

Next-Generation Modeling and Simulation Tools for Stability Control Development

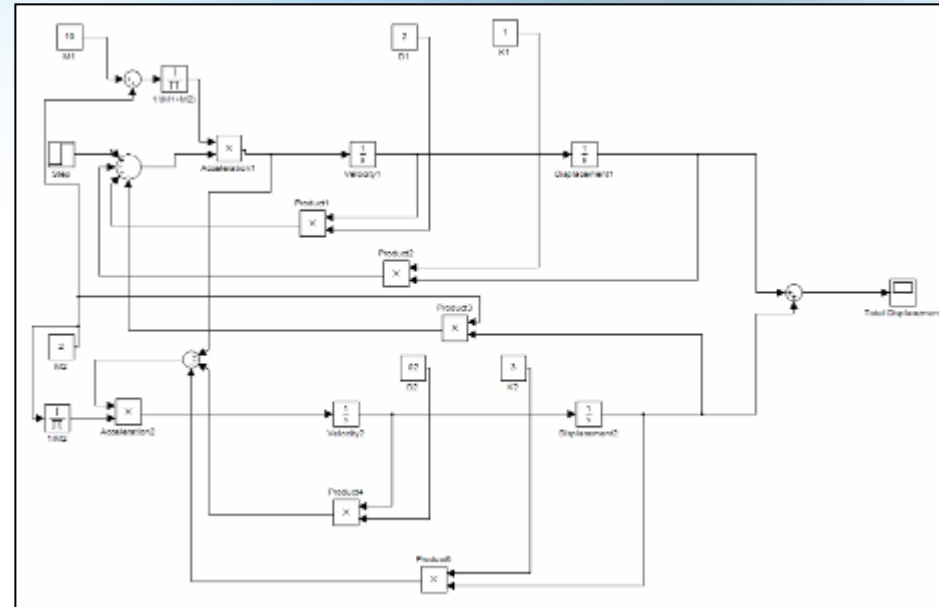
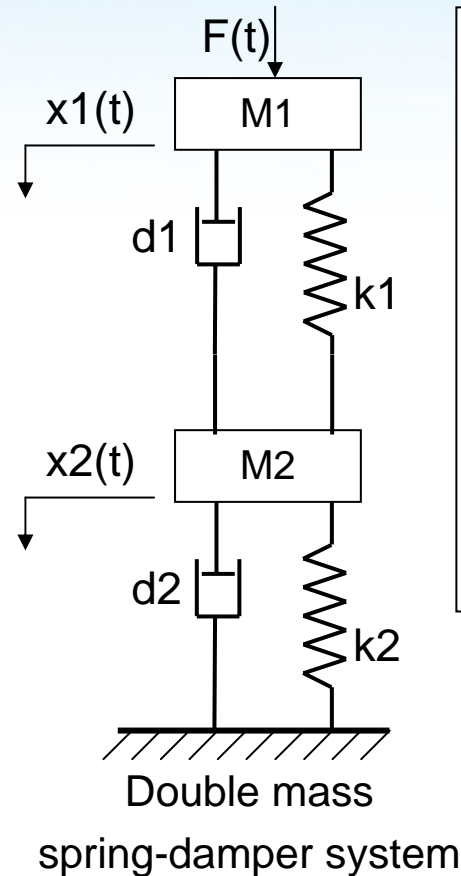
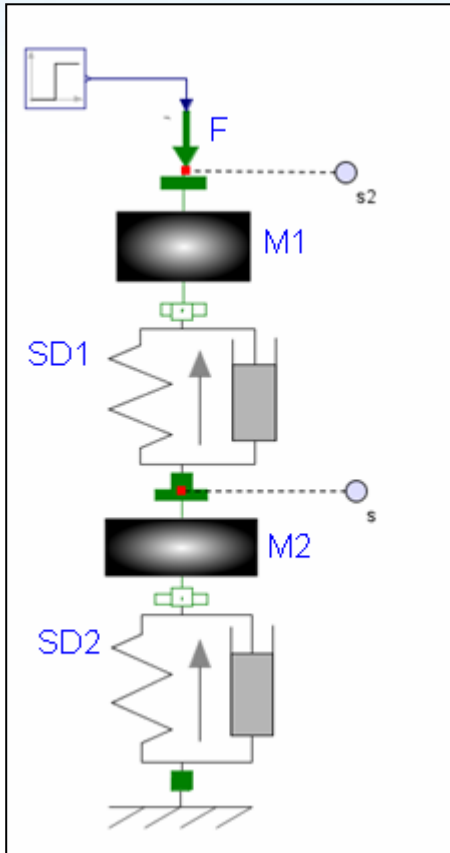


