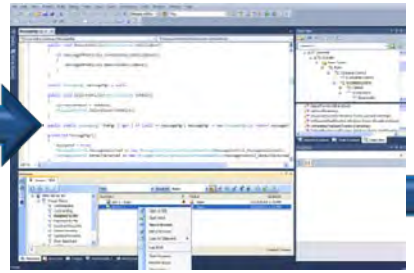
Resolve & Test
Issue

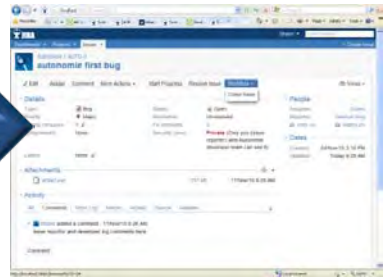
Close Issue

Developer









Technical Accomplishments

New Website Launched

www.autonomie.net

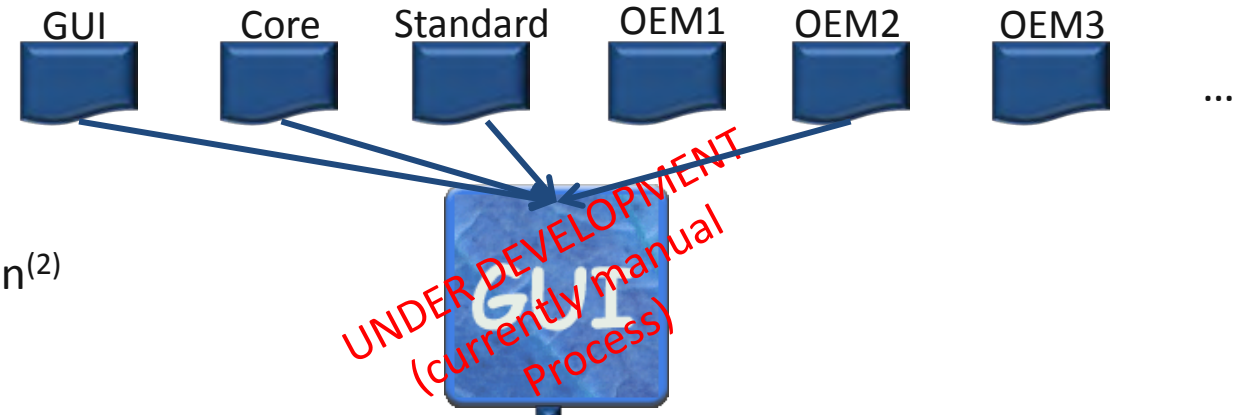
- Describe tool & capabilities
- Download documents (>70 presentations, >55 papers)
- Download versions (demo, HD)
- Manage support (training, videos, user issues…)

- Website statistics (as of 03/10/11):
  - Pages viewed (6500/month)
  - Demo downloads > 135
  - ACEA HD version downloads > 70

Technical Accomplishments

Automatic Release Generation Process

Databases(1)



Database selection(2)

License selection (i.e., USB vs License Key) (1)

Compile & Obfuscate GUI(1)

Check Consistency (i.e., proprietary tags) (1)

