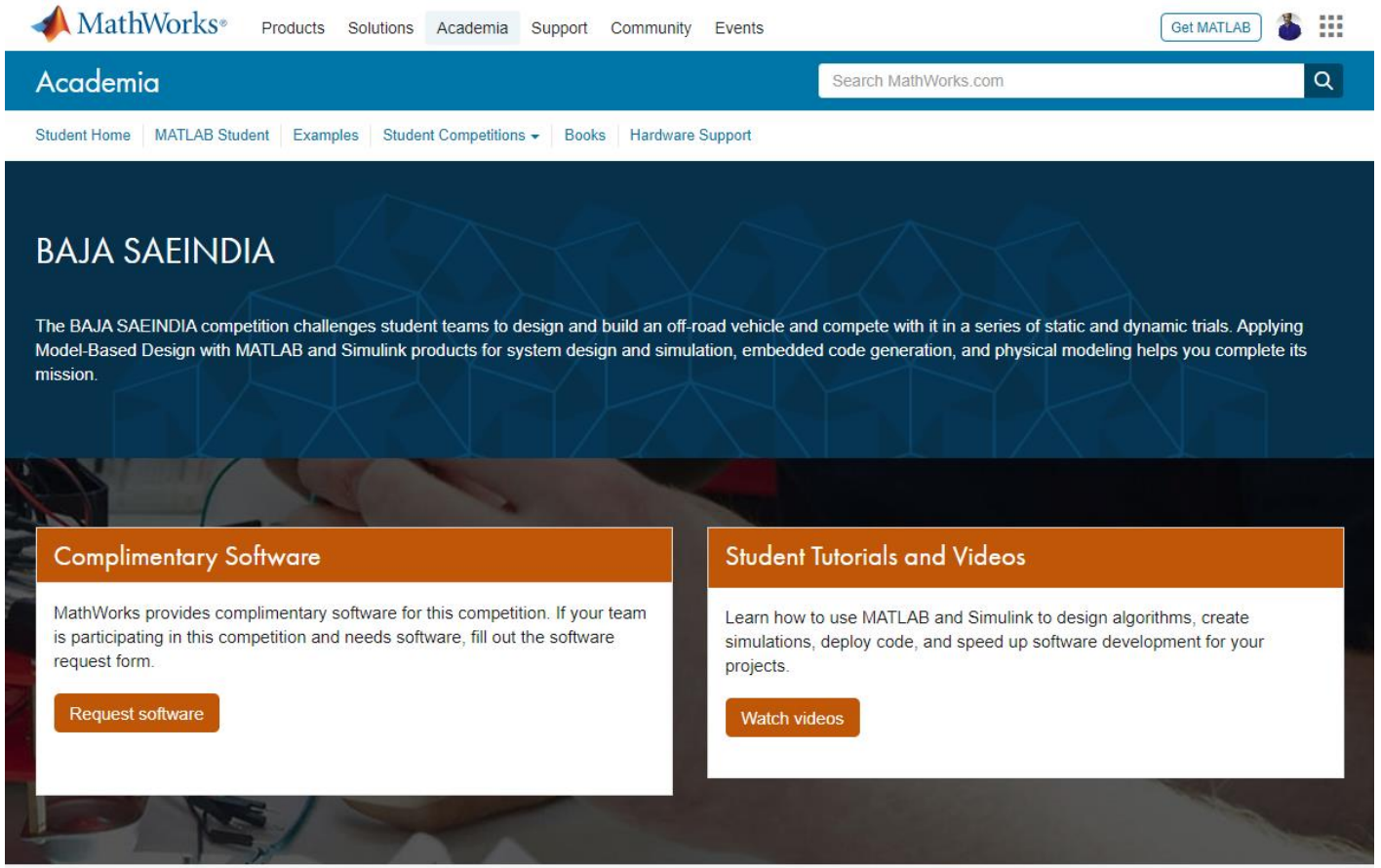
Complimentary Software for BAJA SAEINDIA Teams