Paul Goossens
Product Director

June 2009



Physical Modeling – The Next Generation



Model maps directly to physical components of system

Automatically generates equations of motion

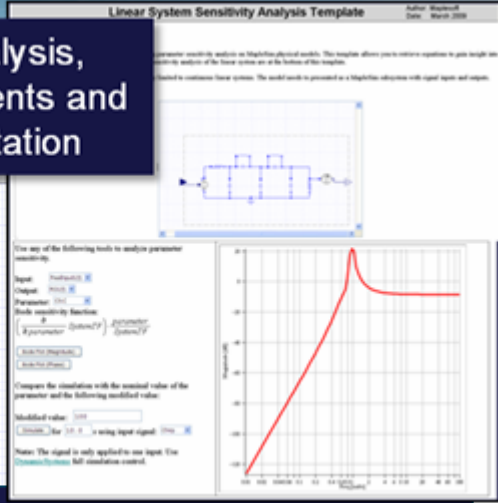
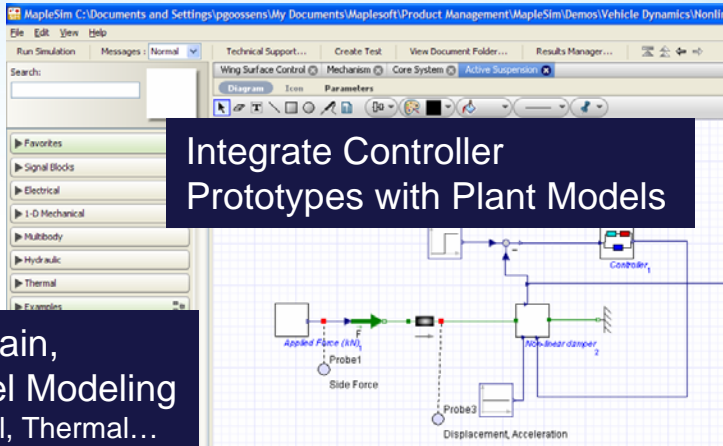


Introducing MapleSim 2

Mathematical Analysis,
Custom Components and
Project Documentation

Integrate Controller
Prototypes with Plant Models

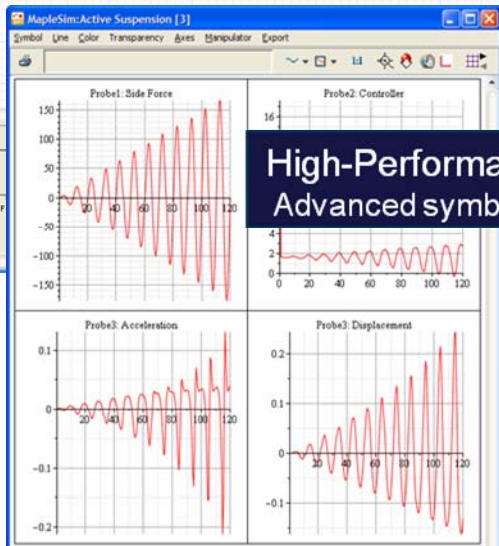
Rapid Multi-Domain,
Component-Level Modeling
Mechanical, Electrical, Thermal...



Unique Multi-Body simulation engine
Fast and accurate for highly complex models



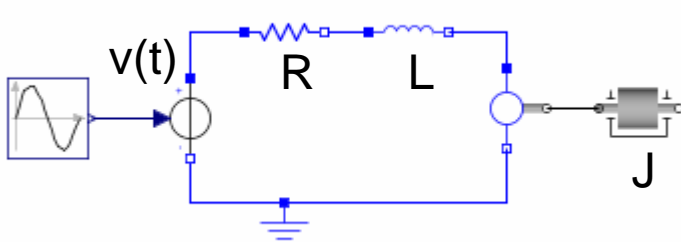
3D Visualization and
Animation



High-Performance Simulation
Advanced symbolic and numeric solvers

Faster model creation cuts project time and cost

- Model diagrams map directly to physical system
- System equations are generated automatically

