Assessing Energy and Cost Impact of Advanced Technologies through Model Based Design

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2016 DOE Hydrogen Program and Vehicle Technologies
Annual Merit Review

June 8, 2016
## Project Overview

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start – October 2016</td>
<td>Bring technologies to market faster</td>
</tr>
<tr>
<td>End – September 2019</td>
<td>Accelerate technology evaluation</td>
</tr>
<tr>
<td></td>
<td>Support requirements definition</td>
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<table>
<thead>
<tr>
<th>Budget</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Project Funding ($4.5M over 3 years)</td>
<td>LMS/Siemens</td>
</tr>
<tr>
<td>FY16 Funding : $1.5M</td>
<td>MathWorks</td>
</tr>
<tr>
<td></td>
<td>Third Party Tool Companies (Gamma Technology, ChiasTek, Esse)</td>
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<tr>
<td></td>
<td>OEM users (GM, Ford, Chrysler, Cummins…)</td>
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<td></td>
<td>National Labs users (NREL, ORNL…)</td>
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<tr>
<td></td>
<td>Multiple other Argonne groups including engine, battery, mathematics …</td>
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</table>
**Relevance**

**VTO Benefits**

**Autonomie**\(^{(1)}\) is used by a very large number of VTO projects to define R&D targets, evaluate the benefits of advanced technologies at a vehicle system level, provide R&D guidance…

- During the 2015 AMR, more than 35 projects were related to Autonomie:
  - More than 10 projects provided inputs to Autonomie\(^{(2)}\)
  - More than 15 projects used Autonomie to perform studies\(^{(3)}\)
  - More than 10 projects used results from Autonomie to perform further studies / analysis\(^{(4)}\)

- Autonomie is also used to support education (Gate), DOT and DOD

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\(^{(1)}\) Autonomie is a vehicle system simulation tool designed to assess the energy and performance of advanced vehicles technologies. [www.autonomie.net](http://www.autonomie.net)

\(^{(2)}\) EDT006, VSS021, VSS030, VSS134, VSS154, VSS160, VSS164, VSS166, VAN002…

\(^{(3)}\) FC017, SA044, SA050, ACE011, ACE022, FT008, VSS097, VSS133, VSS140, VSS141, VSS153, VSS154, VSS161, VSS164, VSS166, VAN001…

\(^{(4)}\) FC017, SA050, SA055, VSS164, VAN001, VAN005, VAN012, VAN013, VAN014…
Relevance
Users Benefits

Autonomie is the only commercially available software that includes full vehicle models with state-of-the-art vehicle level controllers for a wide range of powertrains.

Example: Prius HEV
Vehicle Level Control
Algorithm developed from ANL’s APRF\(^{(1)}\) test data

\(^{(1)}\) Advanced Powertrain Research Facility
# Milestones

<table>
<thead>
<tr>
<th>Task 1: Autonomie Model Based System Engineering&lt;sup&gt;(1)&lt;/sup&gt;</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Release R15 &amp; R15SP1</td>
<td>• Release R16 &amp; R16SP1 (Autonomie 2.0 with current capabilities)</td>
<td>• Release R17 &amp; R17SP1 (Autonomie 2.0 with new large scale simulation capabilities)</td>
<td></td>
</tr>
<tr>
<td>• Demonstrate Process Centric Architecture (Autonomie 2.0)</td>
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<thead>
<tr>
<th>Task 2: Vehicle Validation&lt;sup&gt;(2)&lt;/sup&gt;</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Develop and validate a full thermal vehicle model of the BMW i3-EREV</td>
<td>• Develop and validate a full thermal vehicle model (vehicle TBD)</td>
<td>• Develop and validate a full thermal vehicle model (vehicle TBD)</td>
<td></td>
</tr>
<tr>
<td>• Develop automated validation process</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 3: Quantify and Maximize VTO Energy Impact&lt;sup&gt;(3)&lt;/sup&gt;</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Provide report assessing the impact of VTO technology packages on standard cycles</td>
<td>• Quantify the energy and cost impact of VTO technology packages under real world driving conditions</td>
<td>• Provide report assessing the impact of VTO technology packages on standard cycles</td>
<td>• Quantify the impact of advanced control to maximize VTO technology benefits</td>
</tr>
<tr>
<td>• Quantify the energy and cost impact of individual VTO technologies on standard cycles</td>
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<sup>(1)</sup> New releases of Autonomie developed to support US Government projects across the National Laboratories & outside users