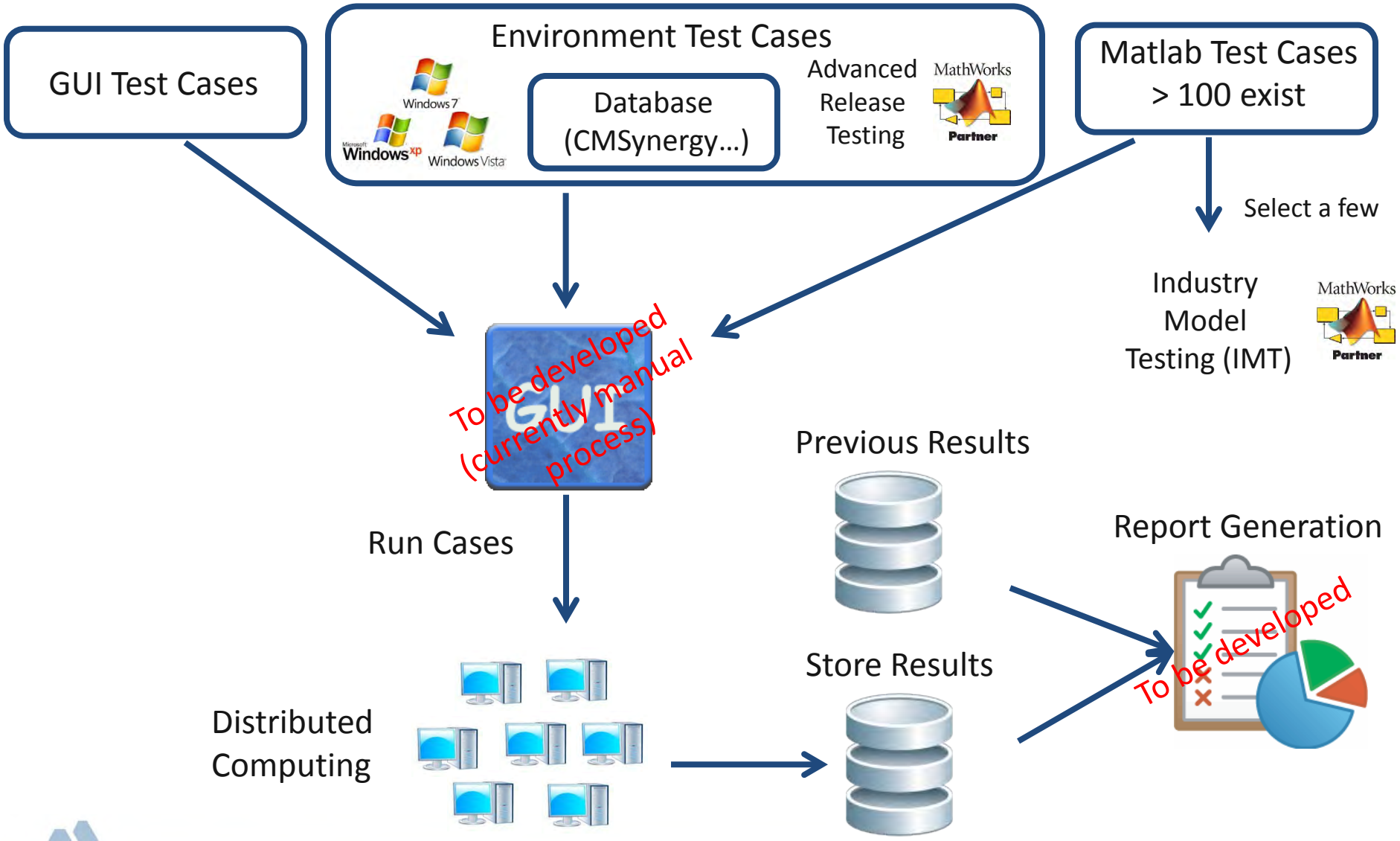
Pcode mfiles(1)

Generate Installer(1)

