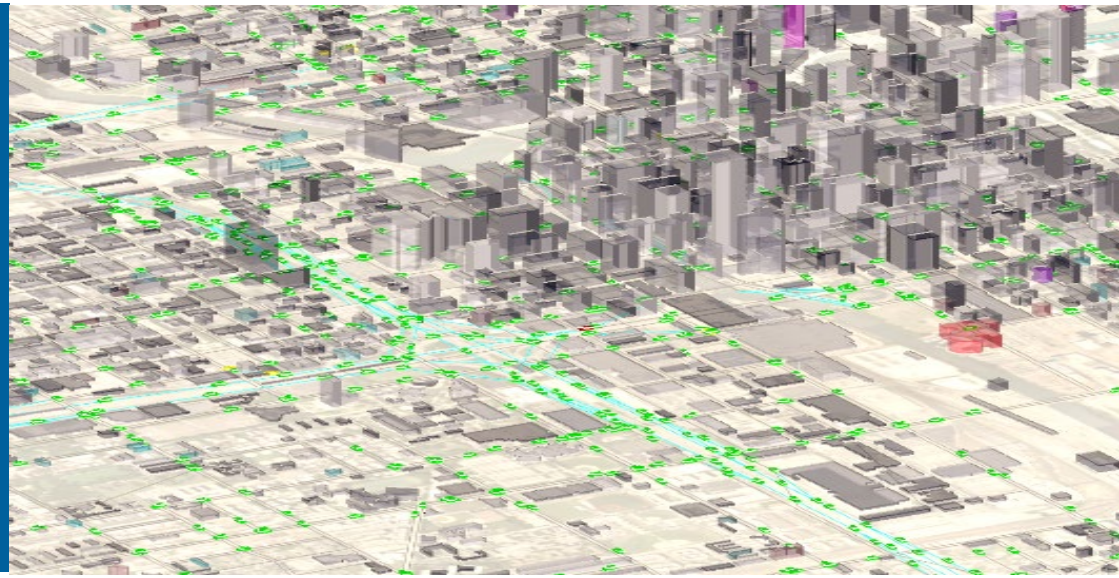
PROJECT ID # EEMS013

CORE TOOLS SIMULATION



Phillip Sharer, Ram Vijayagopal, Paul Delaughter, Michael Juskiewicz, Sylvain Pagerit, Aymeric Rousseau

Argonne National Laboratory
9700 S Cass Ave
Lemont, IL

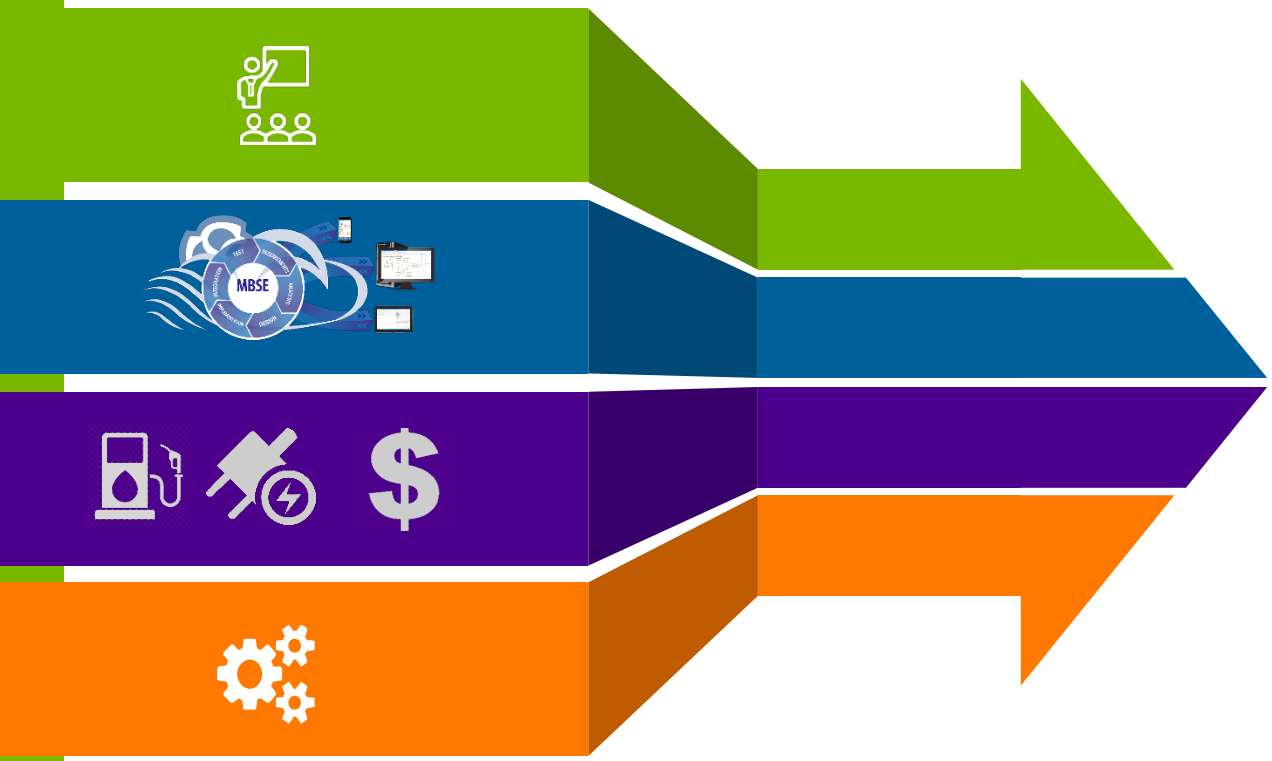
Annual Merit Review 2021, Washington DC

PROJECT OVERVIEW

Timeline	Barriers
• Project start date : Oct. 2018 • Project end date : Sep. 2021 • Percent complete : 90%	• High uncertainty in technology deployment, functionality, usage, impact at system level • Computational models, design and simulation methodologies • Lack of data on individual behaviors relating to e-commerce and freight • Integration of disparate model frameworks
Budget	**Partners**
• Total funding: $3,750,000 • FY21 funding received : $1,250,000	• AMBER and Autonomie users, both within and outside Argonne (e.g., Ford, Hyundai, Toyota…) • US Government-Industry Partnerships (US Drive, 21CTP)

PROJECT RELEVANCE

Support the DOE Vehicle Technologies Office (VTO) system simulations, more specifically the Energy Efficiency Mobility Systems (EEMS) program



Stakeholders Engagement & Deployment

Collect users feedback including issues and new requirements, deploy tools to stakeholders based on their needs

Model-Based System Engineering

AMBER: Develop and maintain MBSE platform to estimate the impact of new technologies on mobility, energy, emission, cost, equity… from pure simulation to Vehicle-in-the-Loop.

Vehicle System Simulation

Autonomie: Maintain state-of-the-art vehicle energy consumption, performance and cost system simulation across vehicle classes, powertrains and component technologies.

System Simulation Workflows

Develop and maintain system simulation workflows designed to answer specific questions from individual component technology (e.g., new engine with single tool) to individual vehicles and large fleets.