<sup>(2)</sup> ANL vehicle testing funded through separate projects

<sup>(3)</sup> Studies designed to provide guidance to VTO managers and inputs to other researchers (i.e., GHG with GREET, market penetration with MA3T…)
Approach – Tool Development

Gather Requirements from Autonomie User Community to Prioritize Development

User Community

- National Laboratories
- Universities,
- OEMs,
- Suppliers,
- Research Institutions,
- Tech 2 Market,
- Other Gov Agencies…

DOE VTO R&D
(i.e. autonomous vehicles)

Enhancements & New Features

Development Prioritization

Conferences, Papers

=> Autonomie was developed and continues to be developed based on user’s requirements
Approach – Performance Data

Gather Component and Vehicle Level Data from Nat. Lab, OEMs, Suppliers, Autonomie User Community and Literature

User Community
- Universities,
- OEMs,
- Suppliers,
- Research Institutions,
- Tech 2 Market,
- Other Gov Agencies…

National Laboratories
(i.e., Vehicle from APRF, Motor from ORNL…)

Comp. & Vehicle Performance Data

Conferences, Papers

Updated Study Inputs
Technical Accomplishments
Autonomie – Model Based System Engineering

Main New Features Summary

The features described below have been developed based on requests and feedback from Autonomie users

- **Plug&Play:**
  - Documented existing APIs and added new ones to facilitate the import of new models and files as well as usage of the tool for large scale simulations
  - Improved memory management to support the simultaneous analysis of much larger number of results
  - Developed new functionalities to allow users to further customize the tool (i.e., settings, import, process…)
  - Integrated source control tools into the GUI to manage file versions

- **Vehicle Energy Consumption Application:**
  - Released more than 100 new turn-key vehicles including
    - Updated light duty vehicles across a wide range of powertrain configurations
    - New light duty vehicles across multiple vehicle classes from compact car to pick up truck
    - New medium and heavy duty vehicles
  - Adopted new powertrain configuration organization to facilitate model reuse (i.e., quickly go from a conventional 2WD to a 4WD or from a conventional to a start-stop system)
Best recommended practice developed over multiple years under an SAE committee led by Argonne

Configurations developed to reduce the number of architecture choices while increasing the number of vehicle powertrain and maximizing model reuse across options.

Example: Grouping final drive, tires and chassis into a single vehicle dynamics block facilitates switching from 2WD to 4WD powertrains

(1) http://standards.sae.org/j3049_201508/
(2) National Laboratory support funded by DOE/VTO
Technical Accomplishments
Autonomie – Model Based System Engineering

Released New List of Turn-key Vehicles

- Light duty conventional vehicles across multiple vehicle classes (compact car to pickup truck) representative of 2015 technologies\(^1\)
- Vehicles provided to perform comparison of powertrain configurations including micro-HEV, Start-stop, xEVs (pre-transmission, powersplit, series, multi-mode…)
- Vehicles provided to perform comparison of individual component technologies (e.g., 5 vs 6 vs 8 speed automatic transmissions or Automatic vs DCT vs CVT)
- Medium and heavy duty vehicles for multiple classes (e.g., Class 3 school bus/van, Class 4 StepVan, Class 5 Construction, Class 7 School bus, Class 8 line-haul/refuse truck…)\(^2\)
- Special use cases: full vehicle thermal model, FMI\(^3\), Hardware-in-the-Loop, linkage with third party tools (GTPower…), two energy-storage vehicles…

\(^1\) Developed under Task 3 of VAN023
\(^2\) Developed under TV032
\(^3\) Functional Mockup Interface - [https://www.fmi-standard.org/](https://www.fmi-standard.org/)
Technical Accomplishments
Autonomie – Model Based System Engineering

Autonomie Process Centric (2.0)
Current Workflow Focused on Few Individual Vehicles