(1) Currently available
(2) Planned in Year 4

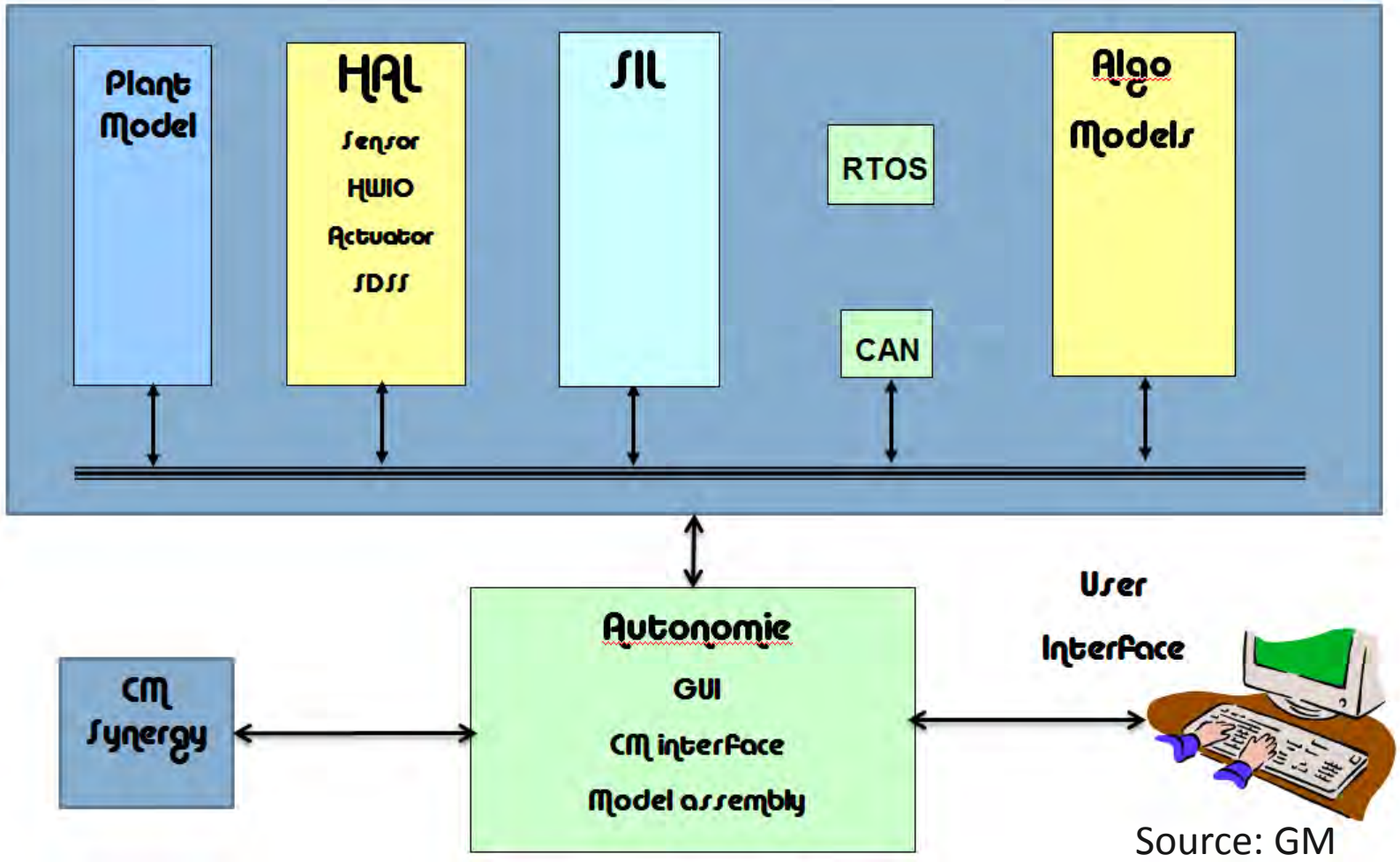
Technical Accomplishments

Automatic Testing Process Status



Technical Accomplishments

Process Development for Control



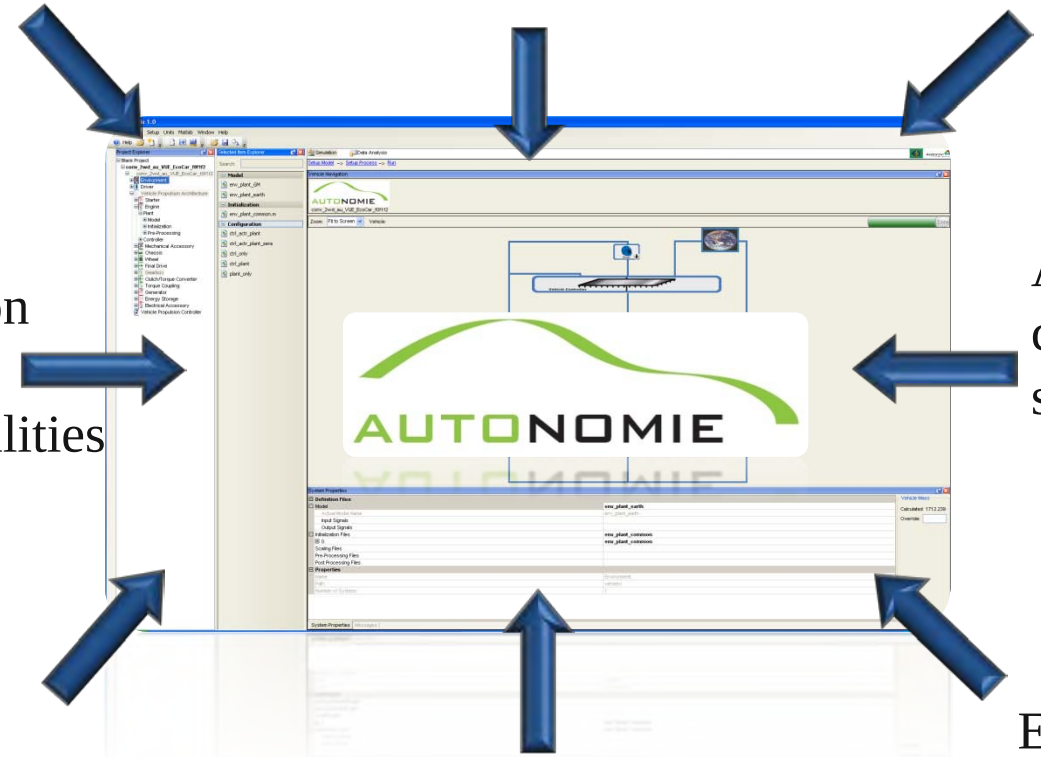
Source: GM

Autonomie Designed to Be Used For All Steps in the Development Process

Build and compare large number of technology, powertrain, options

Easy selection & implementation of data, models, control or cycles

Run batch mode + Distributed computing



Ensure simulation traceability, model compatibilities

Analyze and compare test and simulation data

Database Management

Generic Processes

Enables MIL, SIL, RCP, HIL, CIL

Autonomie Commercialization

Call for Proposal

- Background
  - Several commercial companies using Autonomie have requested more information about how enterprise deployment and support would be handled (e.g., how do we support an engineer in India?).

  => Argonne has been looking for a commercial partner
- Benefits
  - Extended support: worldwide, onsite, 24/7
  - Training
  - Licensing
  - Argonne retains the IP (code) and continues to focus on R&D, studies and code development
- Major Dates
  - Document sent March 2011
  - Partner selected May 2011
  - Agreement signed August 2011

Collaborations

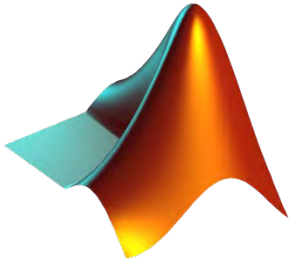
- Autonomie is used to support large number of DOE activities.

Examples of Autonomie Usage in FY10 AMR

Task	Lead	Project #
Life Cycle Analysis with GREET	ANL	AN012
Evaluation of powertrain options and component sizing for MD and HD applications	ANL	VSS048
MD & HD Electric Drive Vehicle Simulation and Analysis	NREL	VSS043
ArvinMeritor CRADA	ORNL	VSS061
Evaluation of flex fuels for PHEVs using modeling and EIL	ANL	VSS049
Advanced Engine System and Emissions Control Modeling and Analysis	ORNL	VSS041
LDV HVAC model development and validation	NREL/ANL	VSS045
System Level Analysis of Hydrogen Storage Options	ANL	ST001