>28 Projects were related to AMBER/Autonomie during AMR 2020

PROJECT RELEVANCE

Examples of Applications Supported by EEMS Core

EEMS CORE	Goals / Initiatives
• Technical support, tools maintenance, license management	• Stakeholder engagement
• AMBER development	• Autonomie, SVTrip, RoadRunner, POLARIS, Aeronomie deployments • Stakeholder engagement

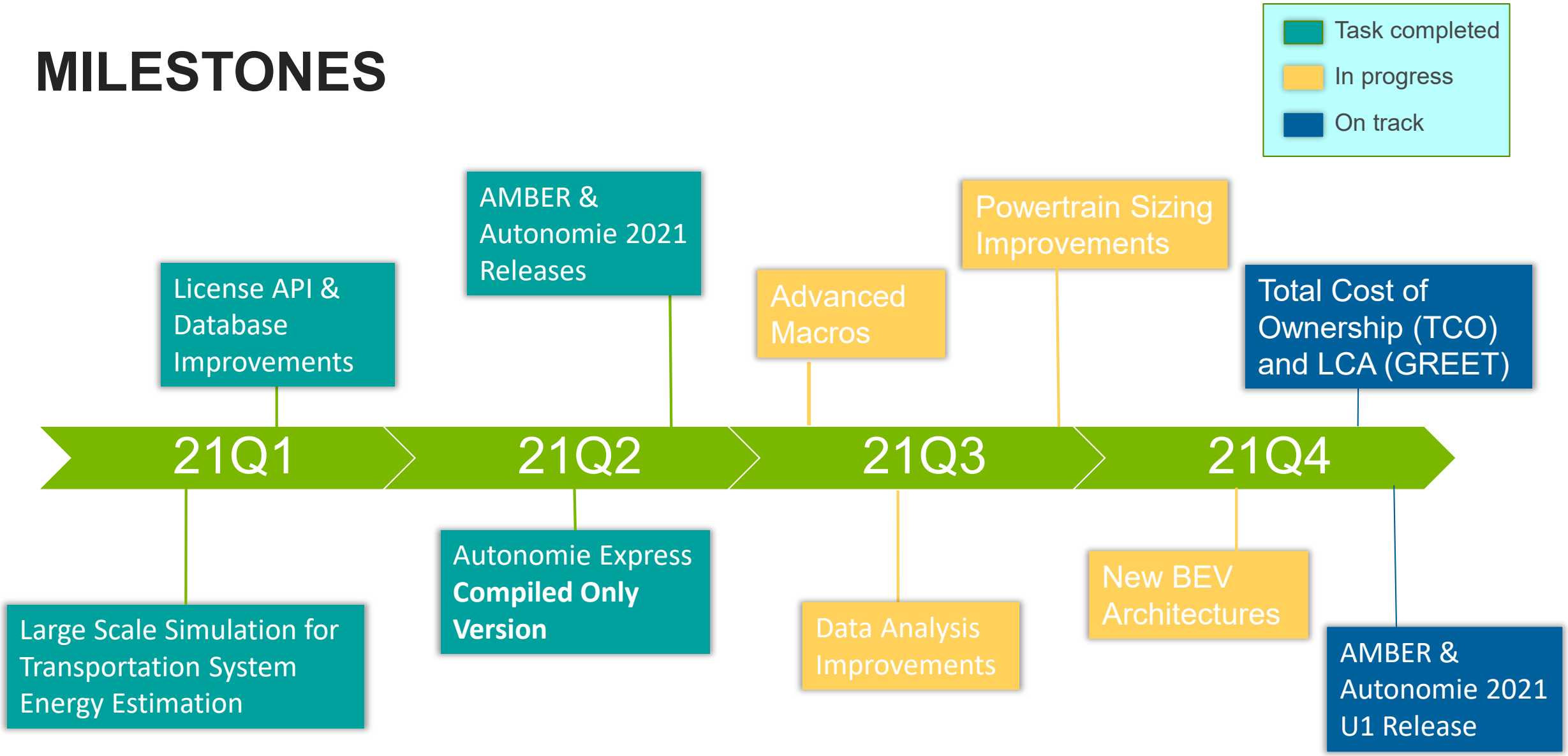
• AMBER workflows
  • Large scale vehicle studies
  • Compiled vehicles…
	• 100K+ simulations (HPC)
	• Micro & Meso simulations

• Autonomie development	• Component technical targets for light duty (USDrive) and medium/heavy duty (21CTP) vehicles • VTO/HFTO technology benefits • Component performance data, cost • New powertrain sizing
• Assign powertrains for MD/HDT	• Freight operational efficiency (SMART)

In support of

SMART Mobility
EEMS FOAs
TI FOAs
VTO Tech managers
USDrive
21CTP
Stakeholders

MILESTONES


Task completed
In progress
On track
License API & Database Improvements
AMBER & Autonomie 2021 Releases
Advanced Macros
Powertrain Sizing Improvements
Total Cost of Ownership (TCO) and LCA (GREET)
21Q1
21Q2
21Q3
21Q4
Large Scale Simulation for Transportation System Energy Estimation
Autonomie Express **Compiled Only Version**
Data Analysis Improvements
New BEV Architectures
AMBER & Autonomie 2021 U1 Release

APPROACH

AMBER Framework Designed to Support Any System Simulation Workflows

Stakeholder Inputs

Tools

AUTONOMIE
SVTRIP
ROAD RUNNER
POLARIS
BatPac
GREET
AERONOMIE
BEAN
tableau

and many more…

AMBER

Workflow Examples

BatPac + AUTONOMIE + GREET

Individual vehicle energy, cost and GHG (VAN023)

AUTONOMIE + SVTRIP + ROAD RUNNER

Energy-efficient control enabled by connectivity and automation (EEMS089)

POLARIS + SVTRIP + AUTONOMIE + GREET

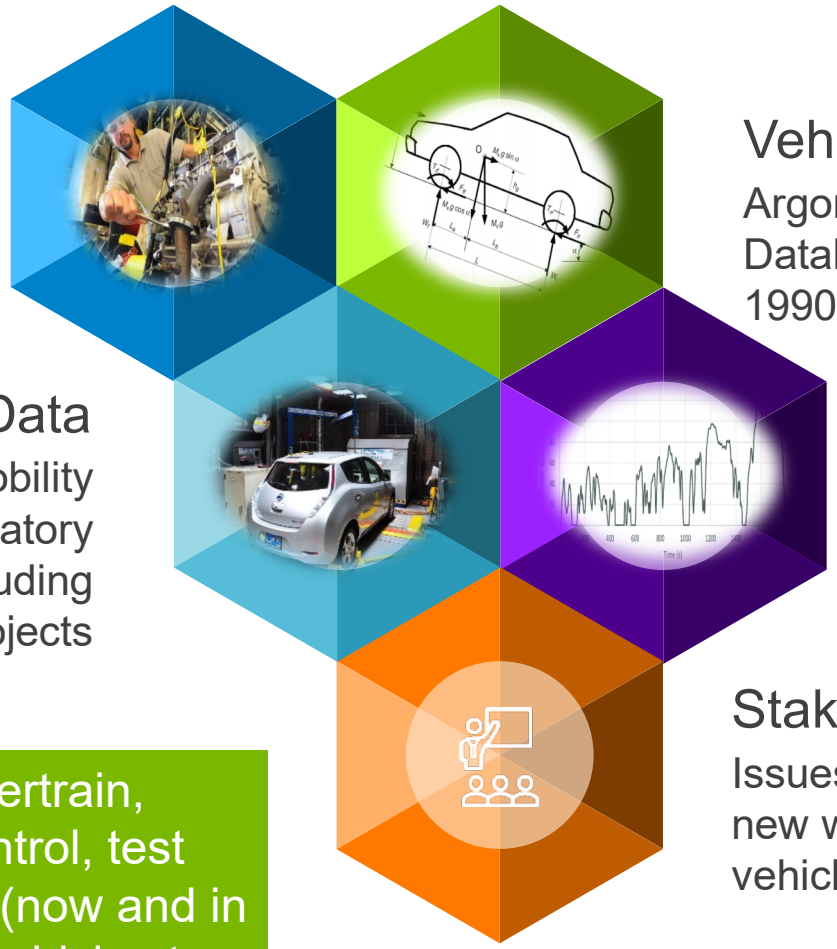
SMART Mobility Workflow (EEMS093, VAN035)