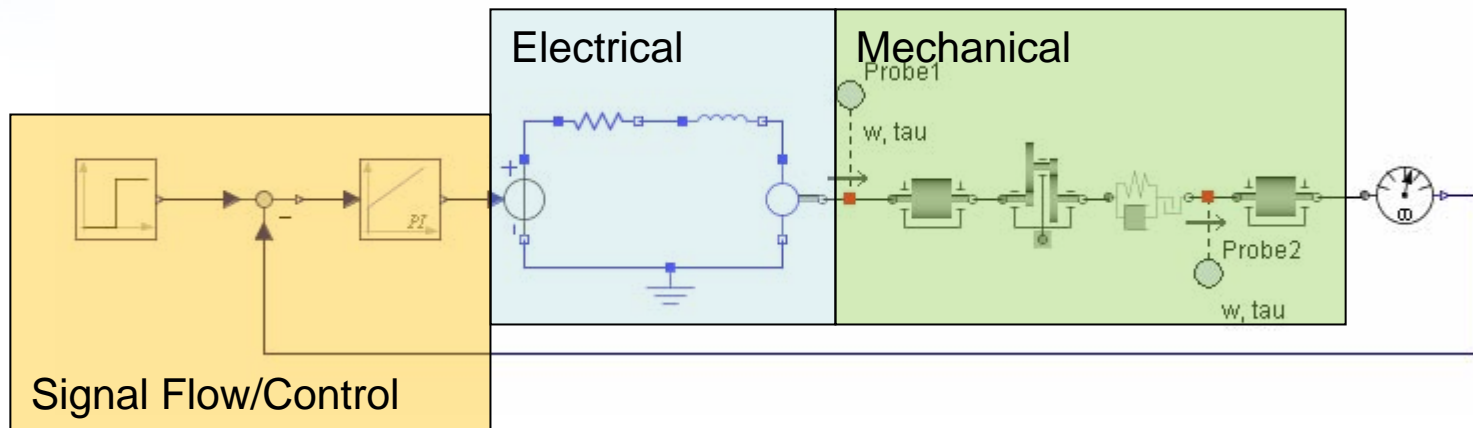


$$L \left(\frac{d}{dt} i(t) \right) + R i(t) = v(t) - K \left(\frac{d}{dt} \theta(t) \right)$$
$$J \left(\frac{d^2}{dt^2} \theta(t) \right) + b \left(\frac{d}{dt} \theta(t) \right) = K i(t)$$

- Rapid, error-free model formulation
- Concise and numerically efficient
- Parametric math model

Faster model creation cuts project time and cost

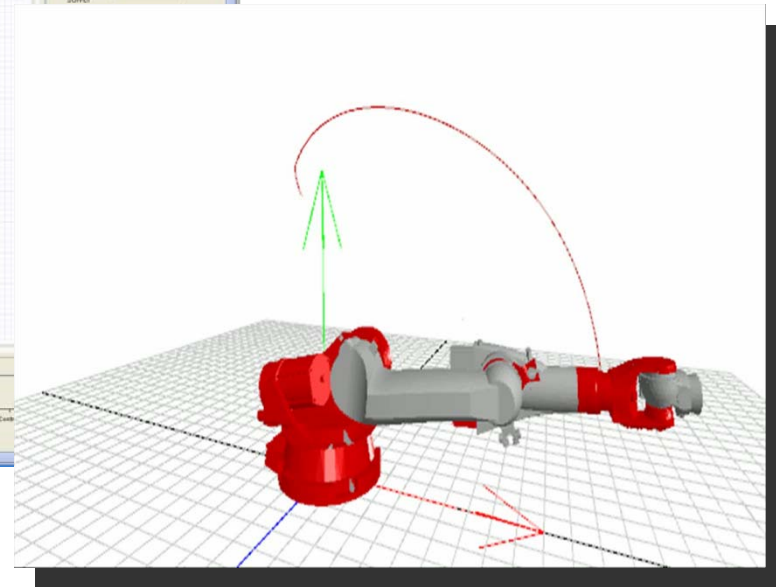
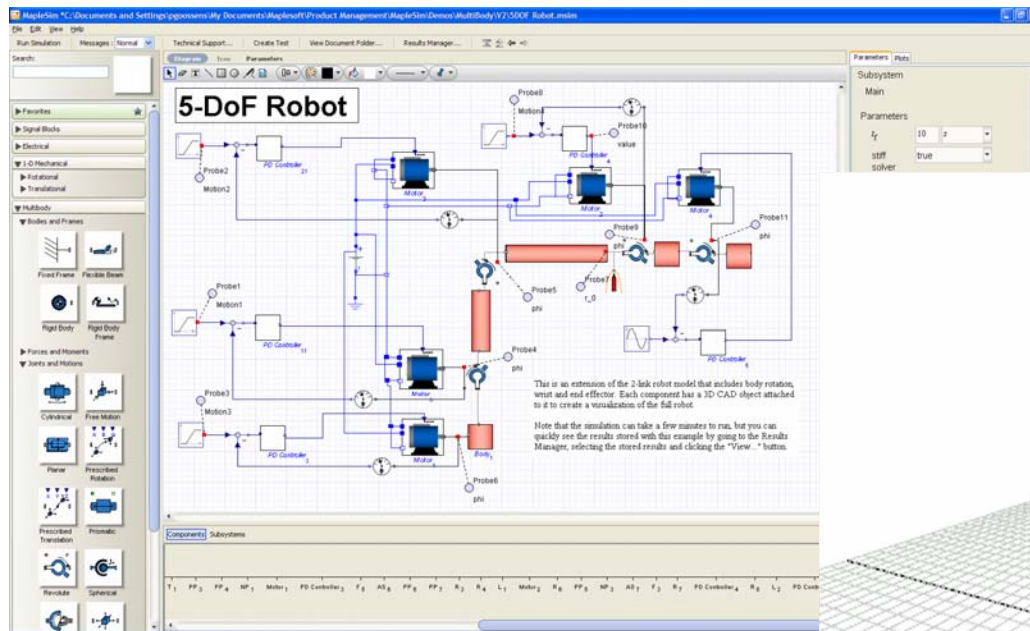
- Model diagrams map directly to physical system
- System equations are generated automatically
- Natural multi-domain modeling



