Project ID # EEMS013

Argonne NATIONAL LABORATORY

AMBER - A New System Simulation Framework for SMART Mobility

AYMERIC ROUSSEAU, PAUL DELAUGHTER, MICHAEL JUSKIEWICZ, SYLVAIN PAGERIT, PHILLIP SHARER

2017 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

June 7, 2016

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Project Overview

Timeline	Barriers
• Project start date : FY16 • Project end date : FY18 • Percent complete : 60%	• Bring technologies to market faster • Integrate a diverse set of simulation tools • Accelerate technology evaluation
Budget	**Partners**
• FY16 Funding : $600K • FY17 Funding : $600K	• Feedbacks from current Autonomie users (>200 institutions) • Specific discussions with few OEMs including Ford & GM

Project Relevance

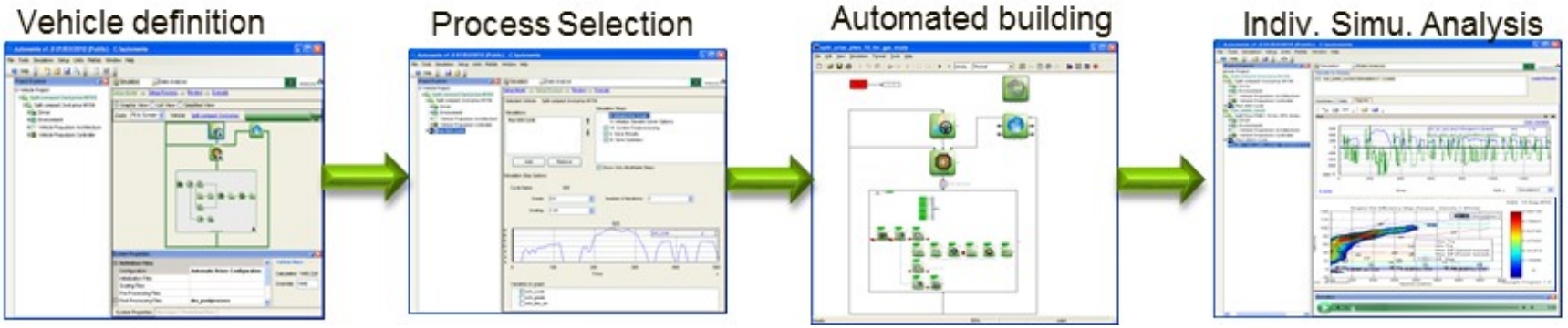
As Mobility becomes Smarter, our Tools have to become Smarter.

- The increased number of vehicle technology options (powertrains, components…) requires an increasingly large number of simulations
- The rise of connectivity and automation requires a new system approach including multiple vehicles operating in their environments
- Existing vehicle system simulation tool have focused on individual vehicles while transportation system simulation tools have not considered vehicle energy
- A new approach is required to continue to support DOE VTO R&D activities (I.e., Smart Mobility, technology benefit analysis…) and the system modeling community.

Project Relevance

The Existing Autonomie Workflow is Single Vehicle Focused

- Highly successful workflow when customizing a single vehicle.
  - All aspects of the vehicle can be easily modified through the User Interface
- Great for small scale studies involving 10 or 20 vehicles
- Not capable to handle large scale studies or Smart Mobility workflows



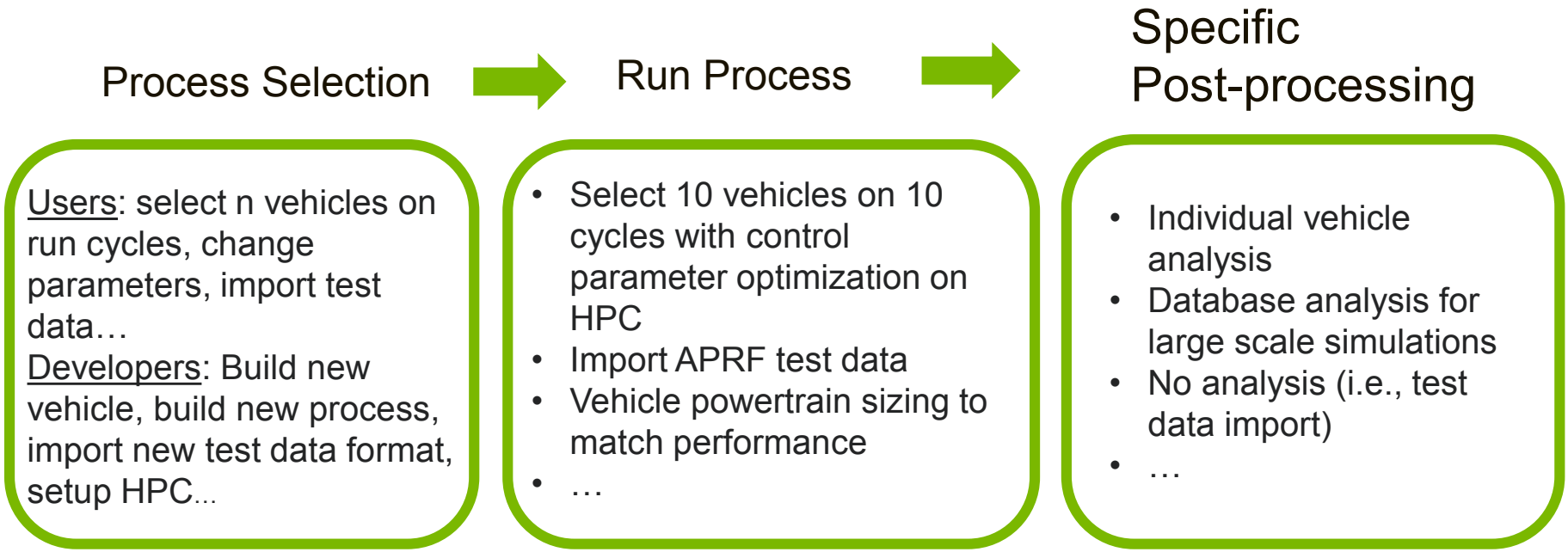
Existing Tool (Autonomie) - Current Workflow Focused on Few Individual Vehicles