- Additional projects include EcoCAR, University classes (teaching), program requirements, GPRA, market penetration...

Collaborations (Cont'd)



- Provide inputs on "best practices"
- Implementation of MathWorks developed models and algorithms to support studies

Gamma Technologies

- Provide technical support to automate the integration of GTPower (engine modeling) into Autonomie

LMS ENGINEERING INNOVATION

AMESim

- Provide technical support to automate the integration of AMESim (transmission modeling) into Autonomie

CarSim®
Mechanical Simulation

- Provide technical support to automate the integration of CarSim and TruckSim (vehicle dynamics modeling) into Autonomie

Future Activities

- Continue to update Autonomie to maintain state-of-the-art
- Continue to provide guidance for DOE R&D activities
- Expand Autonomie usage throughout DOE to promote Virtual Engineering approach
- Continue to enhance the tool based on DOE needs and user's feedback
- Define the industry standard for modeling and simulation to be adopted by the entire industry through existing SAE committee
- Continue to discuss potential use of Autonomie to support future Medium and Heavy Duty fuel consumption labeling / regulations

Summary - ANL Will Continue to Accelerate Technology Development and Introduction

- Support DOE R&D activities
- Support usage of Autonomie for OEMs…
- Support virtual engineering processes throughout OEMs and DOE

Technical Back-Up Slides

AUTONOMIE/PSAT Comparison

Architecture

Capability	PSAT	PSAT-PRO	Autonomie
Plug & Play Architecture	✓		✓
Hierarchical Architecture Standards (Vehicle, syst…)			✓
Model Reusability through System Experts (Concept to Production)			✓
Establish Standard Interfaces (Industry-wide)			✓

Features

Capability	PSAT	PSAT-PRO	Autonomie
Model/data Customization	✓		✓
Powertrain Configuration Customization			✓
Select Appropriate Level of Modeling	✓		✓
GUI Customization (process, post-processing…)			✓
Database Management			✓