Link: https://www.mathworks.com/academia/student-competitions/baja-saeindia

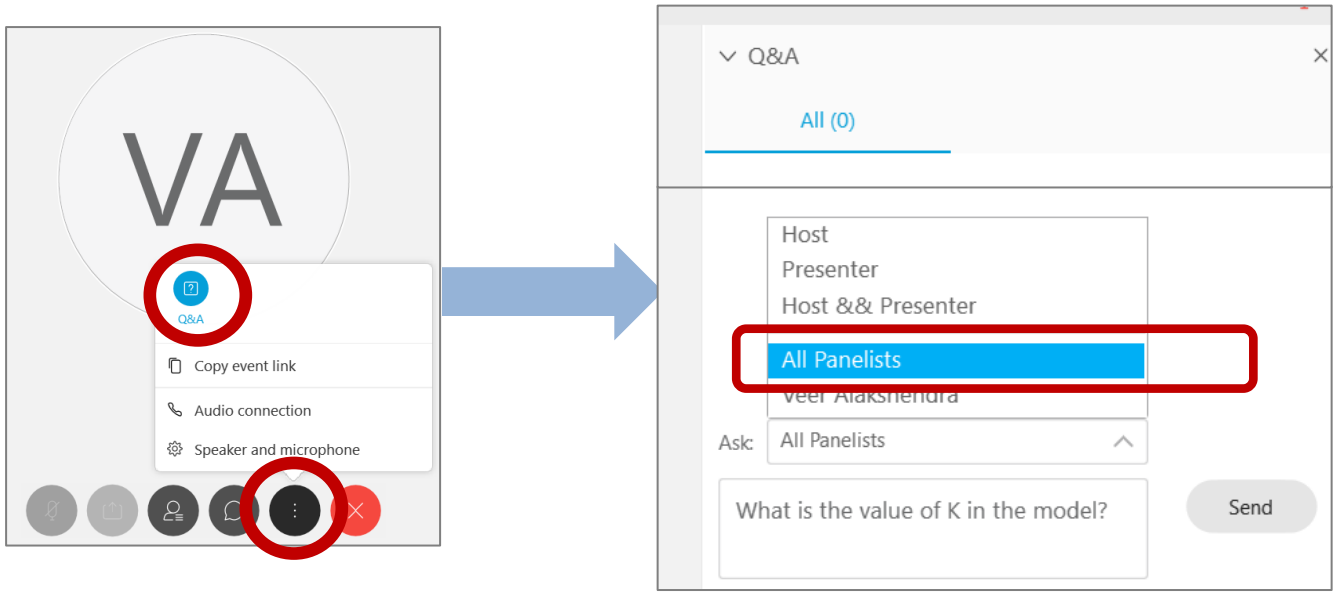


Designing BAJA All-Terrain Vehicles with MATLAB and Simulink

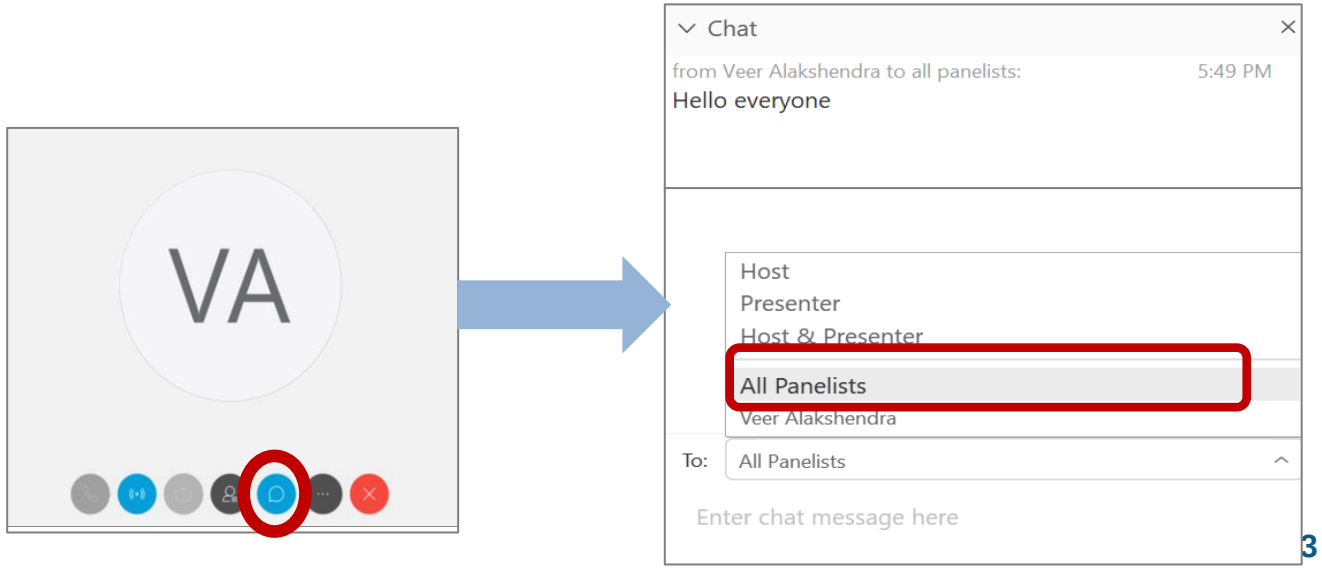
Akshat Kasana,*Team Kshatriya, VIT, Vellore*
Veer Alakshendra, *MathWorks*

During the Webinar

- Use **Q&A** to ask technical questions
  - Send the questions to “All Panelists”

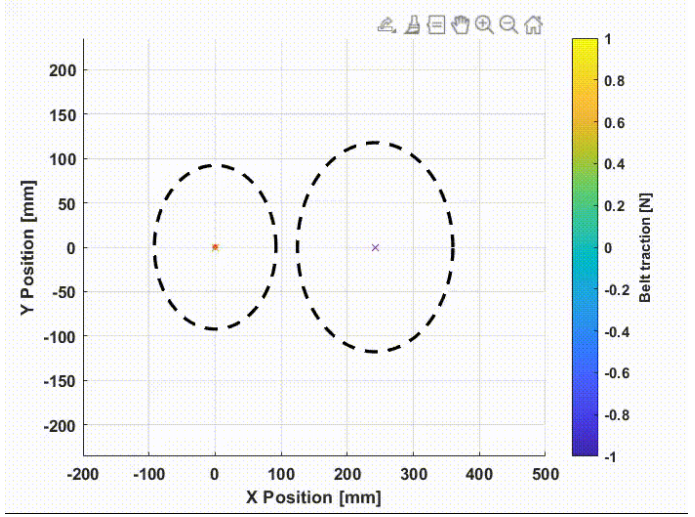


- Use Chat Box for all other queries
  - Send the query to “All Panelists”