Project Relevance

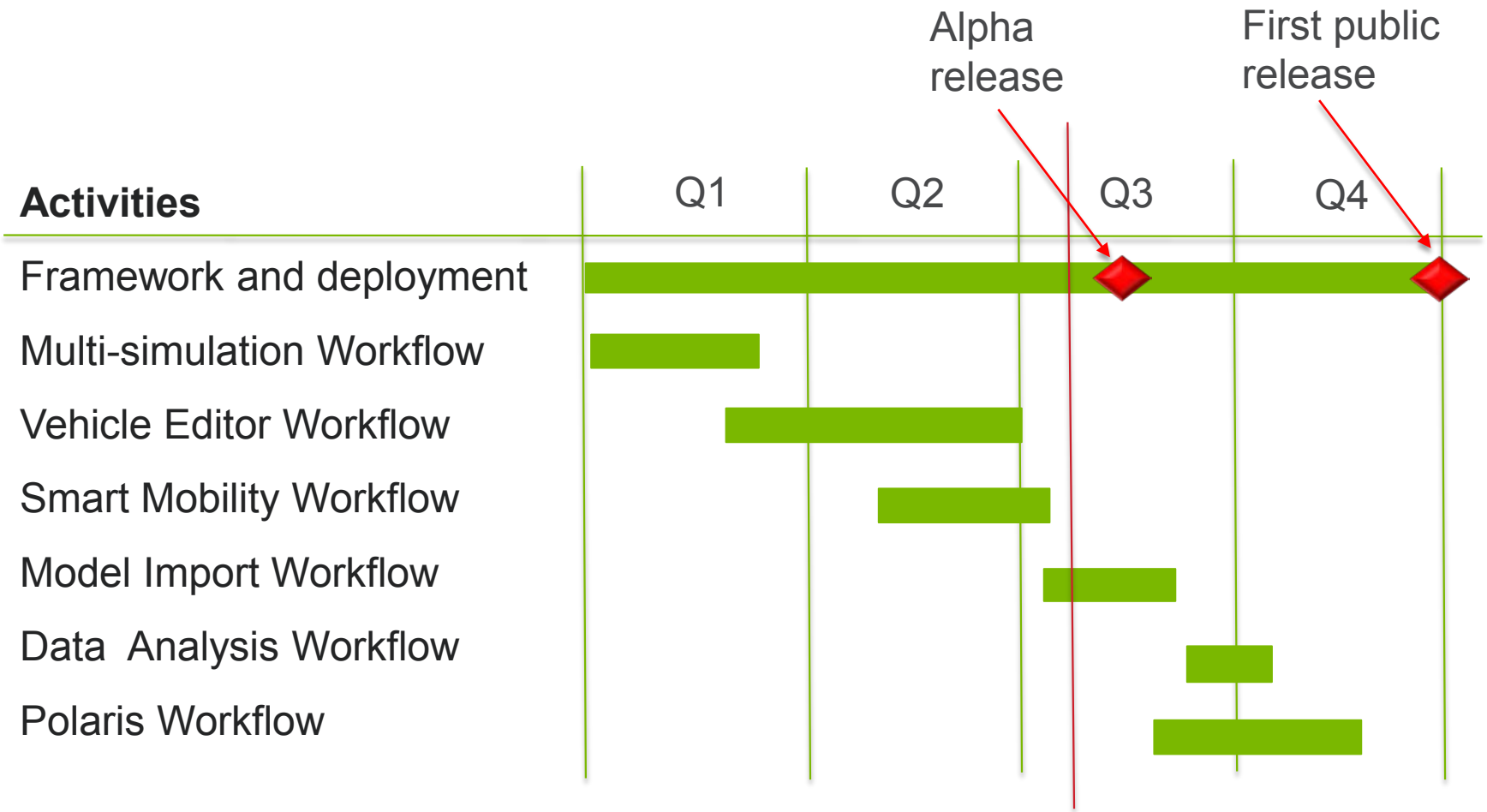
AMBER Satisfies the Critical Need to Integrate Existing Tools into Coherent Workflows to Tackle the HPC Studies of Tomorrow

- Workflow Spectrum: simulation of individual components to large metropolitan areas.
- New Workflows require Large Scale Simulations (HPC)
  - NHTSA study requires 100,000s of vehicles
  - Smart Mobility simulations over metropolitan areas require simulation over 1,000,000 of cycles
  - Smart Mobility requires linking tools such as POLARIS (EEMS014) with vehicle modeling tools such as Autonomie (VAN023)
- OEMS need to manage and simulate vehicle calibrations across a wide range of MBSE workflows from single vehicle to large scale
- New Workflow Supports Industry's R&D Direction