AUTONOMIE/PSAT Comparison

Usage*

Capability	PSAT	PSAT-PRO	Autonomie
Evaluate Fuel Consumption Benefits (technology, size, powertrain configuration…)	✓		✓
Evaluate and Balance FEED in Simulation (Fuel Economy, Emissions & Drivability)			✓
Develop Component Requirements	✓		✓
Simulate Single Component			✓
Develop System/Subsystem Requirements			✓
Develop Vehicle Level Control	✓		✓
Develop System/Subsystem/Component Control			✓
Component-in-the-Loop		✓	✓
Software-in-the-Loop, Hardware-in-the-Loop…			✓

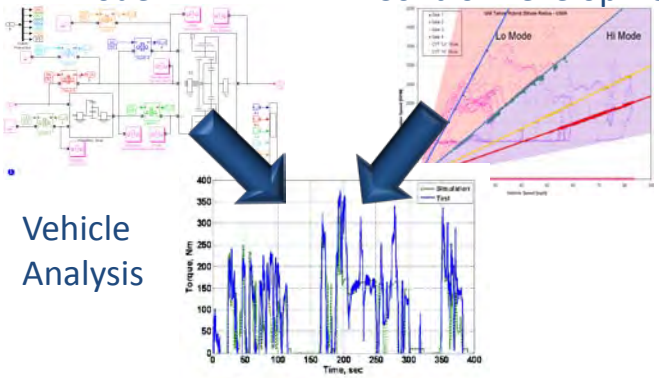
*Final usage depends on the level of details of the models available

Model-in-the-Loop (MIL) Examples Supporting Current DOE R&D Activities

Evaluation of Fuel Consumption Benefits of Advanced Powertrains (VSS_010)

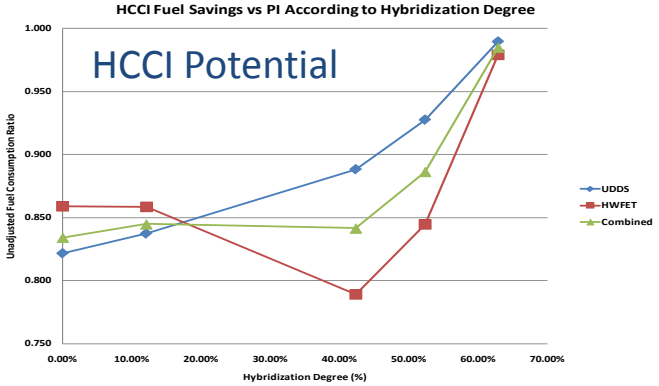
2 Mode HEV

Control Development



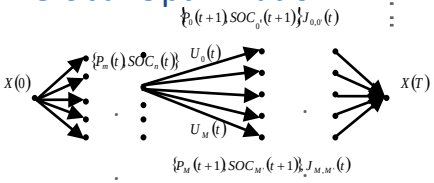
Vehicle Analysis

Evaluation of Fuel Consumption Benefits of Advanced Technologies (VSS011)



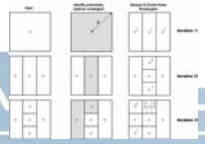
Evaluation of Fuel Consumption Benefits of Advanced Controls