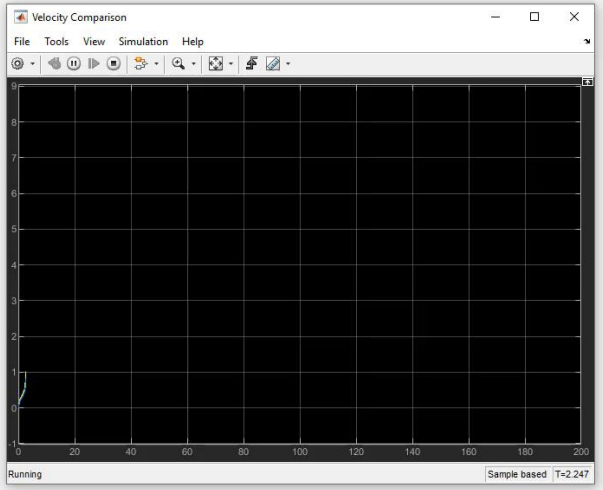


Challenges and Solution

- Component sizing and selection

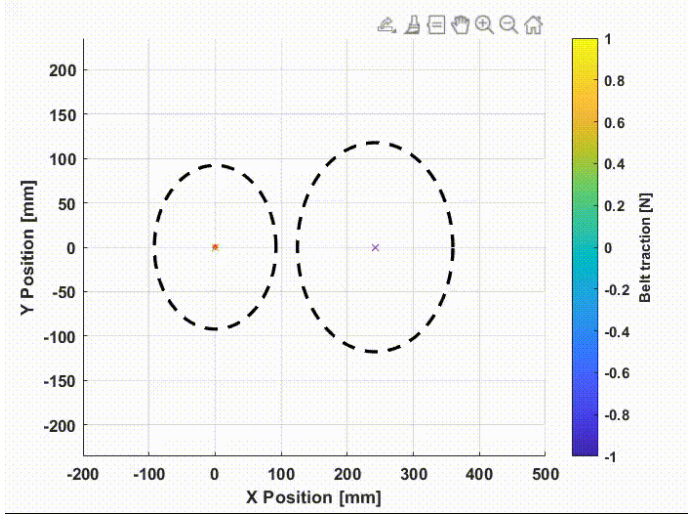


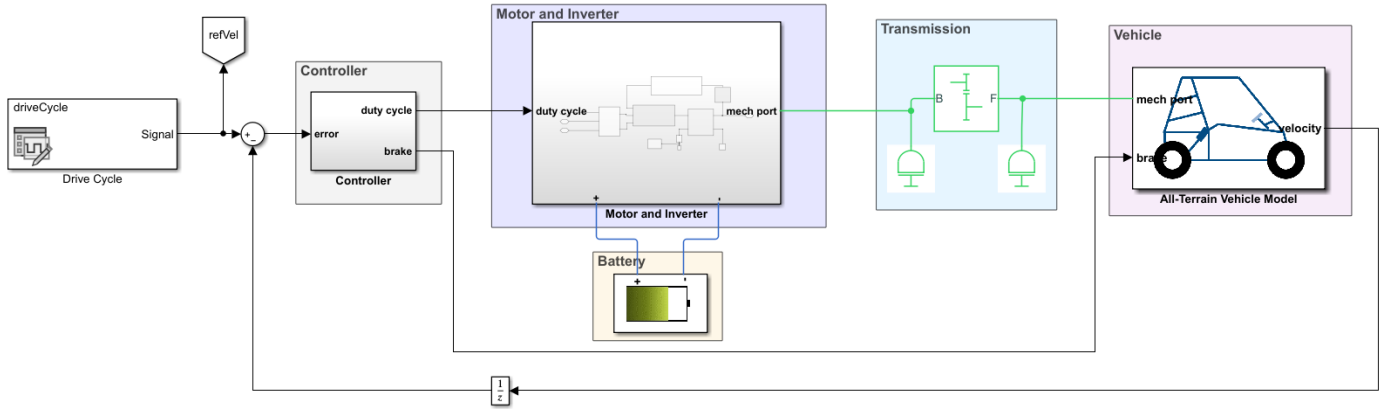
- Vehicle level performance analysis and optimization



Agenda

- Introduction to MATLAB and Simulink
  - Spring mass damper system
  - Usage by teams
- Introduction to Physical Modeling
  - Battery Model
  - BAJA electric vehicle model
- Talk by Team Kshatriya
  - 4WD vehicle simulation
  - Steering ratio and lateral dynamics study
- Multibody Mechanical Systems Modeling
- Resources
- Q&A