APPROACH

Autonomie Continuously Collect Data and Inputs from as Many Sources as Possible

Component Data
OEMs, suppliers, literature, DOE R&D, DOT/NHTSA…

Vehicle Data
Argonne Advanced Mobility Technology Laboratory (AMTL), including DOT/NHTSA projects



Vehicle Technical Specifications
Argonne Vehicle Technology Database (integrate 20+ data sources 1990-2020), A2MAC1…

Driving Cycles / Test Procedure
SAE, OEMs, Suppliers, NREL TSDC/FleetDNA…

Stakeholder Inputs
Issues, new GUI features, new workflows, new vehicles…

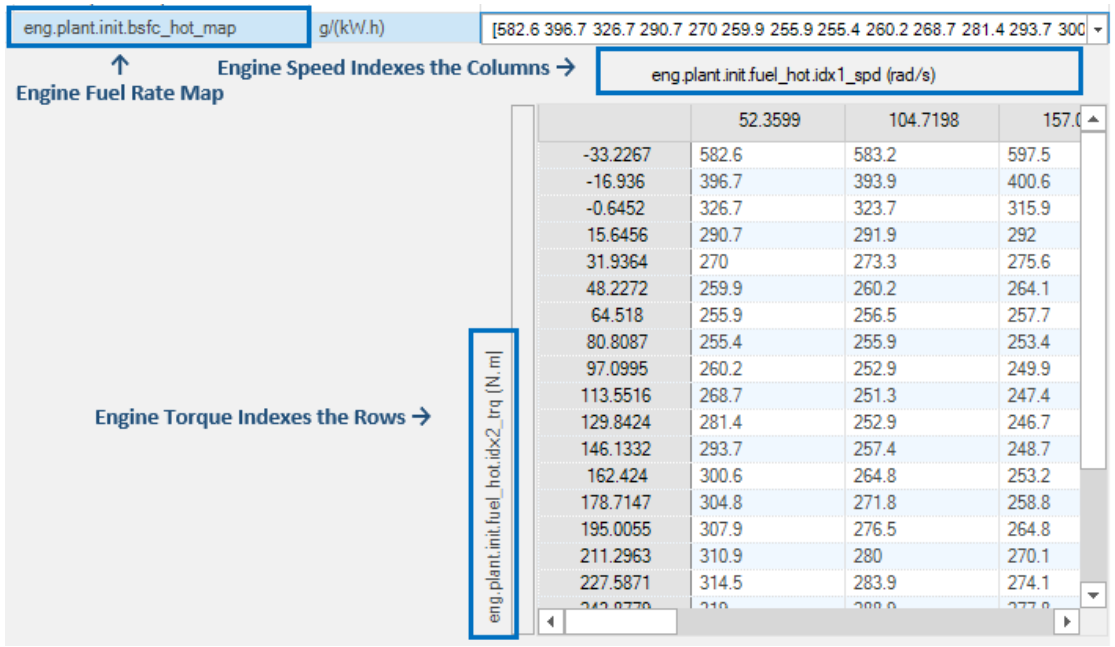
Objective: Model any powertrain, component technology, control, test procedure… in the market (now and in the future) from light-duty vehicles to heavy duty trucks

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

STAKEHOLDER INPUTS DROVE CAPABILITIES AND IMPROVEMENTS

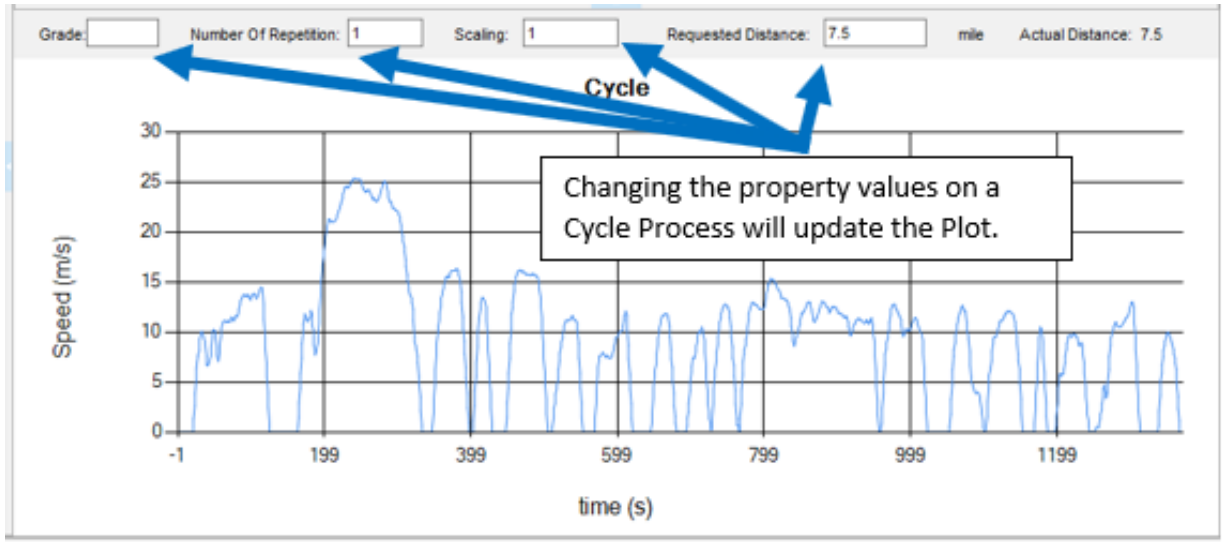
140+ New Features and Enhancements Added Based on User Feedback

Both government and commercial users requested a way to edit 2D and 3D maps directly from the UI



	52.3599	104.7198	157.0
-33.2267	582.6	583.2	597.5
-16.936	396.7	393.9	400.6
-0.6452	326.7	323.7	315.9
15.6456	290.7	291.9	292
31.9364	270	273.3	275.6
48.2272	259.9	260.2	264.1
64.518	255.9	256.5	257.7
80.8087	255.4	255.9	253.4
97.0995	260.2	252.9	249.9
113.5516	268.7	251.3	247.4
129.8424	281.4	252.9	246.7
146.1332	293.7	257.4	248.7
162.424	300.6	264.8	253.2
178.7147	304.8	271.8	258.8
195.0055	307.9	276.5	264.8
211.2963	310.9	280	270.1
227.5871	314.5	283.9	274.1

Users asked for a more dynamic visual representation of changes to cycle options, like # of repetition, scaling, grade…



Argonne NATIONAL LABORATORY

AUTONOMIE EXPRESS – A NEW, FASTER VERSION WITH A LARGE NUMBER OF PRE-DEFINED VEHICLES

Increase Tool Adoption by Targeting Users (vs Developers)

	AUTONOMIE	NEW AUTONOMIE EXPRESS
Source Code	Full code access (component models, controls, data…)	Compiled vehicle models, access limited to component data
Vehicle Models	100+ full vehicle models with controls provided with unlimited ability to create new ones	1500+ vehicle models (and growing fast – VAN023) 10X faster
Licensing	Free (US Gov funded projects, teaching) Paid license for commercial use Requires Matlab/Simulink/StateFlow	FREE Only requires Matlab
Applications	For developers: impact of new powertrains, models, controls, develop new workflows…	For users: simulate existing vehicles on existing workflows (e.g., energy with micro-simulation tools)