New Workflow Supports industry's R&D Direction



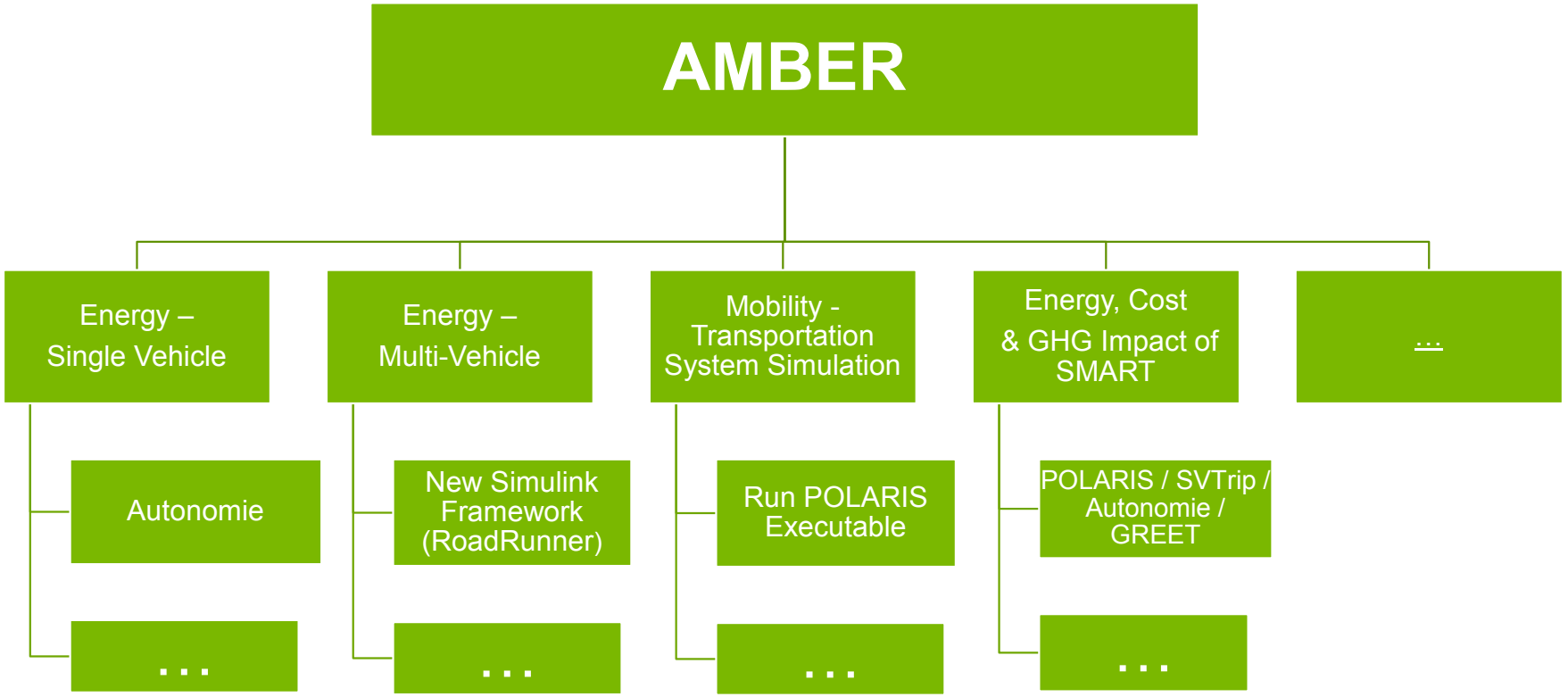
Project Milestones



Approach

Integrate Existing & Develop New EEMS Processes into AMBER

AMBER: **A**dvanced **M**odel **B**ased **E**ngineering **R**esource



But each of these steps are multiple workflow as well…

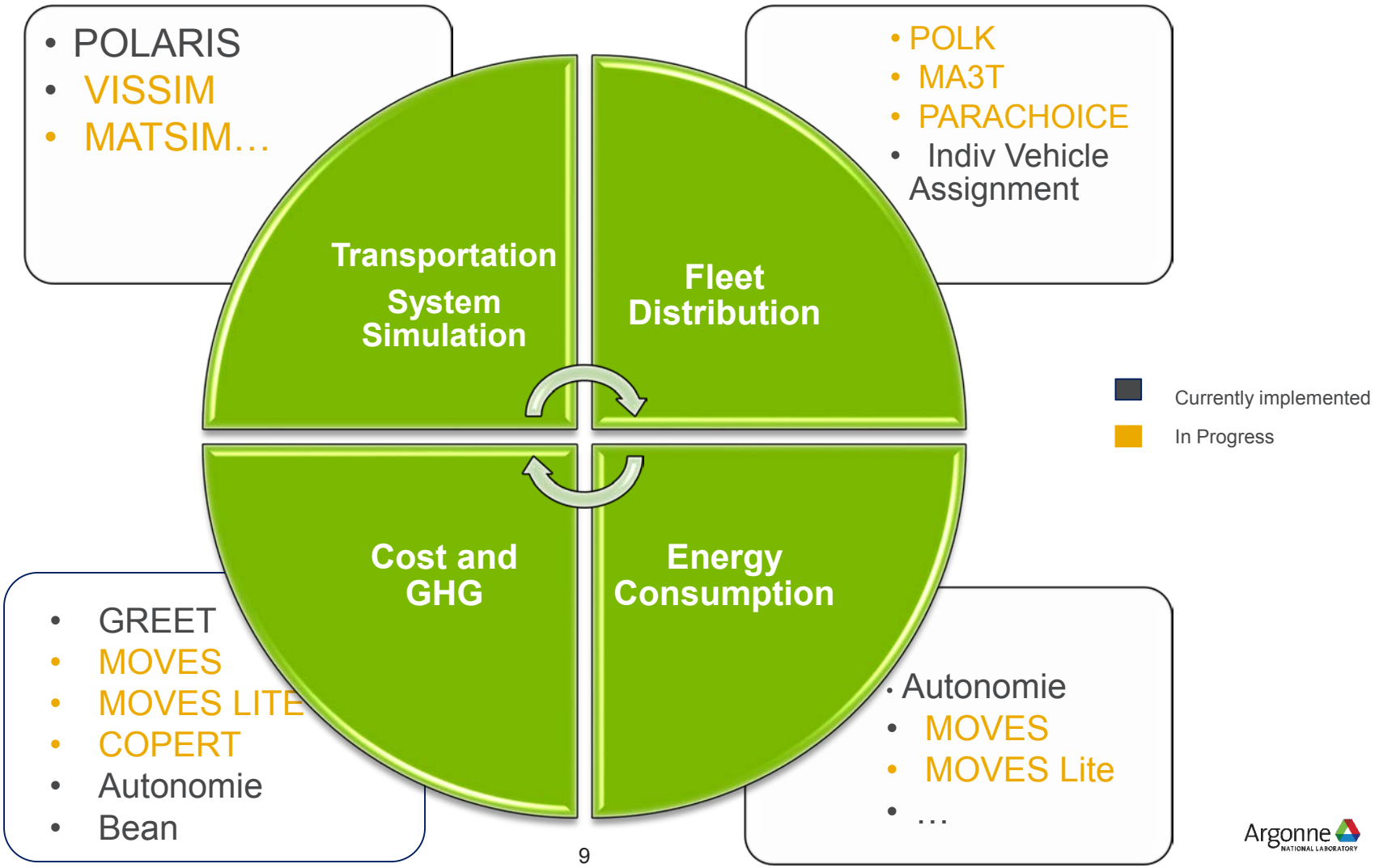
Currently implemented / in Progress

Future Vision

Approach

To Maximize Reusability and Collaboration between Researchers, Our Vision is to Generalize ANY Workflow with AMBER

AMBER: **A**dvanced **M**odel **B**ased **E**ngineering **R**esource



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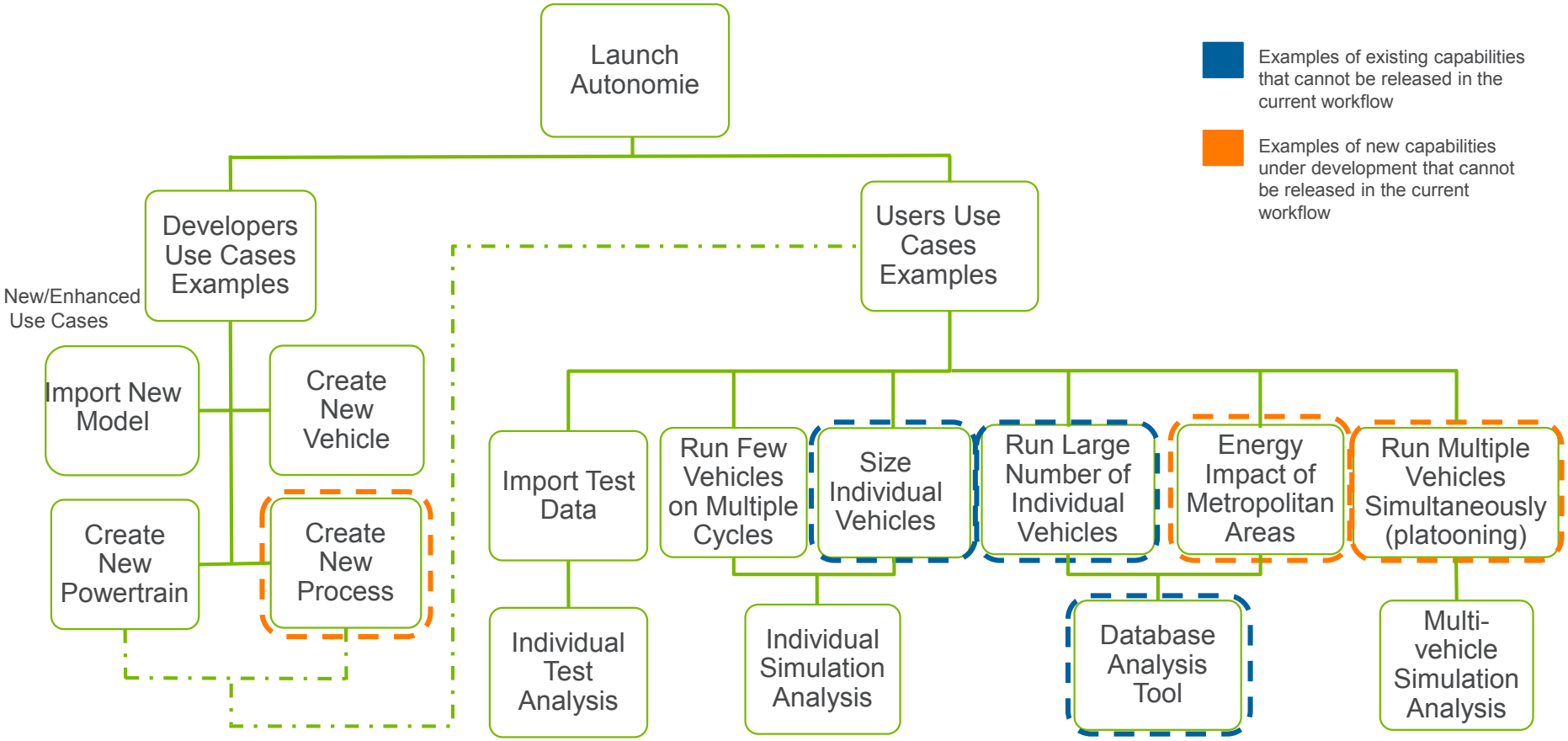
Approach