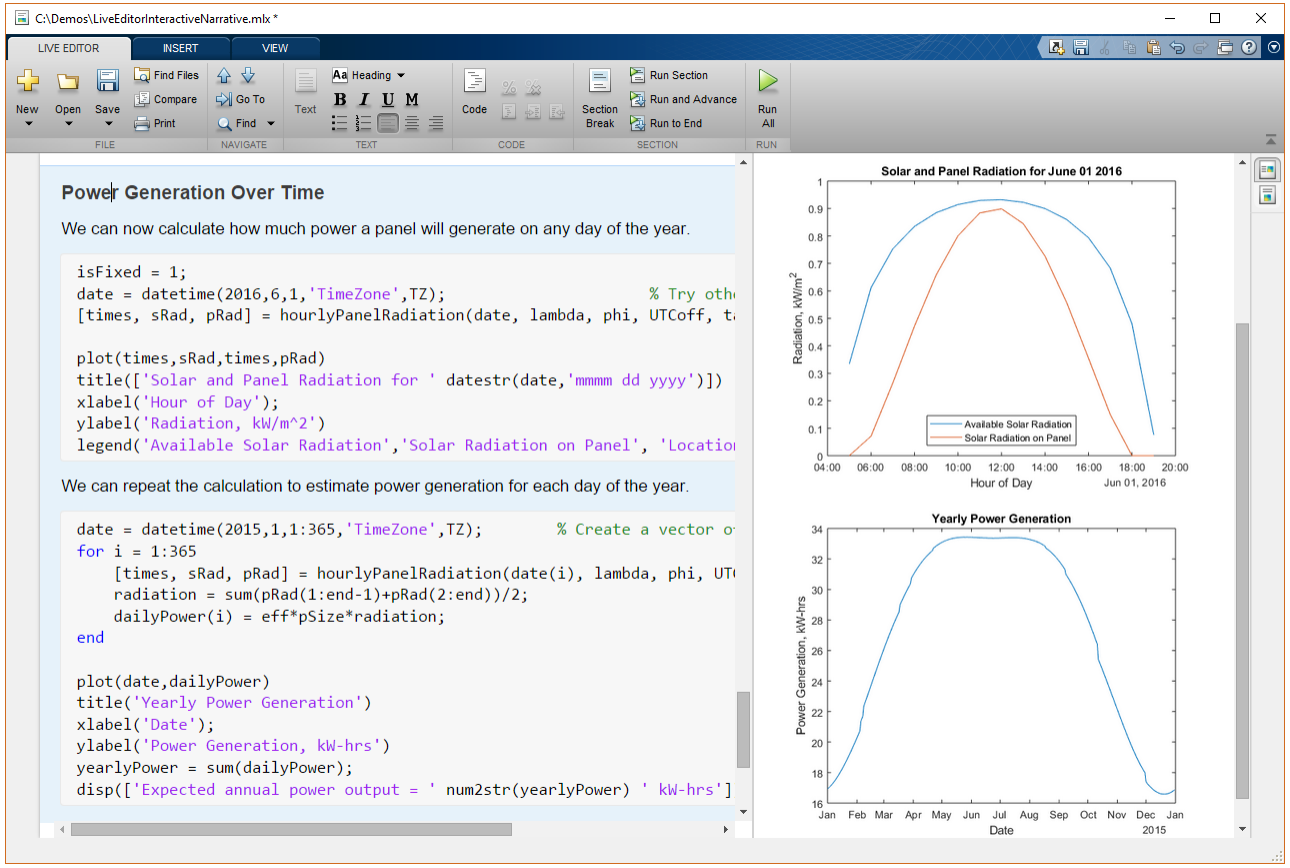
Have you used MATLAB before?

What is MATLAB?

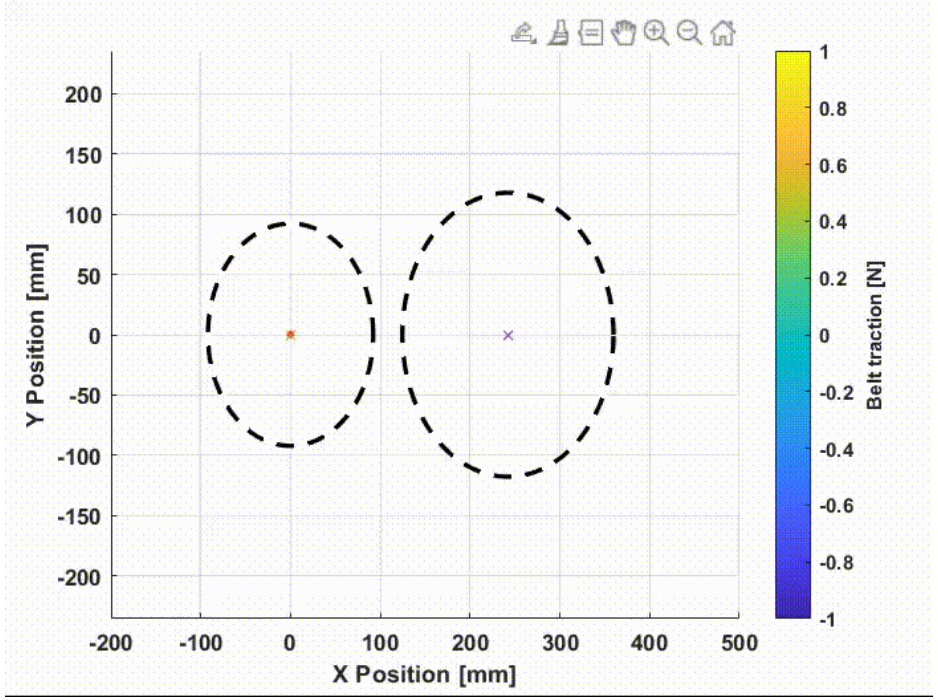
- Programming platform designed specifically for engineers and scientists
- Matrix-based

- What can you do with MATLAB?
  - Analyze data
  - Develop algorithms
  - Create models and applications

- MATLAB Onramp



Usage by BAJA Teams



[Predicting Dynamic Behavior of a Continuously Variable Transmission using MATLAB]

Blog by: Alex and Lucas from the University o f Brasília – Piratas do Cerrado Baja SAE Team.