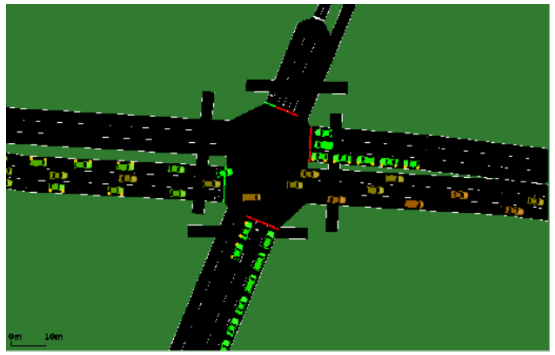
Request Autonomie or Autonomie EXPRESS under
https://vms.es.anl.gov/LicenseRequest/NonGovernmentAutonomie
https://vms.es.anl.gov/LicenseRequest/GovernmentAutonomie

NEW WORKFLOW DESIGNED TO ESTIMATE ENERGY, COST FROM MICRO-SIMULATION TOOLS

Most Commonly Used Tools Integrated

AUTONOMIE *EXPRESS*

Micro-simulation Tools



SUMO

PTV VISSIM

aimsun.

+

Five Timeframes (2020, 2025, 2030, 2035, 2040)

✖

20+ vehicle classes from light-duty to medium and heavy duty

✖

Multiple Powertrains (conv, ISG, HEV, PHEV, BEV, FCEV)

✖

Technology Uncertainties

1000s of vehicle models

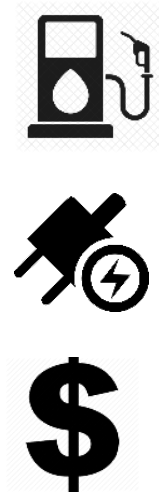
+

AMBER

Workflow

- Assign Autonomie *EXPRESS* models to individual micro-simulation vehicles
- Simulate using individual vehicle speeds from micro-simulation

=



U.S. DEPARTMENT OF ENERGY SMARTMOBILITY Systems and Modeling for Accelerated Research in Transportation

Argonne NATIONAL LABORATORY

AUTONOMIE UPDATED TO EVALUATE NEW & EMERGING TECHNOLOGIES

Component Data

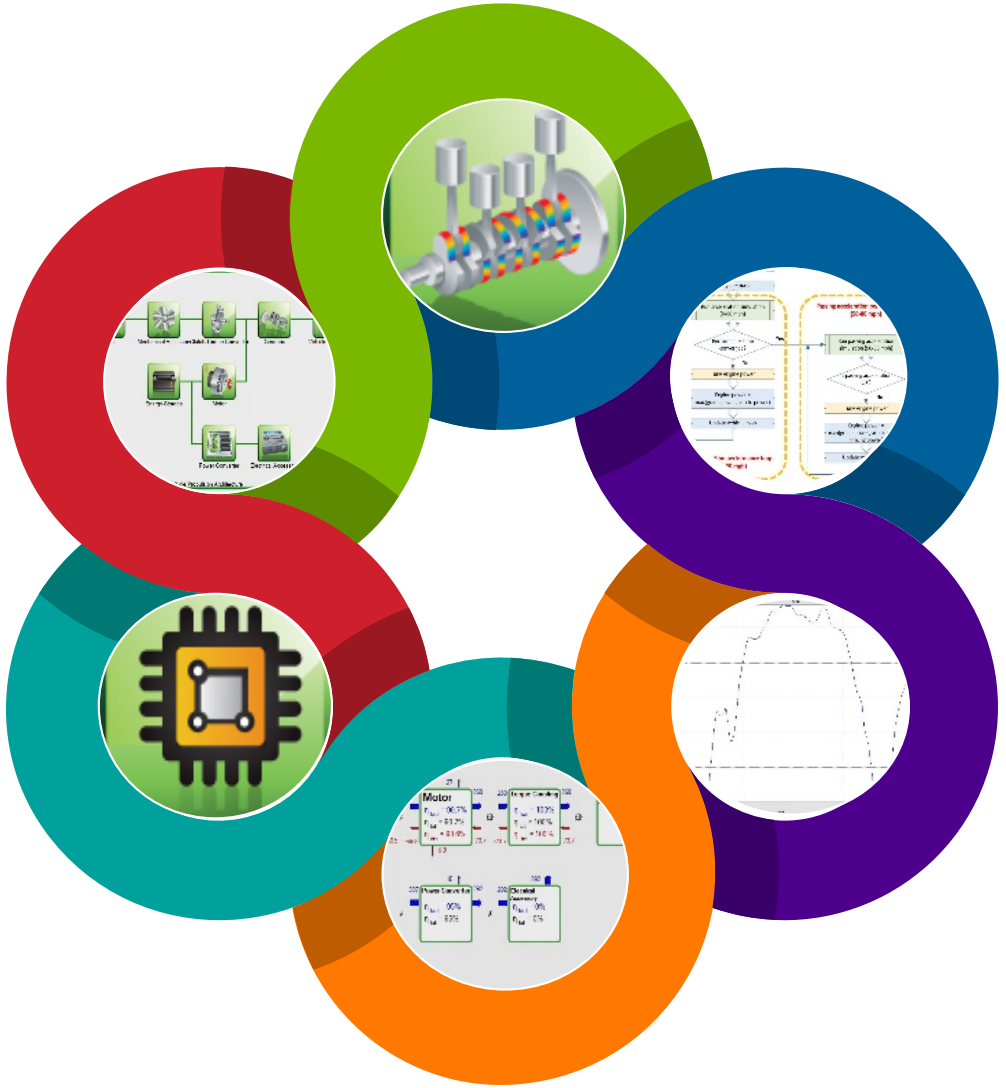
New transmission (F150), torque converter (SwRI), fuel cell (Mirai), MD/HD engines (EPA, SwRI)…

Powertrain Configuration

New BEV architecture for MD/HDT with multiple gears, new fuel cell (Range extender)….

Control

Improved robustness to grade noise, traction limit controls updated with grade dependent weight transfer to driven wheels



Powertrain Sizing

BEV/PHEV/FCEV range algorithm updated to include SAE J1634, CNG & EREV sizing algorithms added. Initiated merging of passenger vehicle and MD/HD truck algorithms