New Workflow Supports Current VTO R&D Direction

Users: select n vehicles on n cycles, change parameters, select optimization algorithm, import test data…
Developers: Build new vehicle, build new process, build new configuration, import new test data format, setup HPC…

- Select 10 vehicles on 10 cycles with control parameter optimization on HPC
- Import APRF test data
- Vehicle powertrain sizing to match performance
- …

- Individual vehicle analysis
- Database analysis for large scale simulations
- No analysis (i.e., test data import)
- …
Technical Accomplishments
Autonomie – Model Based System Engineering

Autonomie Process Centric (2.0)

Import New Model
Create New Powertrain
Create New Vehicle
Create New Process

Launch Autonomie

Developers Use Cases Examples

Users Use Cases Examples

New/Enhanced Use Cases

Import Test Data
Run Few Vehicles on Multiple Cycles
Size Individual Vehicles
Run Large Number of Individual Vehicles
Energy Impact of Metropolitan Areas
Run Multiple Vehicles Simultaneously (platooning)

Individual Test Analysis
Individual Simulation Analysis

Database Analysis Tool
Multi-vehicle Simulation Analysis

Examples of existing capabilities that cannot be released in the current workflow
Examples of new capabilities under development that cannot be released in the current workflow

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

BMW i3-EREV

- Validated vehicle thermal models necessary to assess the impact of temperature for multiple advanced technologies
- Current project expands on the list of powertrains previously validated across multiple temperatures (Conventional, HEV, PHEV, E-REV, BEV)
- Leverage test data from Argonne’s APRF (VSS030)

Extensive Instrumentation Developed in Collaboration with APRF Experts for Model Development and Validation (High Voltage Example)
Technical Accomplishments
Vehicle Energy Impact

Automated Sizing Algorithm Validation

- Vehicle powertrain sizing algorithm have been developed over the years for multiple configurations to size the components to match a specific set of performances.
- The latest algorithms have been validated using specific vehicles

Making Assumptions

<table>
<thead>
<tr>
<th>Spec.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gear ratio</td>
<td></td>
</tr>
<tr>
<td>RG1/SG1 = 2.6, RG2/SG2 = 2.64</td>
<td></td>
</tr>
<tr>
<td>Final drive</td>
<td>3.268</td>
</tr>
<tr>
<td>Wheel radius</td>
<td>0.317 m</td>
</tr>
<tr>
<td>Drag coefficient</td>
<td>0.25 *</td>
</tr>
<tr>
<td>Front area</td>
<td>2.25 m^2 *</td>
</tr>
<tr>
<td>0-60 mph</td>
<td>9.7 sec **</td>
</tr>
</tbody>
</table>

*Sizing Algorithm*

1. Use Grade, Perfs, Regen Estimation equation to initialize Powers of Ess, Eng, Mot, Gen
2. Iteration < 11
3. Fine tuning of Eng
4. Run Accel
5. Get Simulated values
   - MCT Per = Max(Simu Per, Accel Per, Per + Simu Trq / Init Trq)
   - ESS Per = Max(Simu Per, Accel Per)
6. Perfo Time
7. Converged?
   - Yes
   - No
   - Update Mass
8. Run Simulation
9. Fine tuning of Eng
10. Get Simulated values
    - MCT Per = Max(Simu Per, Accel Per, Per + Simu Trq / Init Trq)
    - ESS Per = Max(Simu Per, Accel Per)
11. Perfo Time
12. Converged?
    - Yes
    - No
13. Compute Grade Per
14. Update Eng/FC/Gen Per for Grade
15. Update Values using Simulation Results
16. Update Values using Equation
17. STOP

*Sizing Validation*

<table>
<thead>
<tr>
<th>OEM Source : Toyota Prius HEV MY2010</th>
<th>Sizing results form Autonomie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle weight</td>
<td>1530 kg</td>
</tr>
<tr>
<td>Engine Power</td>
<td>73 kW</td>
</tr>
<tr>
<td>Motor1 Power</td>
<td>60 kW</td>
</tr>
<tr>
<td>Motor2 Power</td>
<td>40 kW</td>
</tr>
<tr>
<td>Battery Power</td>
<td>27 kW</td>
</tr>
<tr>
<td>Acceleration Performance: 0-60 mph</td>
<td>9.7 sec</td>
</tr>
</tbody>
</table>