Global Optimization

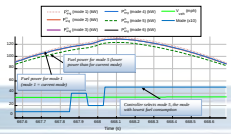


Rule Based

Heuristic Optimization



Instantaneous Optimization



Definition of Component Requirements for Program Goals

Requirements of End of Life Energy Storage Systems for PHEVs

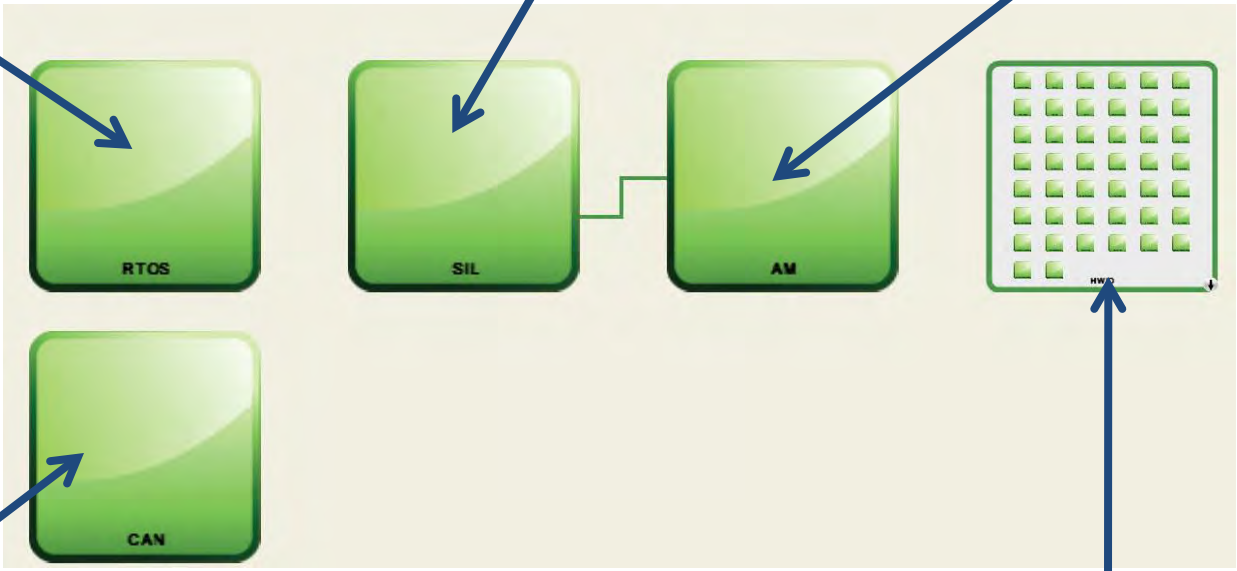
Characteristics at EOL (End of Life)		High Power/Energy Ratio Battery	High Energy/Power Ratio Battery
Reference Equivalent Electric Range	miles	10	40
Peak Pulse Discharge Power - 2 Sec / 10 Sec	kW	50 / 45	46 / 35
Peak Regen Pulse Power (10 sec)	kW	30	25
Available Energy for CD (Charge Depleting) Mode, 10 kW Rate	kWh	3.4	11.6
Available Energy for CS (Charge Sustaining) Mode	kWh	0.5	0.3
Minimum Round-trip Energy Efficiency (USABC HEV Cycle)	%	90	90
Cold cranking power at -30°C, 2 sec - 3 Pulses	kW	7	7
CD Life / Discharge Throughput	Cycles/MWh	5,000 / 17	5,000 / 58
CS HEV Cycle Life, 50 Wh Profile	Cycles	300,000	300,000
Calendar Life, 35°C	year	15	15
Maximum System Weight	kg	60	120
Maximum System Volume	Liter	40	80
Maximum Operating Voltage	Vdc	400	400
Minimum Operating Voltage	Vdc	>0.55 x Vmax	>0.55 x Vmax
Maximum Self-discharge	Wh/day	50	50
System Recharge Rate at 30°C	kW	1.4 (120V/15A)	1.4 (120V/15A)
Unassisted Operating & Charging Temperature Range	°C	-30 to +52	-30 to +52
Survival Temperature Range	°C	-46 to +66	-46 to +66
Maximum System Production Price @ 100k units/yr	$	$1,700	$3,400

Software-in-the-Loop (SIL) Example to Develop Low Level Engine Control

Real Time Operating System (RTOS) ensures call of functions at specific intervals (such as CAN)

Production Code

New algorithm(s) to be tested



Sends and receives CAN signals

Hardware input/output

Component-in-the-Loop (CIL) Example to Evaluate Non-Modeled Phenomena for DOE

Rest of the Vehicle Modeled

AUTONOMIE

Commands (Battery, ABC150, equipment..)

Sensors

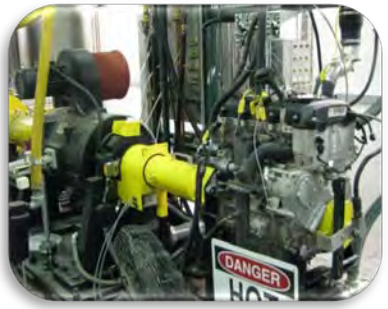
Battery behaves as if in vehicle

Example#1: Impact of battery cold start on PHEVs Fuel Consumption

Example #3: Engine and Battery are Coupled

Commands (ICE, Dyno, equipment..)

Sensors



Engine behaves as if in vehicle

Example #2: Impact of emission and engine cold start on PHEVs Fuel Consumption

ANL is DOE's lead laboratory for Automotive Component-in-the-Loop