Driving Cycles

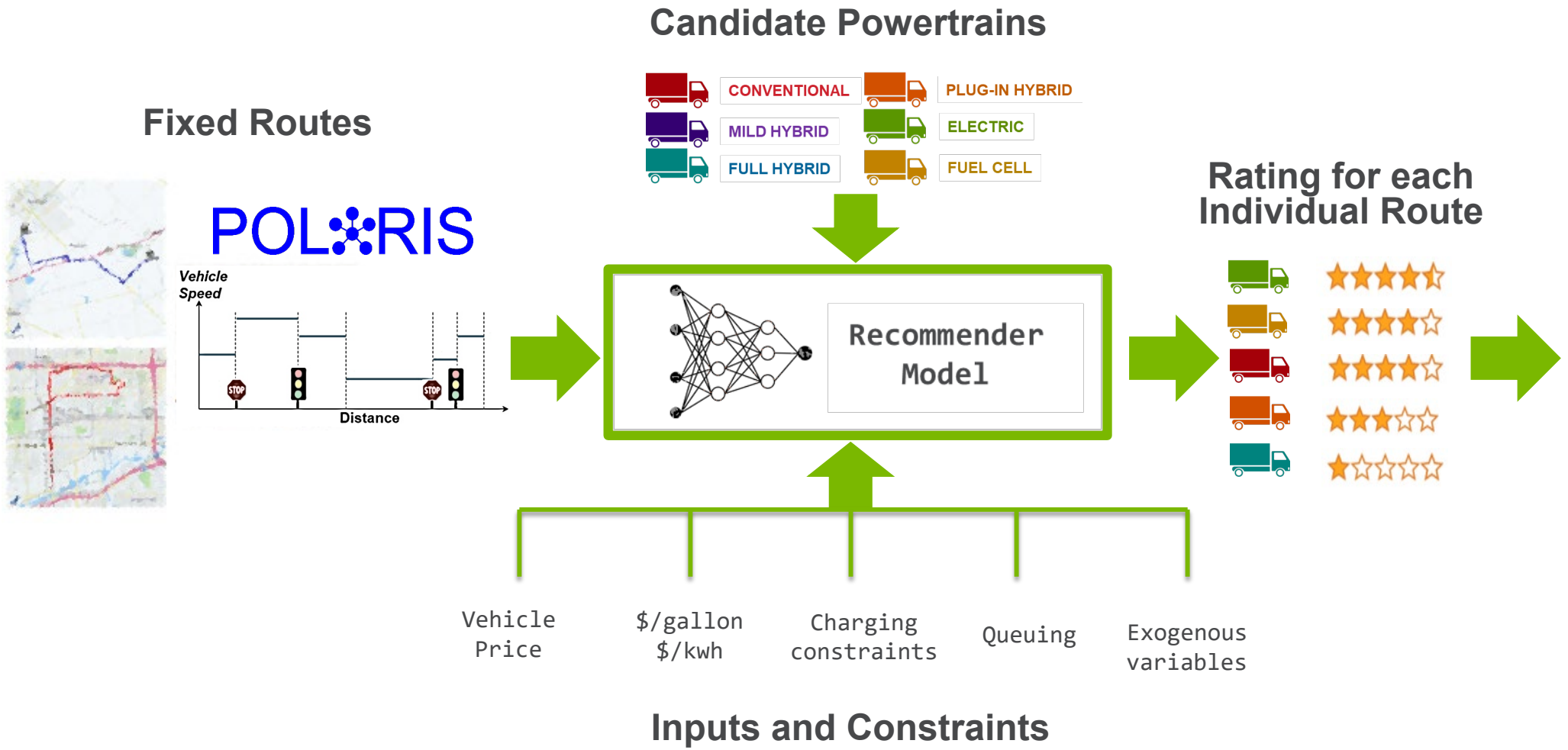
New heavy duty representative real world drive cycles added to Autonomie, including vocation specific cycles from NREL FleetDNA, updated EPA weighting factors, created “Autonomie ready” cycles from FleetNDA & TSDC

Post-processing

Added new powertrain efficiency calculations, improved QA/QC…

MATCHING POWERTRAIN TO MEDIUM/HEAVY DUTY APPLICATIONS

Vehicle-Route Recommender Critical for SMART (EEMS093)

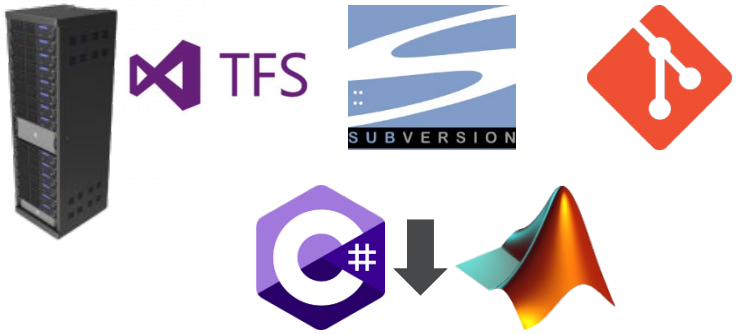


Optimum powertrain assignment (lowest TCO) for each route subject to operational constraints of the fleet

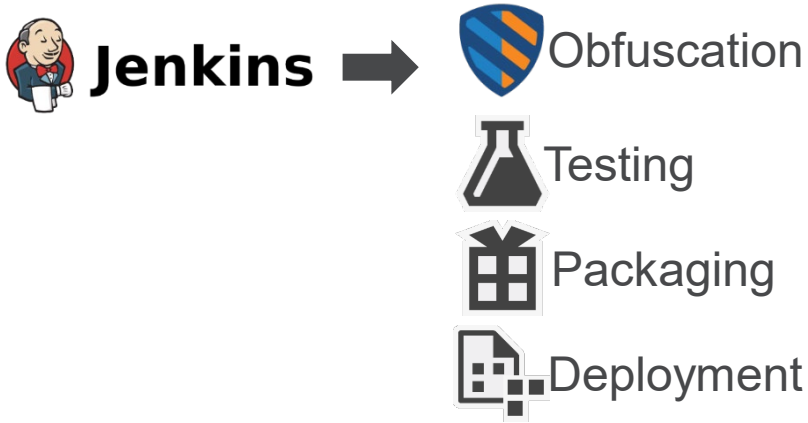
NEW DEPLOYMENT INFRASTRUCTURE AND LICENSE MANAGEMENT

Required to Manage Increasing Number of Tools and Workflows

Integrated Source Control

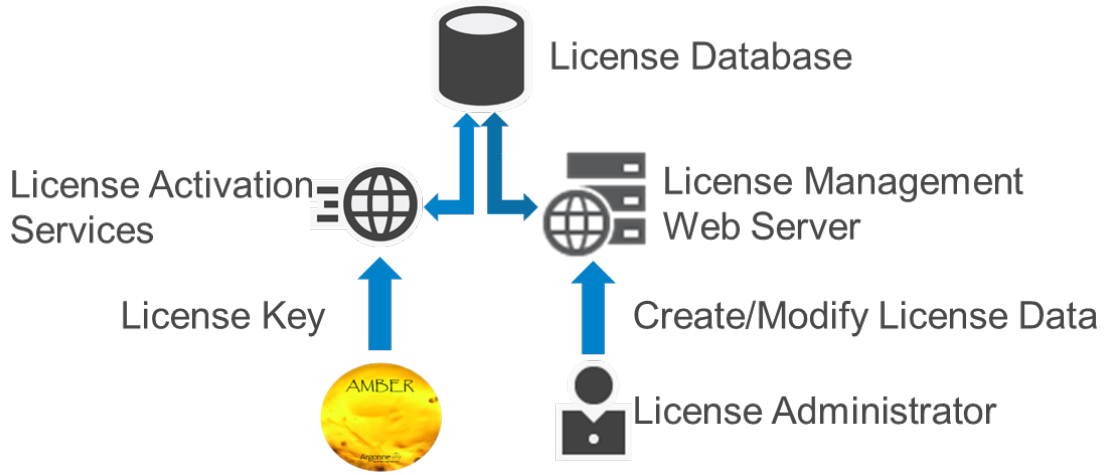


Automated Release Generation



New License Management Features

1) Updated FlexNet API
2) Get packages from license server (Ford)
3) Heartbeat to ensure active communication with FlexNet API
4) Activation support for multiple MAC addresses and hard drive volume serial number