- Baseline vehicle specification : Toyota Prius HEV MY2010
- Specific power for electric motor and battery is from DOE assumptions
- Individual component performance data not available (estimated)

** http://www.zeroto60times.com/vehicle-make/toyota-0-60-mph-times/
Technical Accomplishments
VTO Energy Impact

VTO Packages Energy Impact Report Released

Report (1)

- VTO Benefits
- EV Everywhere analysis
- USDrive C2G (Cradle to Grave) Working group
- GHG (GREET)
- Market penetration tools (MA3T, LAVE-Trans, LVCFlex, ParaChoice, ADOPT)
- BLAST-V (NREL)
- DOE Advanced Tech Modeling runs with NEMS
- Multiple research organizations (IEA, AVERE, NorthWestern Univ…)
- …
Technical Accomplishments

VTO Energy Impact

VTO Individual Energy Impact Study (In Progress)

• The objective is to quantify the contribution of each individual VTO technology (engine, energy storage, battery, fuel cell, H2 storage, light weighting) for each VTO package.

• Large scale simulation process initially developed for DOE to perform package simulations and recently expanded to support DOT/NHTSA CAFE leveraged

• Individual simulations including a permutation of the order of introduction of each technologies have been performed.
Collaboration and Coordination with Other Institutions

- Data & Model Providers
  - National Labs (e.g., ORNL)
  - Argonne (e.g., APRF, Battery…)
  - Expert Tool Companies (e.g., Siemens, Gamma Technology, Mechanical Simulation…)

- Process Definition & Direction
  - OEMs (e.g., GM, Ford…)
  - MathWorks
  - Expert Tool Companies (e.g., Siemens, ChiasTek, Esse…)
Responses to Previous Review Comments

- **Reviewer #5** - The reviewer indicated that the program still looks hard to use with so many technical features even though progress has been made for a large-scale simulation run. This may become more or less of an issue when it is integrated with so many other commercial codes.

  => The new process centric approach (Autonomie 2.0) has been developed with that specific focus in mind

- **Reviewer #3** - The reviewer stated that future plans to enhance the tools are a logical approach; however, finding ways to facilitate industry and user acceptance is important for the future of this project.

  => Argonne has been closely working with several OEMs to review requirements, implementation (i.e., GUI mockup) to ensure final acceptance

- **Reviewer #5** - The reviewer stated it seems good, but felt it was unclear from the presentation what Gamma Technologies or Mathworks brought to the project

  => Argonne has been a Preferred MathWorks Partner for many years, allowing us to access advanced releases for internal testing as well as acquire discounted licenses for demonstrations. Companies such as GT provide no-cost licenses of their tool as well as technical support to test the integration of the latest version of their tools in Autonomie.
Responses to Previous Review Comments

- **Reviewer #5 - The reviewer stated that all future work plans are good, but questioned whether this can be done without using DOE funding or taxpayer dollars, because large commercial license fees may be able to support the model development.**

  => Autonomie is the ONLY commercially available tool that includes full vehicle level models including control. All controllers have been developed with vehicle test data from the APRF. Due to the cost of vehicle testing, it is commercially not viable for any company to fund testing and modeling of so many vehicles for software licensing.

- **Reviewer #5 - The reviewer stated that no explanation was provided about the relevance of this project to petroleum displacement**

  ⇒ Answer was provided by Reviewer #4 - “The reviewer stated that systems modeling, as opposed to actual hardware integration/testing, is increasingly used and essential to accelerate the design and implementation of advanced vehicular technologies. Systems modelling lowers costs and improves time-to-market which leads to significant competitive advantages”
Proposed Future Work

- Continue to enhance Autonomie to support DOE VTO R&D activities by gathering requirements from all users (i.e., Nat Labs, Univ., OEMs, Gov. agencies…), including:
  - Expand Autonomie EcoSystem with linkages to additional expert tools
    - Link with transportation system simulation tools (i.e. POLARIS) to evaluate benefits of connected & autonomous vehicles…
    - Link with market penetration tools (i.e. MA3T) for fleet analysis
  - Focus on large scale simulation leveraging High Performance Computing (i.e., >100,000 individual vehicle packages) and co-simulation
- Continue to provide guidance for DOE R&D activities by assessing the energy and cost impact of advanced vehicle technologies
Summary - ANL Will Continue to Accelerate Technology Development and Market Introduction