AMBER will Allow Deployment of Existing Workflows and Separate Users from Developers

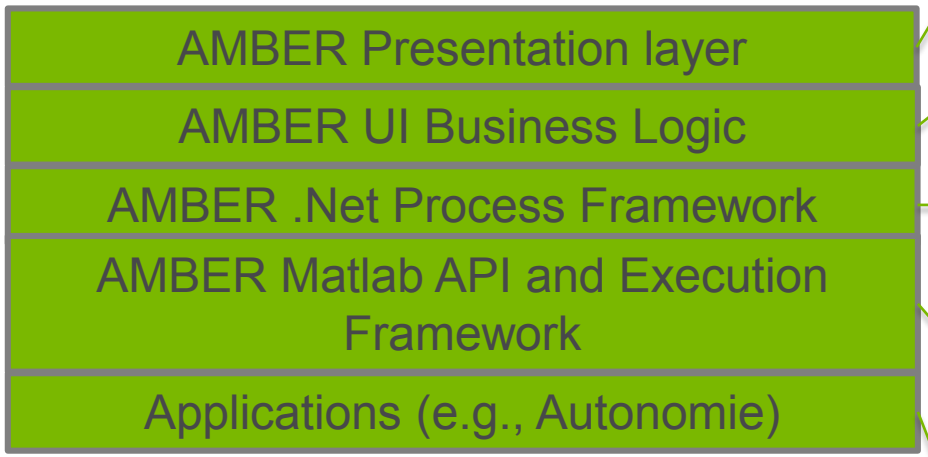


=> New platform will enable dissemination of existing and new capabilities to the entire user community as well as streamline Argonne internal processes

Technical Accomplishments

A Multilayered Approach was Selected to Allow Different Levels of Customization by Users

Developed a framework that will allow users to integrate many diverse tools into workflows



User's can implement their own custom UIs

The UI interfaces are open allowing users to plug their own custom UI into existing BL

UIs can be reused and combined together by the framework layer

Users create their own scripts and Workflows in Matlab using the API to design their own complex simulation logic on top of existing work

Users can use our applications or provide their own.

*Also follows industry best practices

Technical Accomplishments

Customizing the Workflow is Easy

Workflows are built from xml analogous to how we build vehicle models

- Steps in the xml correspond to tabs in the UI
- Don't need a step, just remove it from the xml

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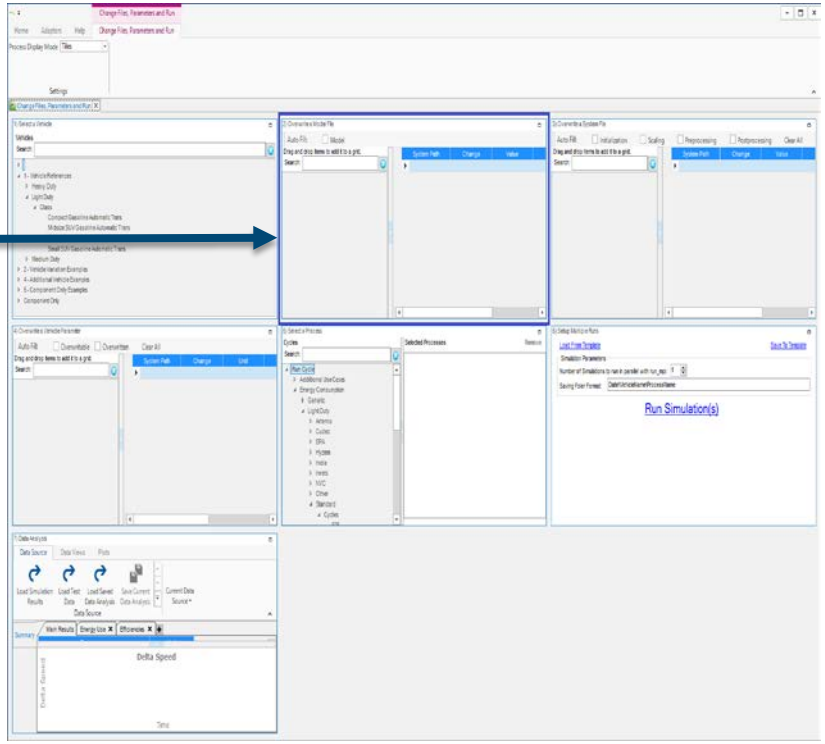

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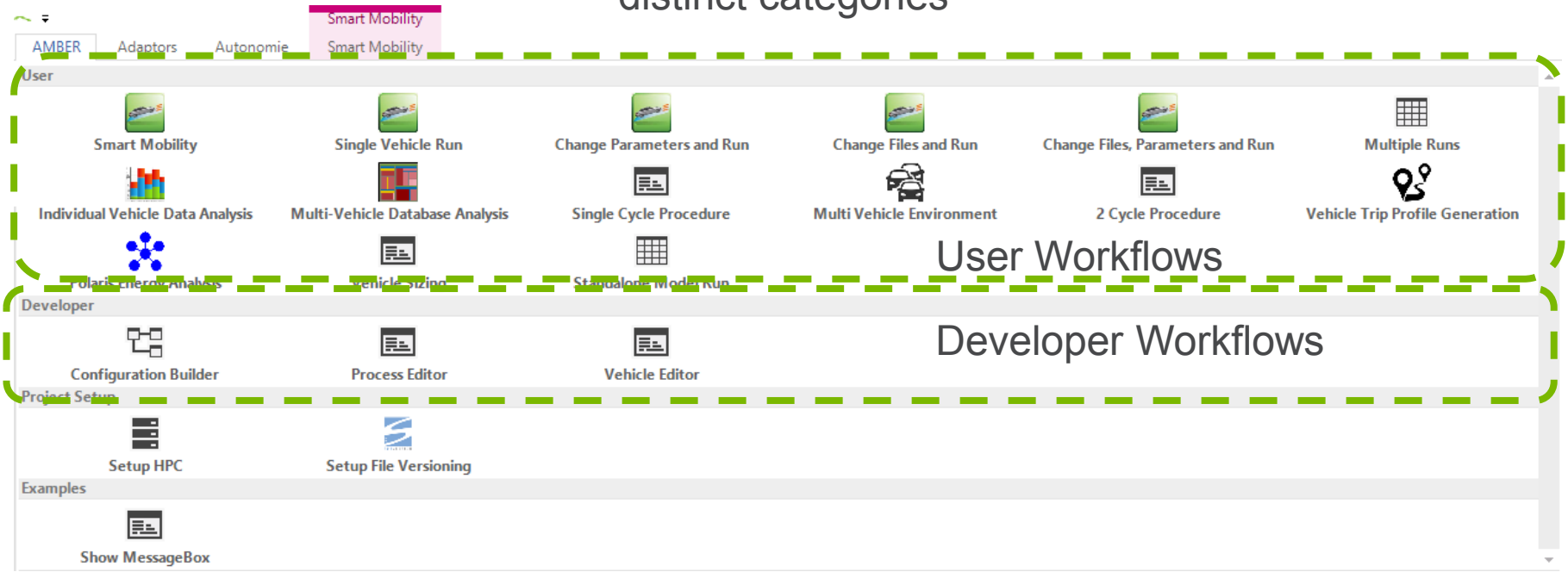
Technical Accomplishments