- Easily connect mechanical with electrical, hydraulics, thermal systems
- Mix traditional signal-flow blocks with physical components
- Design Controller and Physical Model in one environment

Faster model creation cuts project time and cost

- Model diagrams map directly to physical system
- System equations are generated automatically
- Natural multi-domain modeling
- **3D Visualizer** gives immediate insight into behavior of your model





Equation generation and simplification of complex models speeds up simulations

- Multiple stages of model optimization
 - Symbolic preprocessing gives optimal formulation
 - Built-in compilation speeds up numeric computation
 - Model caching delivers high-speed simulation for multiple runs
- Unique technology gives highly efficient models for multi-body mechanical systems
- Optimized generated code for export to real-time and other applications
 - Very efficient, simplified code runs 10 – 100x faster for complex models

Simulation cycle time = 10ms	SimMechanics (μ s)	MapleSim> S-Function> Simulink (μ s)	Speed advantage
Double Pendulum	137	14	9.9x
Four Bar Linkage	288	70	4.1x
Stewart Platform	710	74	9.6x



Powerful tools for model design and analysis reduce development time

- Dynamic analysis, control design and optimization tools
- Easy creation of custom components

Cam Profile Generation Template

Description
Use this template to generate cam profiles for a MapleSim model. The template is based on example 11 in "Mechanical Design Analysis and Modeling, 11th Edition, Gordon and Wang, Page 197."

Generating the Data
The kinematic coefficient method:
$$A_1 = \frac{1}{r_2} \left(\frac{r_2}{r_1} \cos \phi + \frac{r_2}{r_2} \sin \phi \right)$$

Use the right-hand rule to find the sign of the coefficient.
$$A_2 = \frac{1}{r_2} \left(\frac{r_2}{r_1} \sin \phi - \frac{r_2}{r_2} \cos \phi \right)$$

Use the right-hand rule to find the sign of the coefficient.
$$A_3 = \frac{1}{r_2} \left(\frac{r_2}{r_1} \cos \phi + \frac{r_2}{r_2} \sin \phi \right)$$

Use the right-hand rule to find the sign of the coefficient.
$$A_4 = \frac{1}{r_2} \left(\frac{r_2}{r_1} \sin \phi - \frac{r_2}{r_2} \cos \phi \right)$$

Use the right-hand rule to find the sign of the coefficient.
$$A_5 = \frac{1}{r_2} \left(\frac{r_2}{r_1} \cos \phi + \frac{r_2}{r_2} \sin \phi \right)$$

Use the right-hand rule to find the sign of the coefficient.
$$A_6 = \frac{1}{r_2} \left(\frac{r_2}{r_1} \sin \phi - \frac{r_2}{r_2} \cos \phi \right)$$

Use the right-hand rule to find the sign of the coefficient.