- Widespread usage of Autonomie across the automotive community contributes to accelerating the introduction of advanced technologies and the evaluation of their benefits.
- New features included in semi-annual releases prioritized in collaboration with users (including Argonne) to maximize the tool impact.
- Extensive collaboration with other institutions to implement state-of-the-art component performance data and use vehicle test data for model development and validation.
- Vehicle level system simulation is critical to evaluate the impact of new technologies at the component, powertrain, vehicle and fleet level.
- Large number of studies performed to assess the impact of the VTO technologies at the individual and overall program level.
- Most of the current and future developments focused on supporting new VTO initiatives such as Smart Mobility.
TECHNICAL BACKUP SLIDES
Both internal & external users requested an easier way to manage separate set of files & Autonomie settings for multiple projects:

- Autonomie separated in 3 separate folders:
  - Program, containing the base Autonomie program
  - Libraries, containing Autonomie vehicle application library as well as any other defined by the user
  - Projects, containing the user projects

- New a_project file defines setting for each projects, including which folders to include and the Matlab version to use.
New Settings Organization and UIs for Customizations

- Some settings used to be editable only in the associated xml file
- Now all settings have a user interface
Faster Start and Lower Memory Usage

- No more Flash Start screen
- Autonomie automatically starts with the settings of the last project used or double clicked
- The speed of loading multiple simulation results has been increased several folds.
- No more out of memory issues when loading a dozens+ of simulation results
String parameters can now be overwritten directly in the GUI
Improved Waitbar with more Feedback Information to the User

- New Waitbar with improved feedback to user
Improved Function for Batch Import of Matlab Scripts

- MToXml script can take model list & parent system list as input argument for batch import without going through the GUI, e.g.:

```
MToXml('env_plant_common.m', 'env_plant_common.a_init', {'env_plant_earth'}, {'env', 'true'})
```
Editable Bus Names in the Configuration Builder GUI

- Autonomie used to automatically setup the bus name in the configuration builder.
- However, some customers wanted to use their own convention.
- They can now overwrite those names in the editor.
Can Use any Time-based Cycles with Distance-based Models

- Autonomie has hundreds of time based cycles. These include many real world driving cycles.
- All of these time based cycles can now be used with the distance based driver without the user having to spend time converting them into distanced based cycles.
- That is, the vast library of time based cycles in Autonomie can now be easily leveraged by users running heavy duty vehicle simulations.
Automated testing for all vehicles

Every time a vehicle, model or initialization file is modified in our Source Control system, it automatically launches a set of tests to ensure:
- All vehicles are loading, building and running without any errors
- All simulation results stay consistent from previous runs

Dozens of additional unit & release tests are run on the User Interface and whole release as well.
Sample of New Reference Vehicles

Multiple LDVs Classes
- Light Duty
  - Class
    - Compact Gasoline Automatic Trans
    - Midsize SUV Gasoline Automatic Trans
    - Pickup Gasoline Automatic Trans
    - Small SUV Gasoline Automatic Trans

Transmission Comparison
- Transmission
  - Heavy Duty
  - Light Duty
    - Automatic
      - Midsize Gasoline 6 Speed Automatic Trans
      - Midsize Gasoline 6 Speed Automatic Trans
    - Continuously Variable
      - Midsize Gasoline CVT
    - Dual Clutch
      - Midsize Gasoline 8 Speed Dual Clutch Trans
      - Midsize Gasoline 6 Speed Dual Clutch Trans
    - Manual
      - Midsize Gasoline 6 Speed Manual Trans
      - Midsize Gasoline 7 Speed Manual Trans