A Diverse Set of Workflows to Support the DOE R&D in a Larger Context

Users and Developer workflows separated into distinct categories



Specific workflows to support specific projects

Smart Mobility

For EEMS

Multiple Runs

For VTO Benefit Analysis

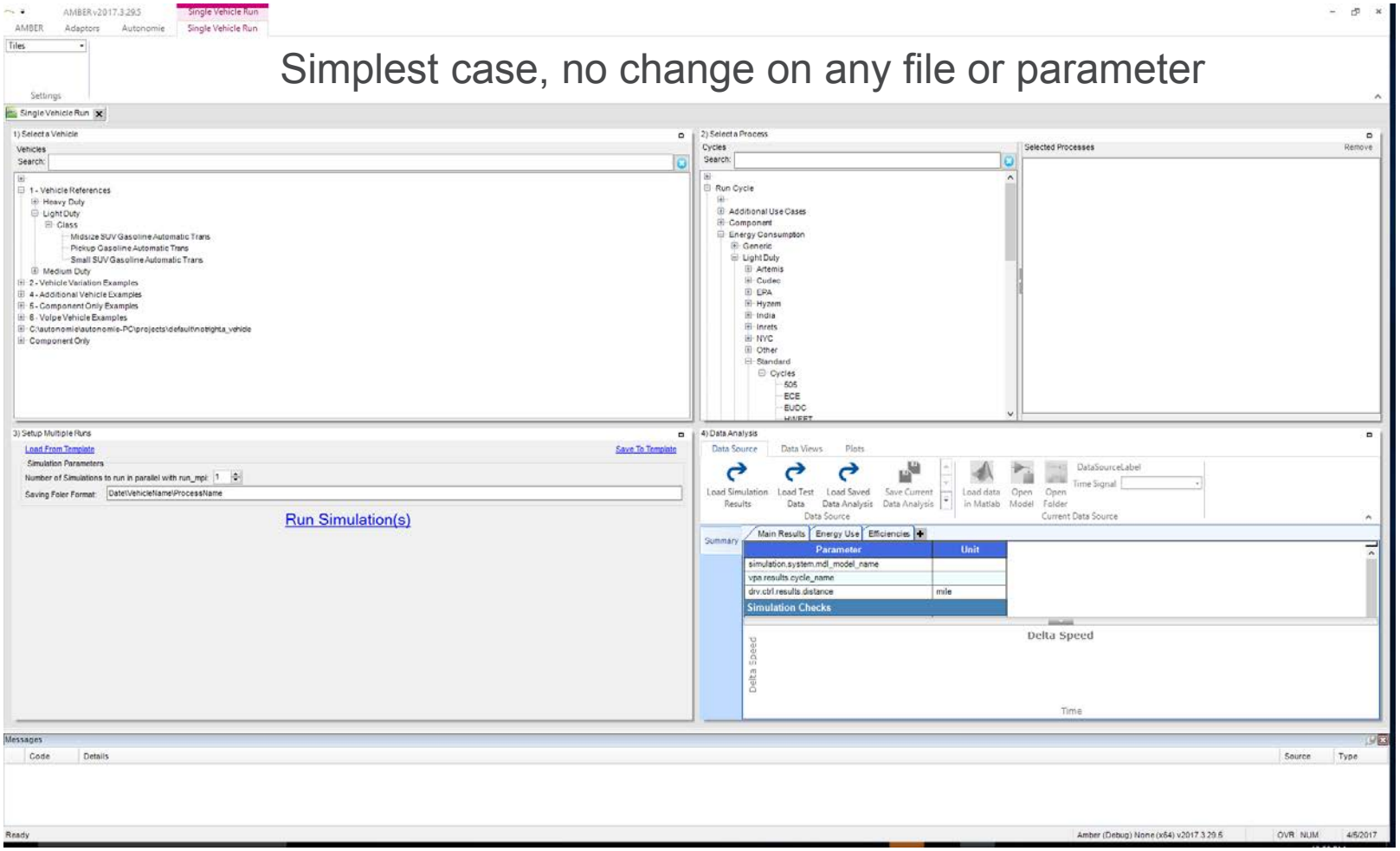
Vehicle Editor

For Component Technology Impacts

Technical Accomplishments

For the Same Application, Different Workflows are Provided to Only Show the Information Needed

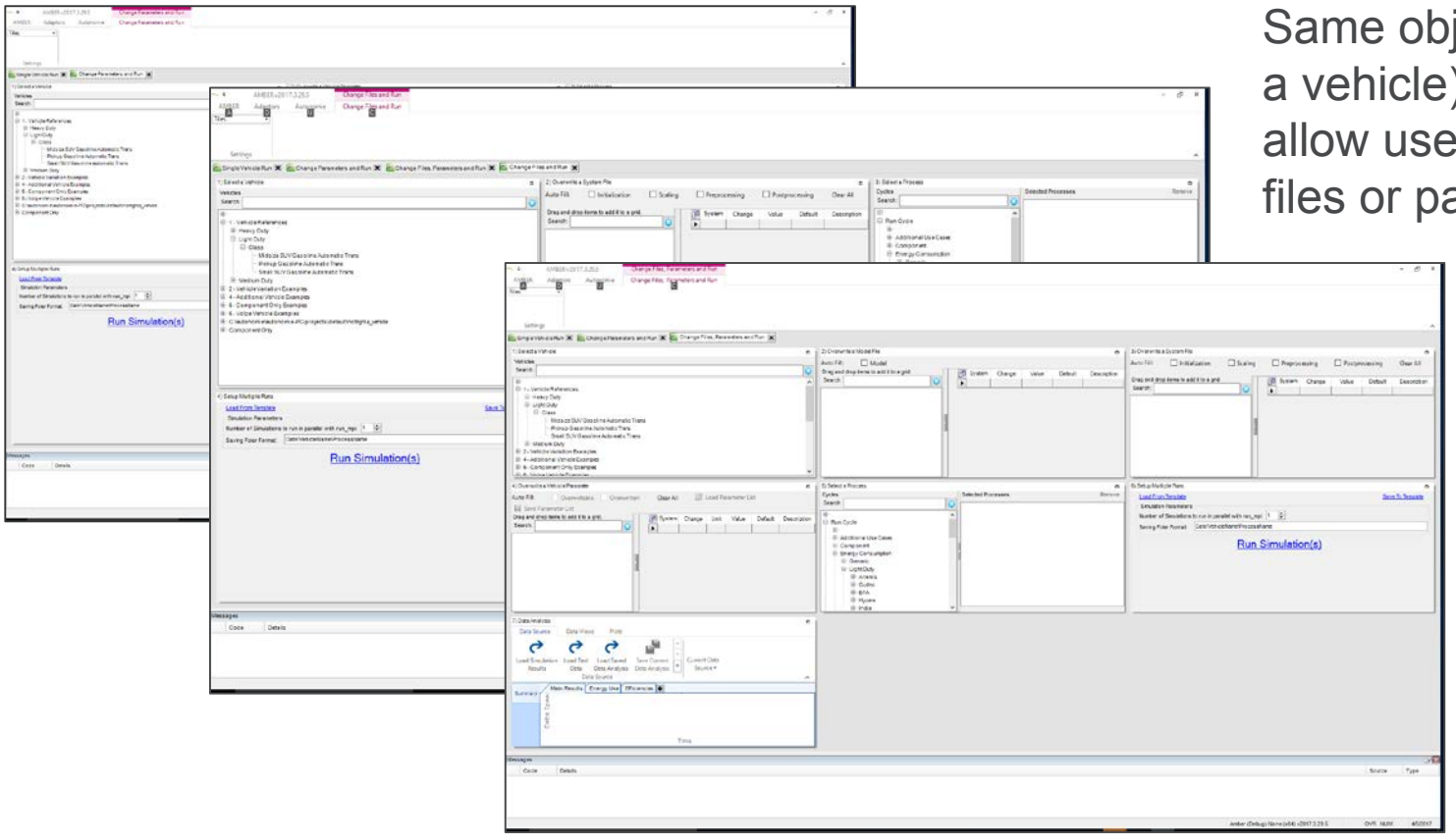
Select a Vehicle, Select a Cycle Workflow