Dr. Vishwanath Karad MIT World Peace University, Pune

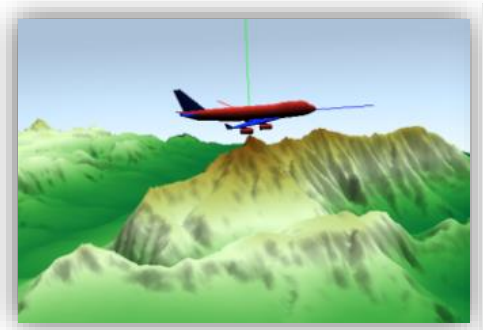
1st Place Overall, 1st Place in Overall Dynamics, 1st Place in Gradeability, 1st Place in Susupension and Traction, 1st Place in All Terrain Peformance, 2nd Place in Overall Statics, 2nd Place in Acceleration, 3rd Place in Cost Event - BAJA SAEINDIA 2021

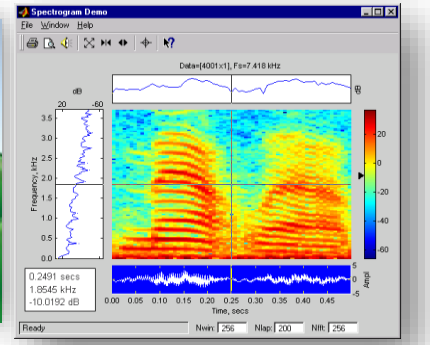
Team Piranha Racing, a team with a legacy of 12 years from MIT WPU won the BAJA SAE 2021 competition along with a total of 8 trophies. They used MATLAB to verify the pressure generated in their master cylinders, to simulate their stopping distance, and model their 4WD Powertrain through which they optimized their reduction ratio. These simulations helped the team complete their engineering product design cycle enabling them to better understand their ATV.

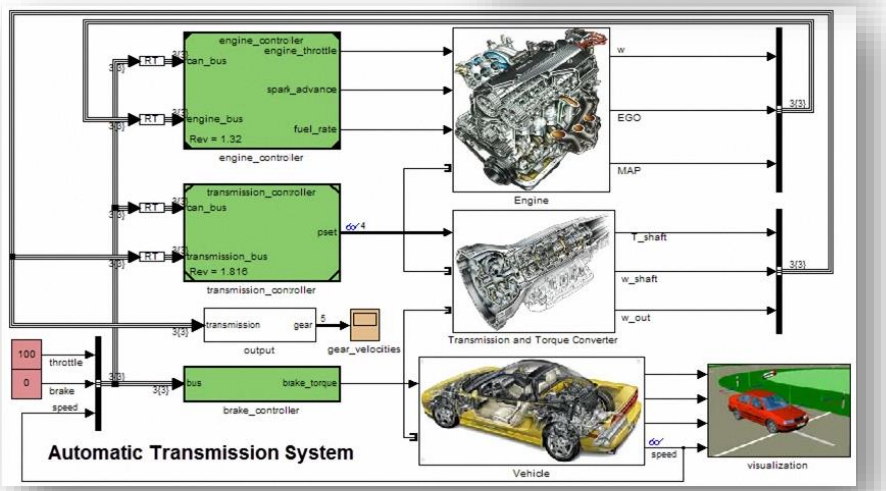
What is Simulink?

The leading environment for modeling, simulating and implementing dynamic and embedded systems

- Block-diagram environment
- Model, simulate, and analyze multi-domain systems
- Accurately design, implement, and test complex systems for:
  - Communications
  - Control
  - Signal processing
  - Video and image processing
- Platform for Model-Based Design







- [Simulink Onramp]

User Story

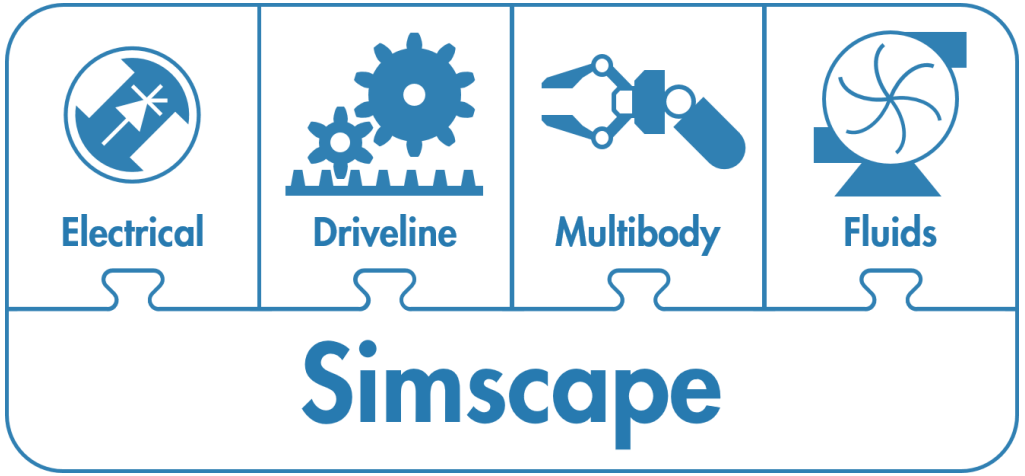
Nissan Improves Emission Performance and Reduces Calibration Time for Air-Fuel Ratio Controllers