Powertrain Comparison
- Powertrain
  - Heavy Duty
  - Light Duty
    - Electric Range Extended Vehicle
      - EREV Midsize Diesel 30 Mile AER
      - EREV Midsize Diesel 40 Mile AER
      - EREV Midsize Gasoline 30 Mile AER
      - EREV Midsize Gasoline 40 Mile AER
    - Electric Vehicle
      - Electric Midsize 100 Mile Range Auto Manual Trans
      - Electric Midsize 200 Mile Range Fixed Gear Trans
      - Electric Midsize 300 Mile Range Auto Manual Trans
      - Electric Midsize 300 Mile Range Fixed Gear Trans
    - Hybrid Electric Vehicle
      - HEV/Belt-IG Midsize Gasoline 6 Speed Auto Trans
      - HEV/Belt-IG Midsize Gasoline 6 Speed Dual Clutch Trans
      - HEV/Belt-IG Midsize Gasoline 8 Speed
      - HEV/Belt-IG Midsize Gasoline CVT
      - HEV/Crank IG Midsize Gasoline 8 Speed Auto Trans
      - HEV/Crank IG Midsize Gasoline 6 Speed Dual Clutch Trans
      - HEV/Crank IG Midsize Gasoline 8 Speed Auto Trans
      - HEV/Crank IG Midsize Gasoline CVT
  - Micro
    - Post-Transmission
    - Power Split
    - Pre-Transmission
    - Series Engine
    - Series Fuel Cell
  - Plug-in Hybrid Electric Vehicle
    - Post-Transmission
    - Power Split
    - Series Engine
    - Series Fuel Cell

32
Sample of New Reference Vehicles (Cont’d)

MD & HD Classes

- **Medium Duty**
  - **Class 2**
    - Class2b Pickup 2wd Diesel Automatic Trans
    - Conv AutoTrans 2wd Class 2b Van
  - **Class 3**
    - Conv AutoTrans 2wd Class 3 School Bus
    - Conv AutoTrans 2wd Class 3 StepVan
    - Conv AutoTrans 2wd Class 3 Utility Truck
  - **Class 4**
    - Conv AutoTrans 2wd Class 4 StepVan
  - **Class 5**
    - Conv AutoTrans 2wd Class 5 Construction
  - **Class 6**
    - Class6 Delivery 2wd Diesel Automatic Trans
    - Conv Manual Class 6 Construction

- **Heavy Duty**
  - **Class 7**
    - Conv Manual Class 7 SchoolBus
  - **Class 8**
    - Class8 Bus 2wd Diesel Automatic Trans
    - Class8 Linehaul 4wd Diesel 10 Speed Manual Trans
    - Conv Manual Class 8 Linehaul
    - Conv Manual Class 8 Refuse Truck
    - Conv Manual Class 8 Tractor
    - Conv Manual Class8 Construction

Specific Applications

- **4 - Additional Vehicle Examples**
  - 2 Energy Storage Systems
    - HEV Parallel Pre Trans Midsize Dual Energy Storage
    - HEV Power Split Midsize Dual Energy Storage
    - 2x2 Wheel Drive
    - HEV Belt ISG 2x2wd Midsize Gasoline Auto Trans
  - 4 Wheel Drives
    - Pickup 4wd Gasoline Automatic Trans
  - Distance Based
    - Class8 Linehaul 4wd Diesel 10 Speed Manual Distance Driver
    - FMI
    - Midsize CoSimulation 32 bit FMU Demo
    - Midsize CoSimulation 64 bit FMU Demo
    - Midsize Model Export 32 bit FMU Demo
    - Midsize Model Export 64 bit FMU Demo
  - Scheduled Gear
    - Midsize Scheduled Gear NEDC Cycle
  - SimDriveline
    - EREV Voltac Midsize Gasoline SimDriveline
    - HEV Power Split Midsize SimDriveline Planetary
    - Midsize SimDriveline Connection Demo
  - Thermal
    - HEV Power Split Midsize Fixed Ratio Thermal
    - Midsize Thermal Systems
  - Third Party Linkage
    - Co-Simulation
      - Midsize Cosimulate Demo
    - Modeling Tools
      - HEV Power Split CarSim Demo
      - Midsize Carsim Demo
  - 6 - Component Only Examples
    - CIL Models
      - Engine On Dyno GTPower
  - 6 - Verification and Validation
    - PHEV Power Split Midsize 2wd Soc Verification Demo
    - PHEV Power Split Midsize 2wd Ground Fault Demo