Technical Accomplishments

The User Interface Adapts to the Task Complexity

- Adaptive UI: Modify Vehicle Parameters , Modify Vehicle Files, Modify Vehicle Parameters and Files



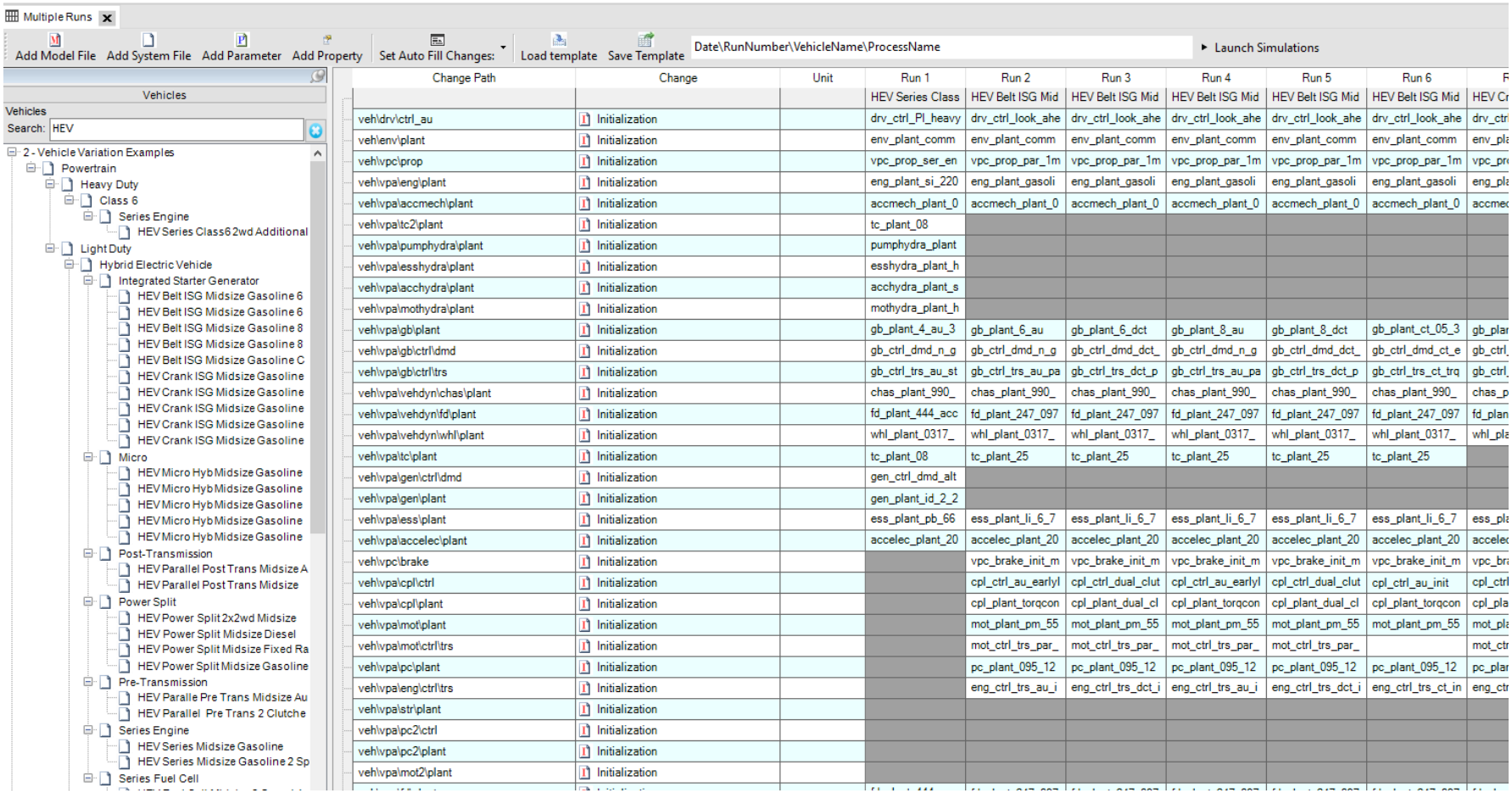
Same objective (simulate a vehicle), but we now allow users to change files or parameters