"At Nissan, we have been finding new ways to speed development and improve our products with Model-Based Design for many years. Most recently, it was with the introduction of MATLAB and Simulink optimization products to reduce emissions by improving the performance of an existing AFR controller design."

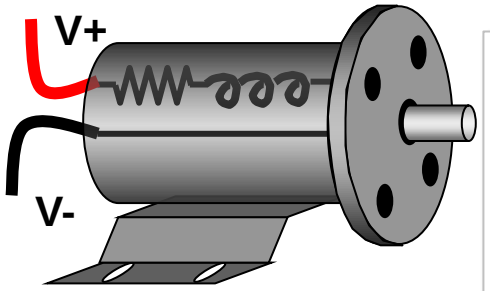
— *Hiroshi Katoh, Nissan Motor Corporation*

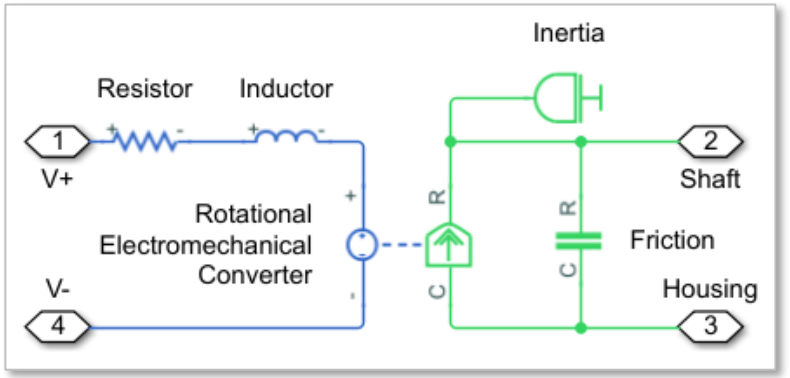
The Nissan Altima.

Simscape
Overview



- Enables physical modeling (acausal) of multidomain physical systems
  - Assemble a schematic
  - Equations derived automatically
  - Leverage MATLAB and Simulink

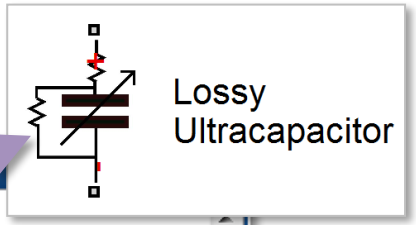




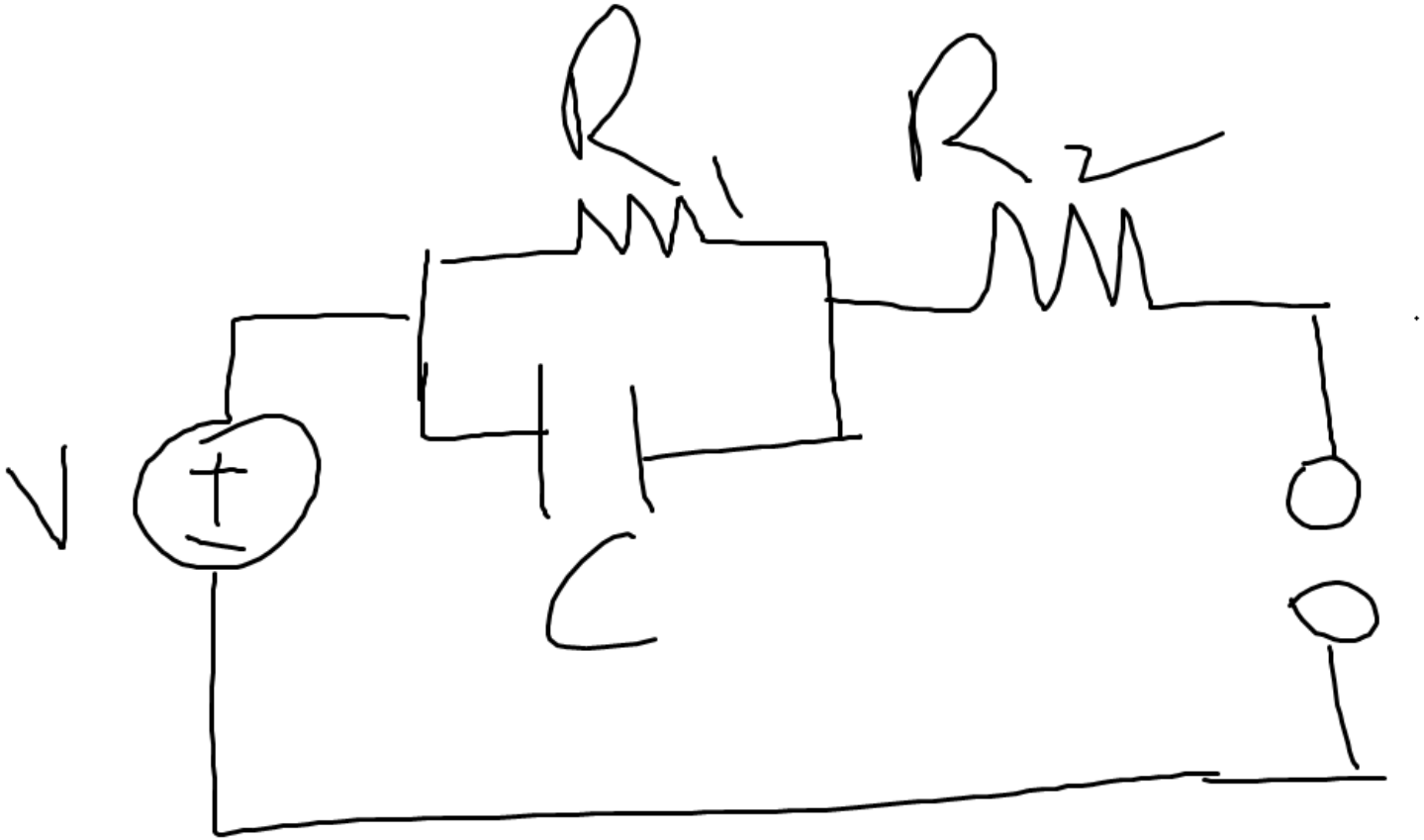
- With Simscape you can:
  - Refine requirements for system
  - Discover integration issues early
  - Design control systems and logic
  - Optimize system-level performance
  - Test embedded software without hardware prototypes