Cam Profile
Use the right-hand rule to find the sign of the coefficient.
$$r(\theta) = r_1 + \frac{r_2}{\cos \phi} \left(\frac{r_2}{r_1} \cos \phi + \frac{r_2}{r_2} \sin \phi \right)$$

Use the right-hand rule to find the sign of the coefficient.

Linear System Sensitivity Analysis Template

Description
Use this template as a starting point for performing parameter sensitivity analysis on MapleSim physical models. This template allows you to retrieve equations to gain insight into the behavior of your model. Tools for parameter sensitivity analysis of the linear system are at the bottom of this template.
Note: The ability to retrieve equations is currently limited to continuous linear systems. The model needs to be provided as a MapleSim sub-system with input signal and output.

Model Diagram

Use any of the following tools to analyze parameter sensitivity.

Input:
Output:
Parameter:
Block sensitivity function:
$$\frac{\partial Y}{\partial P}$$

Compare the simulation with the nominal value of the parameter and the following modified value:
Modified value:
 for a using input signal:

Note: The signal is only applied to one input. Use [DynamicSystems](#) full simulation control.

Monte-Carlo Simulation Template

Model Description
Use this template to perform a Monte-Carlo simulation on a MapleSim model. Use this template to define the parameters of your model and use a statistical analysis using the distribution tools built for probability plots on a model in the physical model world.
Model Diagram

Monte-Carlo Simulation
Generate Monte-Carlo simulation results for a sub-system or multiple equations. The simulation uses a random number of points and a random number of iterations to generate the plot. Click the Monte-Carlo button for more information.

Results

Statistics



High-Performance Multi-Domain Modeling and Simulation



Demonstration



Real-time Simulation

Motivation: **Real-time simulation** and control of engineering models of **arbitrary topology**

- **Real-time simulation**

MapleSim is built on top of Maple's symbolic engine. All models are generated symbolically, yielding efficient simulation code.

- **Arbitrary topology**

MapleSim is a general systems modeling tool. The user is not restricted to predefined topologies when generating simulation code.

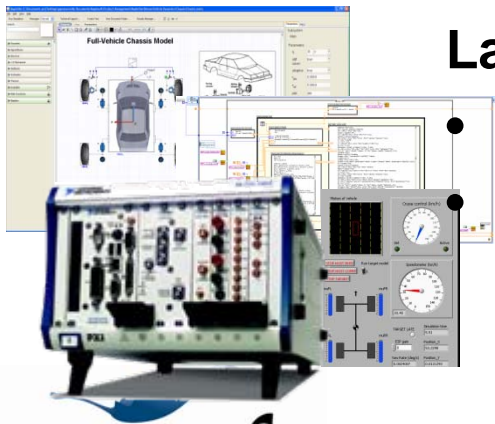


MapleSim Connectivity Toolbox

Rapid deployment of MapleSim models into your simulation and HIL tool chain

Simulink: C-based S-Functions

- Compatible with Real-Time Workshop
- High-fidelity, high-performance models for dSPACE, xPC Target, ETAS LabCar, RT-LAB etc...



LabVIEW: C code VI for Simulation Module

- Compatible with LabVIEW/RT
- High-fidelity, high-performance models for all hardware platforms from National Instruments: PXI, FPGA...

Maplesoft

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Example: MapleSim/LabVIEW HIL Demo



Host PC with...

- MapleSim
- Full-chassis model
- Connectivity Toolbox
- LabVIEW
- Simulation Module

PXI Chassis

- LabVIEW/RT

Controller Module

Digital Out

CAN bus Interface

Control Output Display

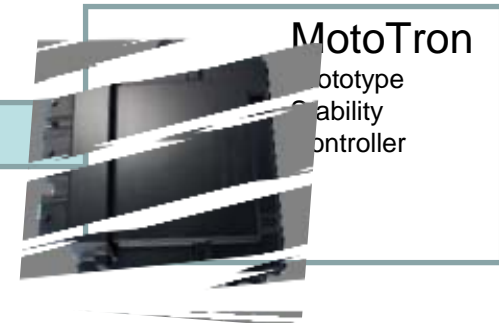


MotoTron

Prototype
Stability
Controller

Maplesoft

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Vehicle Model

MapleSim 2 - C:\Documents and Settings\pgoossens\My Documents\Maplesoft\Product Management\Wa

File Edit View Help

Run Simulation Messages: Normal Technical Support... View Document Folder... Results Manager...