Simple Tasks Should Have Simple UIs

Technical Accomplishments

Running Large Studies with Autonomie is Now Possible

Multiple Run Workflow



Change Path	Change	Unit	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
			HEV Series Class	HEV Belt ISG Mid	HEV Belt ISG Mid	HEV Belt ISG Mid	HEV Belt ISG Mid	HEV Belt ISG Mid
veh\drv\ctrl_au	Initialization		drv_ctrl_Pl_heavy	drv_ctrl_look_ahe	drv_ctrl_look_ahe	drv_ctrl_look_ahe	drv_ctrl_look_ahe	drv_ctrl_look_ahe
veh\env\plant	Initialization		env_plant_comm	env_plant_comm	env_plant_comm	env_plant_comm	env_plant_comm	env_plant_comm
veh\vpc\prop	Initialization		vpc_prop_ser_en	vpc_prop_par_1m	vpc_prop_par_1m	vpc_prop_par_1m	vpc_prop_par_1m	vpc_prop_par_1m
veh\vpa\eng\plant	Initialization		eng_plant_si_220	eng_plant_gasoli	eng_plant_gasoli	eng_plant_gasoli	eng_plant_gasoli	eng_plant_gasoli
veh\vpa\accmech\plant	Initialization		accmech_plant_0	accmech_plant_0	accmech_plant_0	accmech_plant_0	accmech_plant_0	accmech_plant_0
veh\vpa\tc2\plant	Initialization		tc_plant_08					
veh\vpa\pumphydra\plant	Initialization		pumphydra_plant					
veh\vpa\esshydra\plant	Initialization		esshydra_plant_h					
veh\vpa\acchydra\plant	Initialization		acchydra_plant_s					
veh\vpa\mothydra\plant	Initialization		mothydra_plant_h					
veh\vpa\gb\plant	Initialization		gb_plant_4_au_3	gb_plant_6_au	gb_plant_6_dct	gb_plant_8_au	gb_plant_8_dct	gb_plant_ct_05_3
veh\vpa\gb\ctrl\dmd	Initialization		gb_ctrl_dmd_n_g	gb_ctrl_dmd_n_g	gb_ctrl_dmd_dct_	gb_ctrl_dmd_n_g	gb_ctrl_dmd_dct_	gb_ctrl_dmd_ct_e
veh\vpa\gb\ctrl\trs	Initialization		gb_ctrl_trs_au_st	gb_ctrl_trs_au_pa	gb_ctrl_trs_dct_p	gb_ctrl_trs_au_pa	gb_ctrl_trs_dct_p	gb_ctrl_trs_ct_trq
veh\vpa\vehdyn\chas\plant	Initialization		chas_plant_990_	chas_plant_990_	chas_plant_990_	chas_plant_990_	chas_plant_990_	chas_plant_990_
veh\vpa\vehdyn\fd\plant	Initialization		fd_plant_247_097	fd_plant_247_097	fd_plant_247_097	fd_plant_247_097	fd_plant_247_097	fd_plant_247_097
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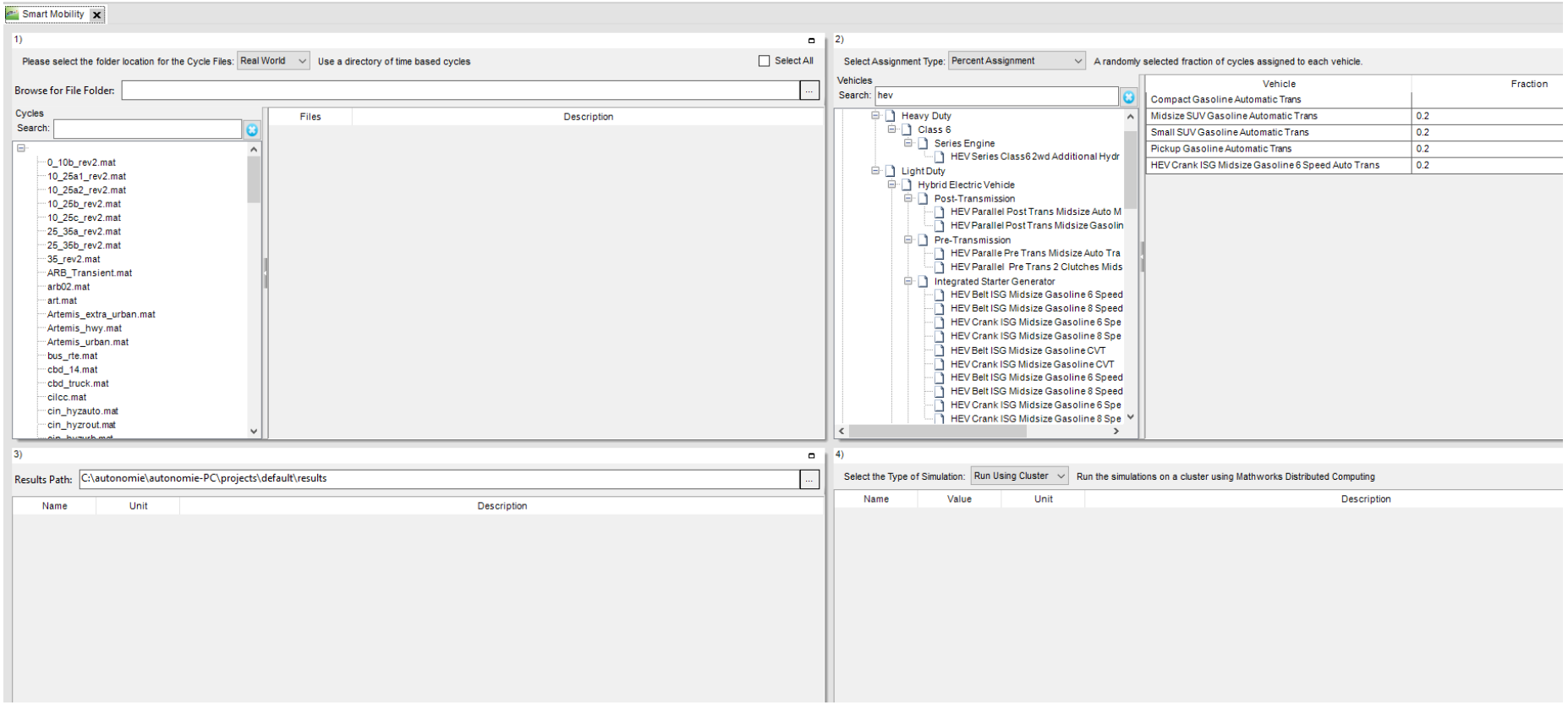
veh\vpa\tc\plant	Initialization		tc_plant_08	tc_plant_25	tc_plant_25	tc_plant_25	tc_plant_25	tc_plant_25
veh\vpa\gen\ctrl\dmd	Initialization		gen_ctrl_dmd_alt					
veh\vpa\gen\plant	Initialization		gen_plant_id_2_2					
veh\vpa\ess\plant	Initialization		ess_plant_pb_66	ess_plant_li_6_7	ess_plant_li_6_7	ess_plant_li_6_7	ess_plant_li_6_7	ess_plant_li_6_7
veh\vpa\accelec\plant	Initialization		accelec_plant_20	accelec_plant_20	accelec_plant_20	accelec_plant_20	accelec_plant_20	accelec_plant_20
veh\vpc\brake	Initialization			vpc_brake_init_m	vpc_brake_init_m	vpc_brake_init_m	vpc_brake_init_m	vpc_brake_init_m
veh\vpa\cpl\ctrl	Initialization			cpl_ctrl_au_earlyl	cpl_ctrl_dual_clut	cpl_ctrl_au_earlyl	cpl_ctrl_dual_clut	cpl_ctrl_au_init
veh\vpa\cpl\plant	Initialization			cpl_plant_torqcon	cpl_plant_dual_cl	cpl_plant_torqcon	cpl_plant_dual_cl	cpl_plant_torqcon
veh\vpa\mot\plant	Initialization			mot_plant_pm_55	mot_plant_pm_55	mot_plant_pm_55	mot_plant_pm_55	mot_plant_pm_55
veh\vpa\mot\ctrl\trs	Initialization			mot_ctrl_trs_par_	mot_ctrl_trs_par_	mot_ctrl_trs_par_	mot_ctrl_trs_par_	
veh\vpa\pc\plant	Initialization			pc_plant_095_12	pc_plant_095_12	pc_plant_095_12	pc_plant_095_12	pc_plant_095_12
veh\vpa\eng\ctrl\trs	Initialization			eng_ctrl_trs_au_i	eng_ctrl_trs_dct_i	eng_ctrl_trs_au_i	eng_ctrl_trs_dct_i	eng_ctrl_trs_ct_in
veh\vpa\str\plant	Initialization							
veh\vpa\pc2\ctrl	Initialization							
veh\vpa\pc2\plant	Initialization							
veh\vpa\mot2\plant	Initialization							