$$i = (C_0 + C_v v)\frac{dv}{dt} + \frac{v}{r_d}$$

```
Editor - C:\+MyComponent...ossyUltraCapacitor.ssc
40  equations
41    i == (C0 + Cv*vc)*vc.der + vc/Rd;
42    v == vc + i*R;
43  end
```

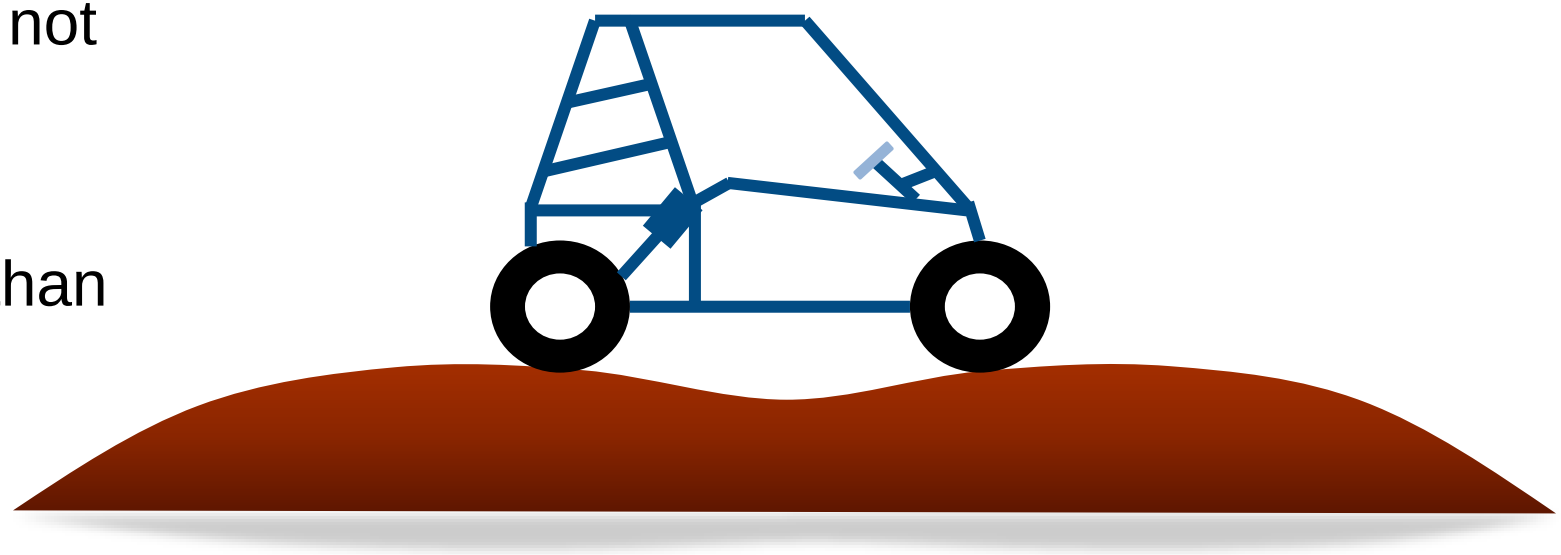


Equivalent Circuit