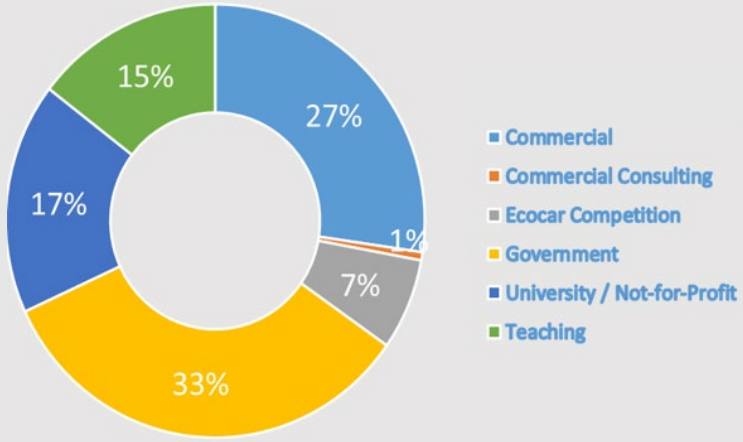
RESPONSES TO PREVIOUS YEAR REVIEWERS' COMMENTS

- Question : Approach to performing the work
  - 2/3 of reviewers positively rated the project approach
  - One reviewer expressed concerned about the simulation uncertainties and real world representations:
    - ***Response****: Extensive vehicle testing and validations have been performed over the last 20+ years, and new ones added every year, including validation work for multiple DOE, DOT projects and OEMs. Results from the large scale studies are peer reviewed by independent experts…*
- Question : Technical Accomplishment and Progress toward project goals
  - 2/3 of reviewers reported very good project milestones reached
  - One reviewer requested more information on how the simulation time can be down to 5s per simulation for large scale studies when setting each simulation in the GUI may take more time:
    - ***Response****: In large scale studies, most simulations are a combination of vehicles and cycle scenarios. The new AMBER GUI simplifies the selection of those vehicles and cycles, and automate all their combinations, before running the simulations with compiled vehicles, speeding up the process by several order of magnitudes compared to previous tools.*
- Question : Proposed Future Research
  - 2/3 of reviewers reported the current plan was good and relevant.
  - One reviewer requested a list with priorities, especially for MD & HD:
    - ***Response:*** *Our list of priorities continuously evolves based on stakeholders inputs and DOE study needs. Current priorities: new powertrain configuration and sizing as well as component data and TCO*

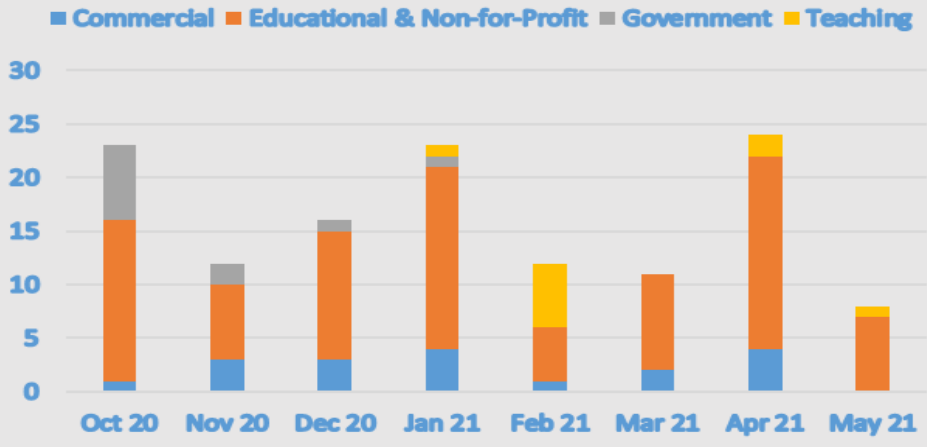
COLLABORATION AND COORDINATION

Core Tools Used Across Companies and R&D Organizations

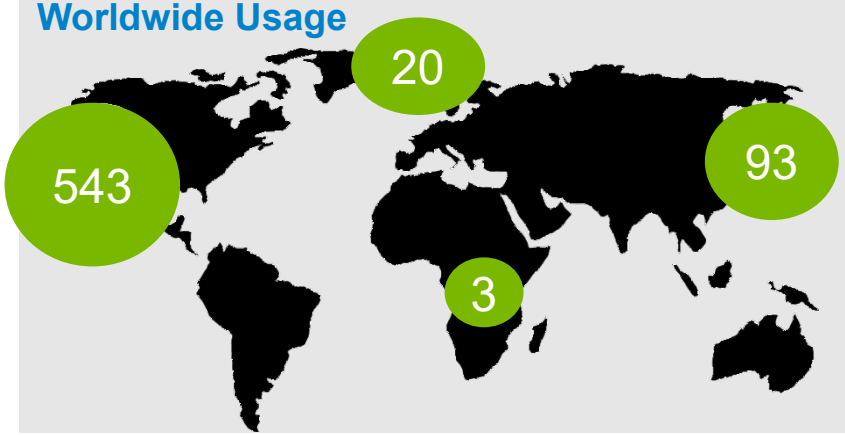
Total Number of Licenses (659)



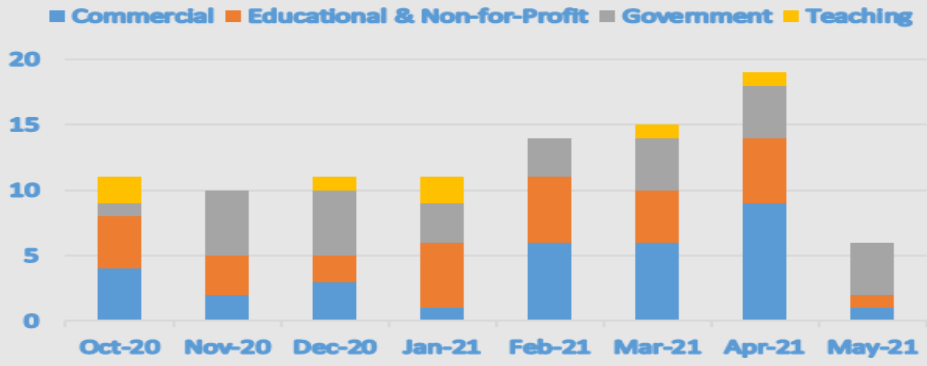
License Requests (FY21)



Worldwide Usage



Technical Support Requests (FY21)