Search:

*TurboSeal4a FullVehicle_3D_1

Diagram Icon Parameters

Favorites

Signal Blocks

Electrical

1-D Mechanical

Multibody

Thermal

Examples

Conn

Vehicle Params₁

VehicleBody

TS₁

TS₃

Vehicle Model Parameters:

- K_{spring} 500000 $\frac{N}{m}$
- K_{damper} 5000 $\frac{N s}{m}$
- Crr 0
- Clong 238200
- Clat 238200
- mu1 1
- mu2 1
- r2 0.385

FTSS₁ TS₁ Vehicle Params₁ TS₂ TS₃ C₃ G₁ C₇ S₂ VehicleBo

Tire Model

- Fiala
- Calspan
- Pacejka
- User-defined

Double-Wishbone Suspension Assembly

The kinematics of a double-wishbone suspension are modeled using the multibody components in MapleSim. Because the parameters for the components are derived from relationships between the hard points - that is, the positions of the joints that define the geometry of the suspension - this model features a technique for defining the component parameters in MapleSim as symbolic variables and then using Maple to compute the parameters. Once calculated, the parameter values can be sent directly to the model to populate the components so that the model can be simulated.

See **DefiningHardPoints** in the document folder to find out how this is done so that you can apply this technique to any of your applications.

Semi-Trailing Arm Suspension

This is an independent rear suspension configuration that relies on a specific mechanical topology to produce the desired kinematic response to a disturbance from the road. The dynamic response is defined by the spring/damper arrangement and compliant bushings on the joints between the lower control arm and the chassis.

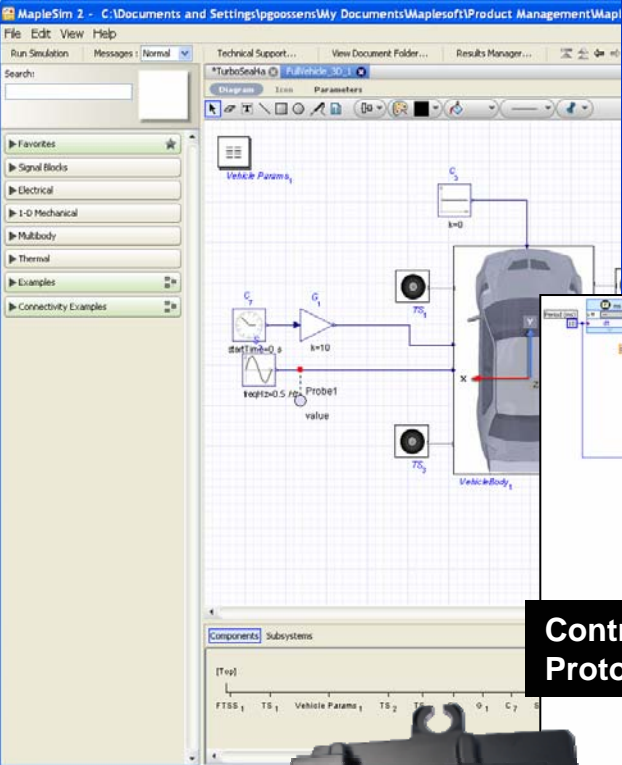
The elastic bushing model was developed as a custom component by MapleSoft partners, MotionPro Inc.

max. 400000
stans



Model Code Generation to LabVIEW

Code Generation of Model for LabVIEW



```
Save Folder
Type of Model
Library
Model
Generate to LabVIEW
Save Code to Directory

View Code
LabVIEW C code
*****
Function: simOut
Abstract:
  * x(t), t, x, v(t)
  *
void simOut(long N, double t, double *MAPLEx, double *MAPLEdy;
double m1, v1, Temp1;
```

Vehicle Model loaded on to LabVIEW/Real-Time

Controller loaded on to Prototype Controller

Speedometer [mph] 35.4

Vehicle Heading

Vehicle Position

Initial Speed [mph]: 45 Simulation Time [s]: 2.79

Run Simulation Activate Controller

LabVIEW Operator Interface



Without Stability Controller



With Stability Controller



High-Performance Multi-Domain Modeling and Simulation

- Faster plant model creation cuts project time and cost
- Equation generation and simplification of complex models speeds up simulations
- Powerful tools for model analysis and control design reduce development time

Shorten the product development cycle

Questions?



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