Technical Accomplishments

Quantifying the Energy Impact of Smart Mobility using POLARIS Fully Integrated

Smart Mobility Workflow



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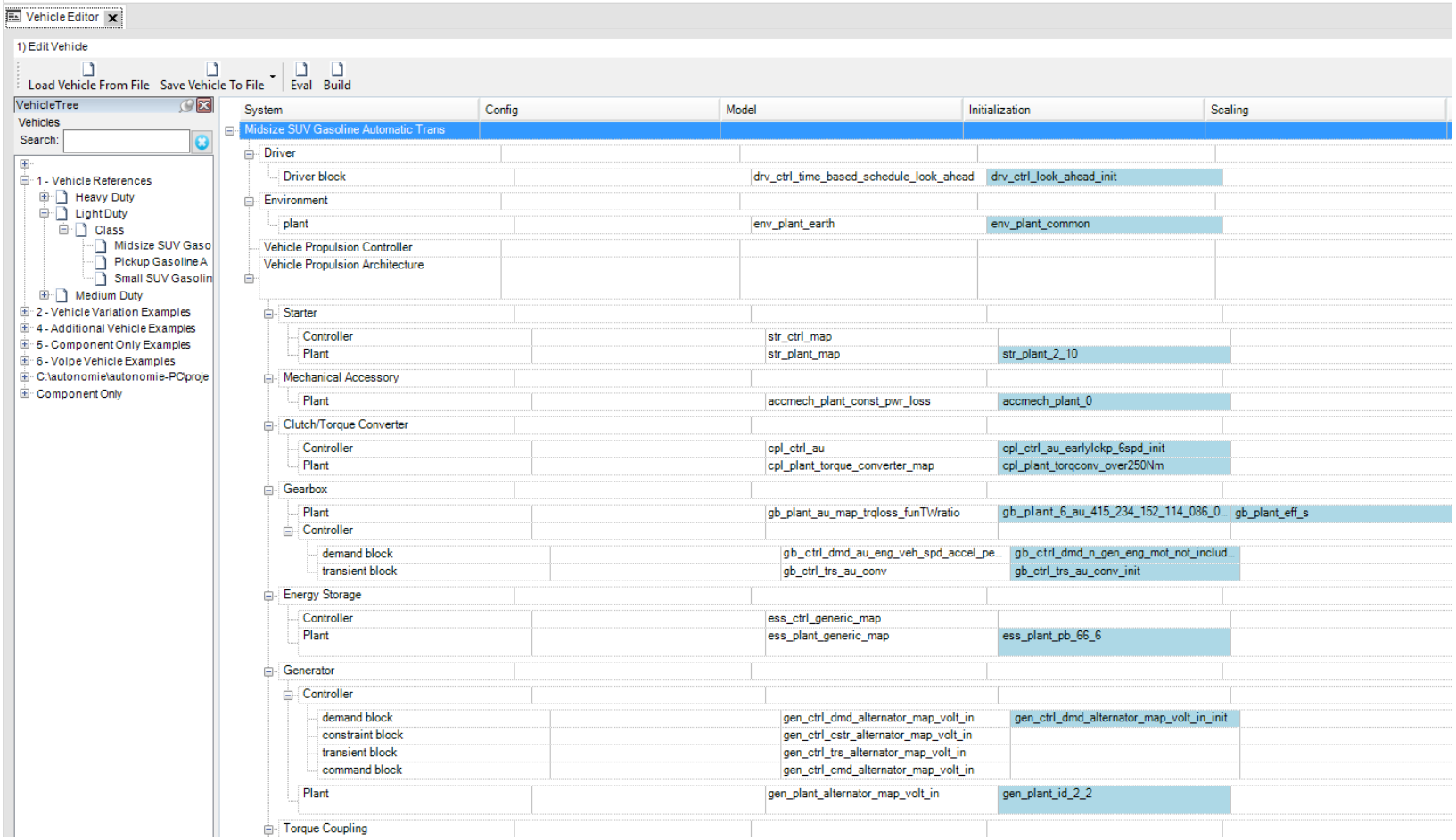
Technical Accomplishments

Developers are also Provided Only the Information they Need Through Fast, Streamlined Vehicle Editor

Create a New Vehicle Workflow

File View



Response to Previous Year Reviewers' Comments

- The reviewer specified Autonomie as having been used worldwide by companies and research organizations and as a true success story of the program.

We don't seek to replace Autonomie; we are broadening the success of Autonomie to encompass additional simulation tools and transportation research, which did not fit into the natural, vehicle-centric workflow of Autonomie

Partnerships and Collaborations

- The decision to replace the previous system simulation framework (Autonomie Plug&Play) was driven by Autonomie's user community (>200 institutions), including Argonne's System Modeling and Control Group.
- The requirements were developed through interactions with the user community
- Numerous meetings have occurred with companies (e.g., Ford, GM…) to make sure that the tool structure was consistent with the requirements
- Specific workflows have been identified to test the capabilities of AMBER before its release

Remaining Challenges and Barriers

- Develop new processes that are computationally efficient (leverage HPC), cost effective and minimize licensing requirements
- Facilitate integration of new interfaces and tools: many aspects of the graphical user interface will be open
- Continue to provide sufficient flexibility for users

Proposed Future Research

- Deploy AMBER in FY17 Q4
- Add new use cases to support current and future VTO technologies with focus on Smart Mobility and very large scale simulations
- Define priority list with inputs from users (DOE and Industry), including
  1. Launch Polaris (executable) from AMBER workflow
  2. Initialize specific vehicles (i.e., Ford Focus MY15) using Argonne's new vehicle technology database
  3. Implement Road Runner (multi-vehicles with their environment) workflow
  4. Integrate a Large Scale Study Workflow for VTO benefit analysis including HPC and powertrain sizing
  5. Automated vehicle model development and validation from vehicle test data

Any proposed future work is subject to change based on funding levels

Summary

We Can Now Deploy Processes That Were Impossible to Implement Before

- Developed a new software that enable DOE and OEMs to integrate multiple tools into Model Based Engineering Workflows to accelerate technology development and market introduction
- All the vehicle models remain unchanged to ensure backward compatibility (Autonomie application)
- Most of the processes previously integrated in Autonomie Plug&Play have been migrated to AMBER (i.e., single vehicle workflow)
- Several existing processes have been integrated into AMBER (New – Never before done with Autonomie Plug&Play) including large scale simulations (thousands of vehicles) and Smart Mobility (POLARIS/SVTrip/Autonomie)
- First public release planned for FY17 Q4
- Future workflow development will focus on new needs from DOE VTO (I.e., Smart Mobility, Machine Learning…) and our user community

TECHNICAL BACK-UP SLIDES

Differences Between Autonomie Plug&Play and AMBER

- Maintaining compatibility between 1.0 and 2.0
  - Vehicles files, the same .a_vehicle file and xml
  - Model files, the same .a_model file and xml
  - System .m files, the same .a_init, .a_preproc, .a_postproc, .a_scale and xml is used
  - Configurations, the same .a_config and .a_layout are used,
    - however there are plans to add an option dropping the .a_layout but retaining the .a_config. Replacing the .a_layout would be a .slx or .mdl.
- Processes are different
  - .a_process file xml is different
  - .a_run file xml is different
  - Files are assembled through references
- The matlab API is different
  - Units conversion_calc()
  - Reporting interface to add values to the html report will change
  - Matlab function calls: such as run_simulation which runs any .a_run files in the current user folder will be replaced with pxf_run_process('name.a_run')
  - Looking at adding a compatibility layer of functions to expose functionality in a equivalent format.