Projects Supported

US DOE (VTO, HFTO), US DOT, US DOD, FOAs, SPPs…

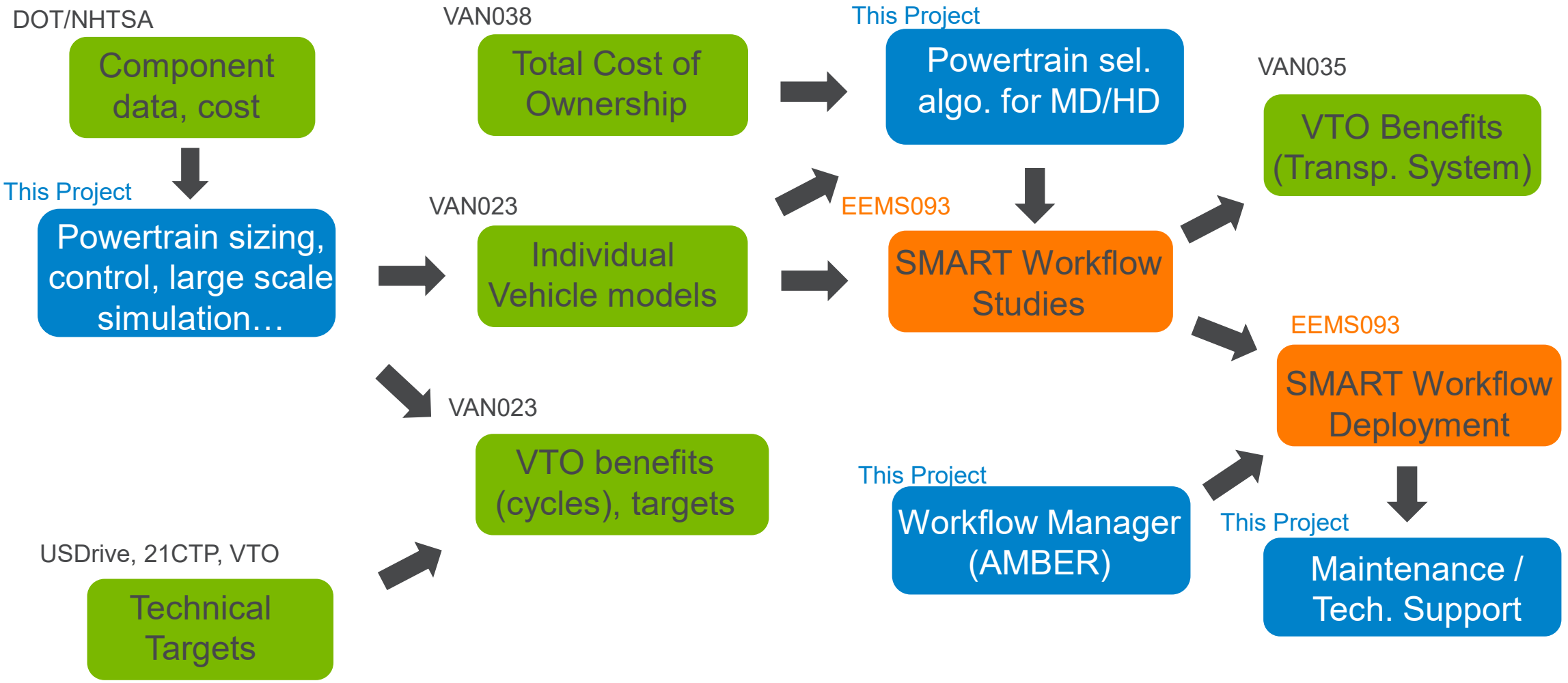
Programs Supported

SuperTruck

Argonne NATIONAL LABORATORY

COLLABORATION AND COORDINATION

Core Tools Tightly Integrated Across Multiple Projects, Government Agencies



REMAINING CHALLENGES AND BARRIERS OF THIS PROJECT

- Maintain latest versions of different tools (25+ software currently used for development, version control, license management…)
- Manage increasing number of workflows
- Predict future stakeholder needs in terms of workflow
- Continue to access latest vehicle, component data to represent state-of-the-art technologies
- Access vehicle dynamometer testing to understand latest powertrain and component controls to validate our models
- Maintain and expand Argonne Vehicle Technology Database to understand current technology trends
- Develop full vehicle models, including control, of all combinations currently in the market or under development

PROPOSED NEXT STEPS*

Expand Workflow and Model Capabilities

Autonomie Models

- Continue to enhance models, data… to represent state-of-the-art
- Expand new transportation modes (off-road, rail, boats, micro-transit…)?
- Add new real world cycles (& deploy)
- MD/HDT validation (data source?)
- Powertrain thermal modeling
- Predictive vehicle design (learn from current vehicle designs)

Autonomie Workflows

- Build & deploy workflow to estimate individual component technology benefit including automated control calibration
- Workflows for users (e.g., compiled vehicles, AI/ML, online tool, MathWorks free)
- Predictive vehicle design (ML)
- Powertrain selection for specific routes (e.g., buses)
- Expand automated model development & validation

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

PROPOSED NEXT STEPS*

Expand Stakeholder Engagement & Deployment

Maintain Tools / Support Users

- AMBER, Autonomie (full, compiled, machine learning)
- Add SVTrip, RoadRunner, POLARIS, Aeronomie
- Track/address issues and new requirements
- Update 25+ software versions

Expand AMBER

- Expand APIs to support integration of additional 3rd party tools (e.g., xIL)
- New data analytics workflows (including larger datasets, videos…)
- Reduce XML complexity (i.e., reference) / coordinate w/ DOT
- HPC workflow

Deploy Models / Tools / Workflow

- Expand testing across all tools
- Expand training (specific version w/ videos, exercises).
- Select / manage deployed vehicles (2.5M+) and drive cycles

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

SUMMARY

Stakeholder Engagement & Deployment

AMBER, Technical support, software management

Model-Based System Engineering

Improved code structure, new license management, enhanced deployment infrastructure

Vehicle System Simulation

New data, models, control, powertrains, improved powertrain sizing

MBSE Workflows

New and improved workflows for vehicle energy consumption, performance and cost (e.g., compiled version, large scale simulation)

Supports

- 30+ VTO & HFTO projects
- 10+ US DOT & DOD projects
- Licensed to 275+ organizations with 650+ users

U.S. DEPARTMENT OF ENERGY SMARTMOBILITY Systems and Modeling for Accelerated Research in Transportation

Argonne NATIONAL LABORATORY

QUESTIONS?

SUPPORTING A GROWING USER BASE

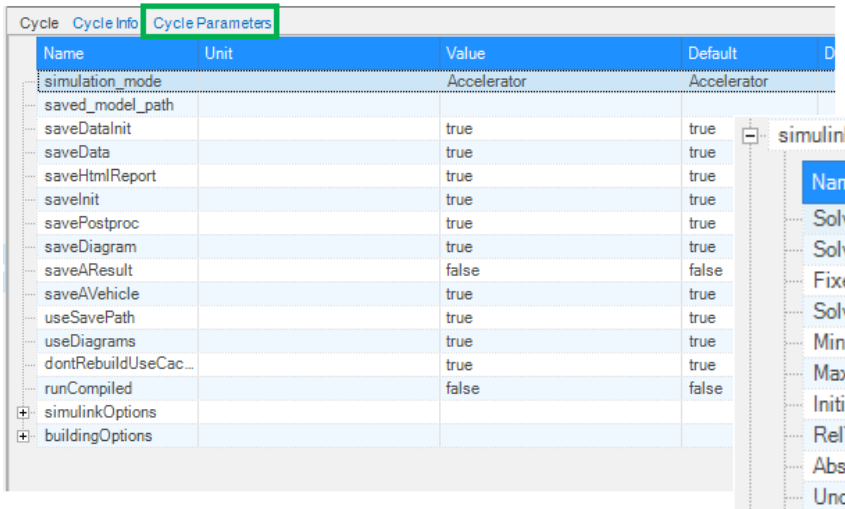
- Licensing is critical to
  - Protecting our IP
  - Managing license data for us and for users
    - What type of license?
      - evaluation, government, commercial, education, etc
    - How many licenses?
    - When does their support end?
- Integrated new FlexNet API
- Created new license database in SQL Server
- Cleaned license data – 10 years of licensing information from Autonomie
- Speeding Adoption
  - Web tool development for Licensing, floating license generation

STAKEHOLDER INPUTS DROVE CAPABILITIES IMPROVEMENTS

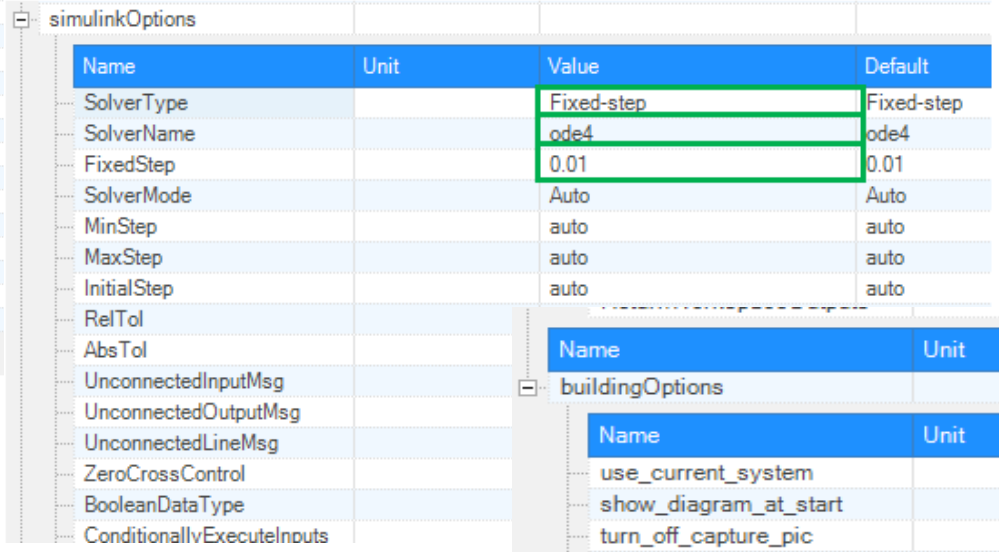
140+ New Features and Enhancements added based on user feedbacks

Advanced users requested a more fine grained parameter options to optimize their simulation process

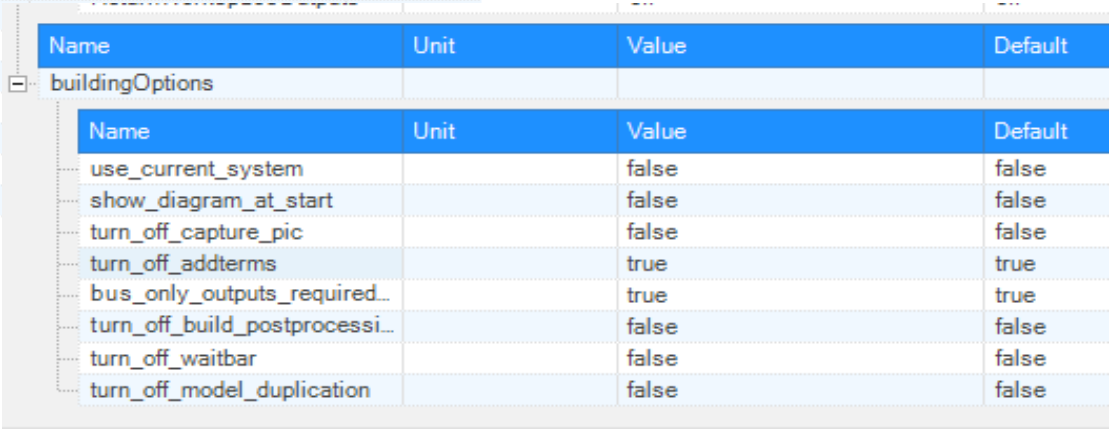
Added new tab to access advanced parameters



Provided access to the simulation solver options



Provided access to advanced parameters to optimize the model building process



MODERNIZING THE FRAMEWORK FOR EVEN LARGER STUDIES

- Running large scale studies is the backbone of our research
- REV13 to AMBER vehicle conversion and comparison
  - Identified changes to models, initialization data, vehicle architectures, …
  - Explored differences between REV13 and AMBER results
  - Developed sizing tests that run nightly and generate test reports
- Test-Driven development to assist in refactoring the sizing algorithms so that they run with AMBER APIs

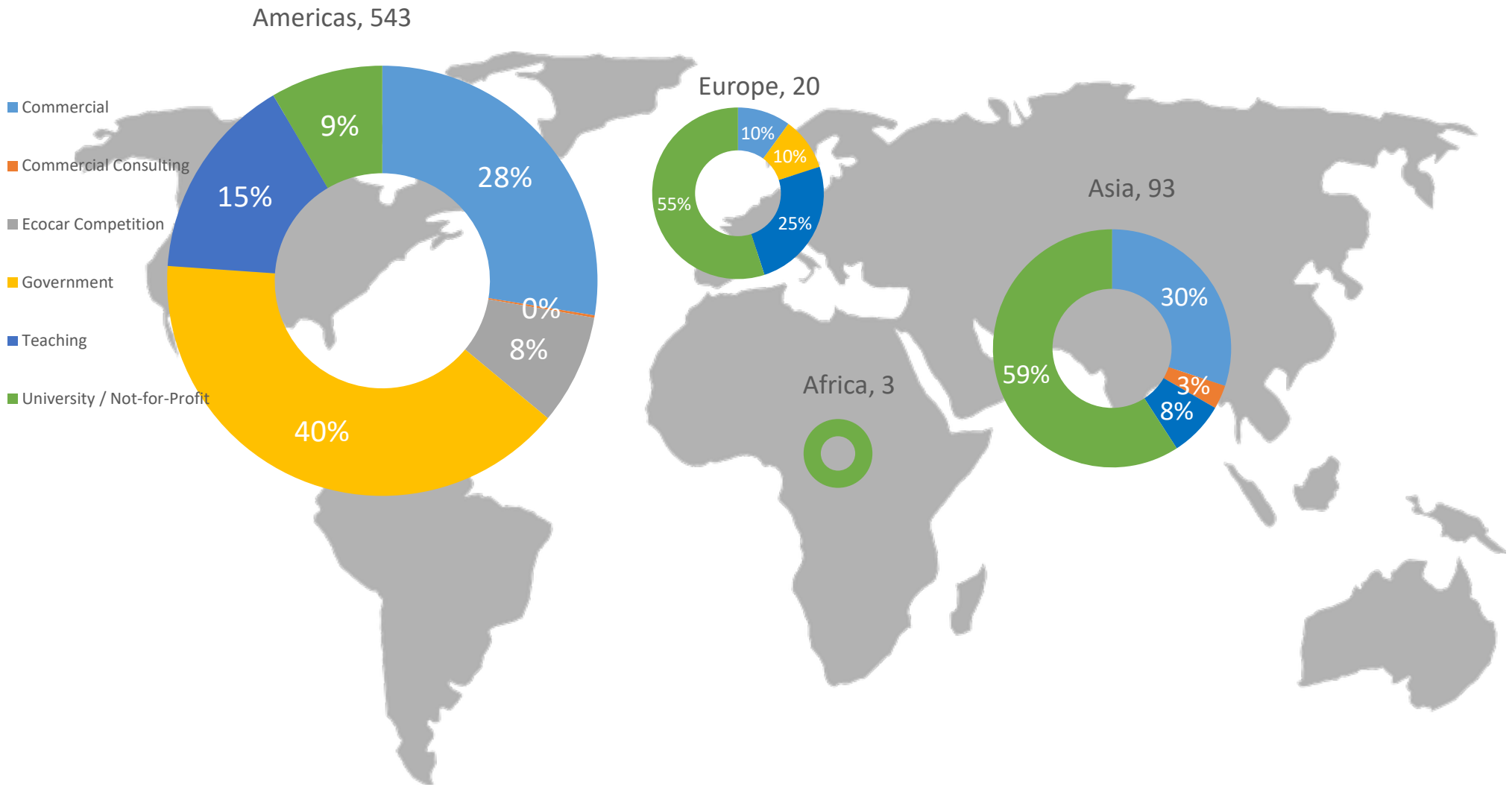
DEPLOYING THE DOE ENERGY AND MOBILITY SIMULATION TOOLS

- Server and Cluster Improvements
  - Updated software
  - Increased Cores from 428 to 1028

- Jenkins Automation Server to run tests and package
  - Updated and maintained
  - Put a new server in production
- Updated SVN server to support development

COLLABORATION AND COORDINATION

Core Tools Used Across Companies and R&D Organizations



Argonne NATIONAL LABORATORY