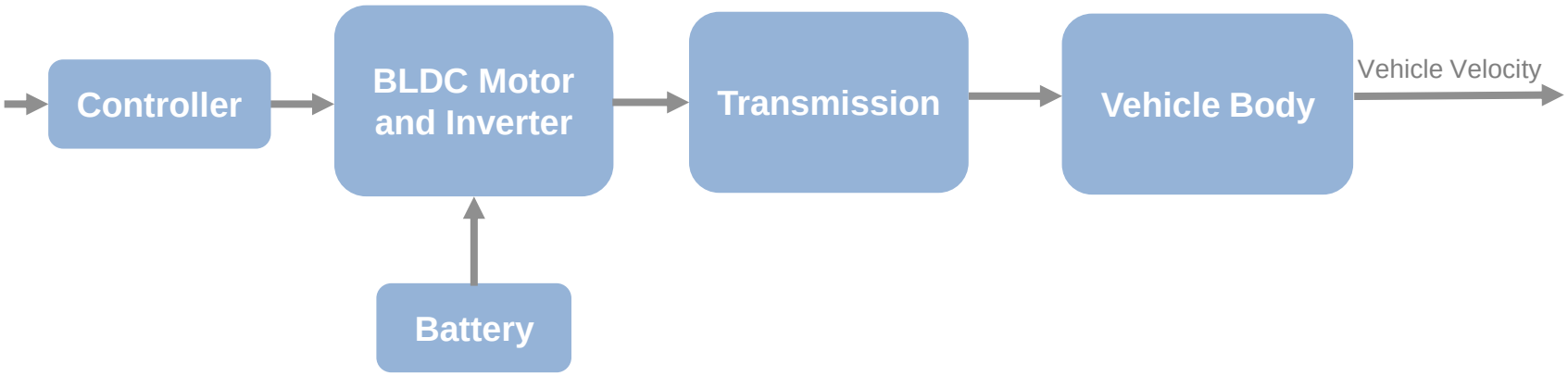


BAJA Electric All-Terrain Vehicle

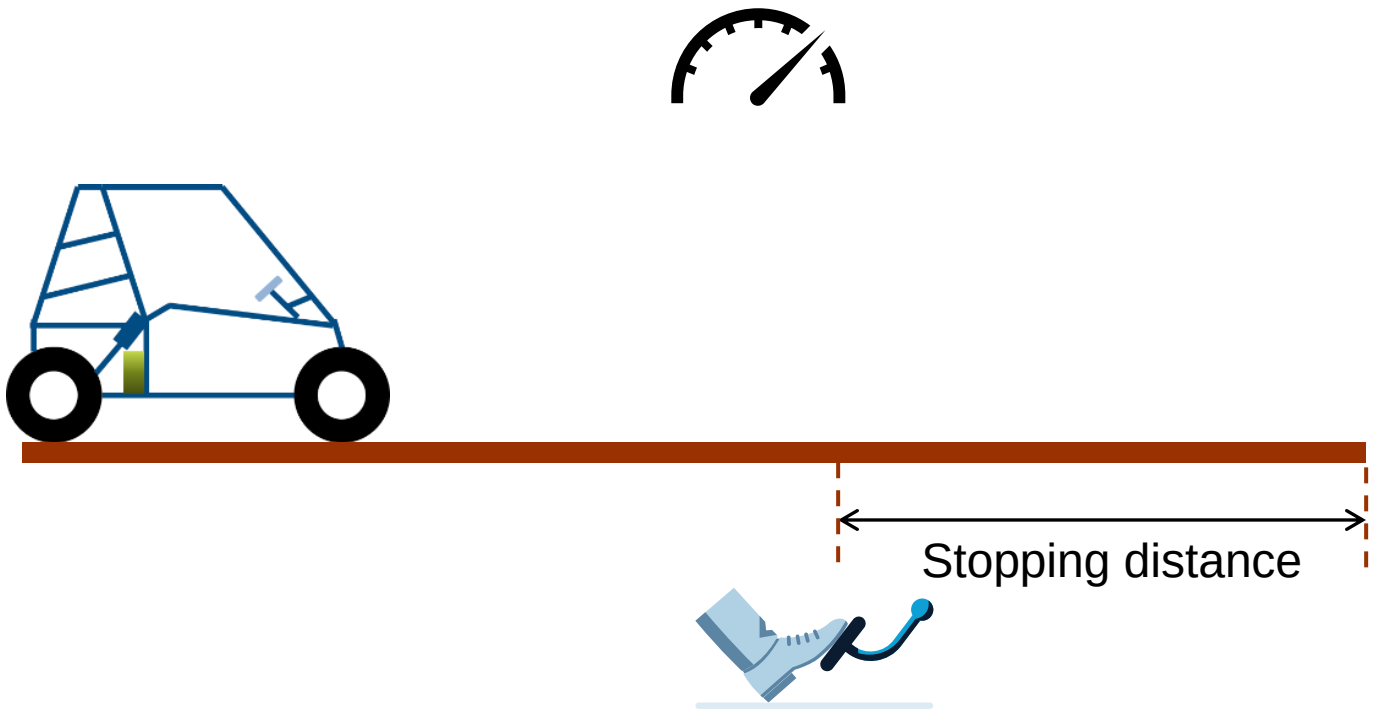
- Vehicle is driven by BLDC motor
- Battery Specifications shall not exceed 48V, 110Ah
- Maximum speed not more than 40 kmph



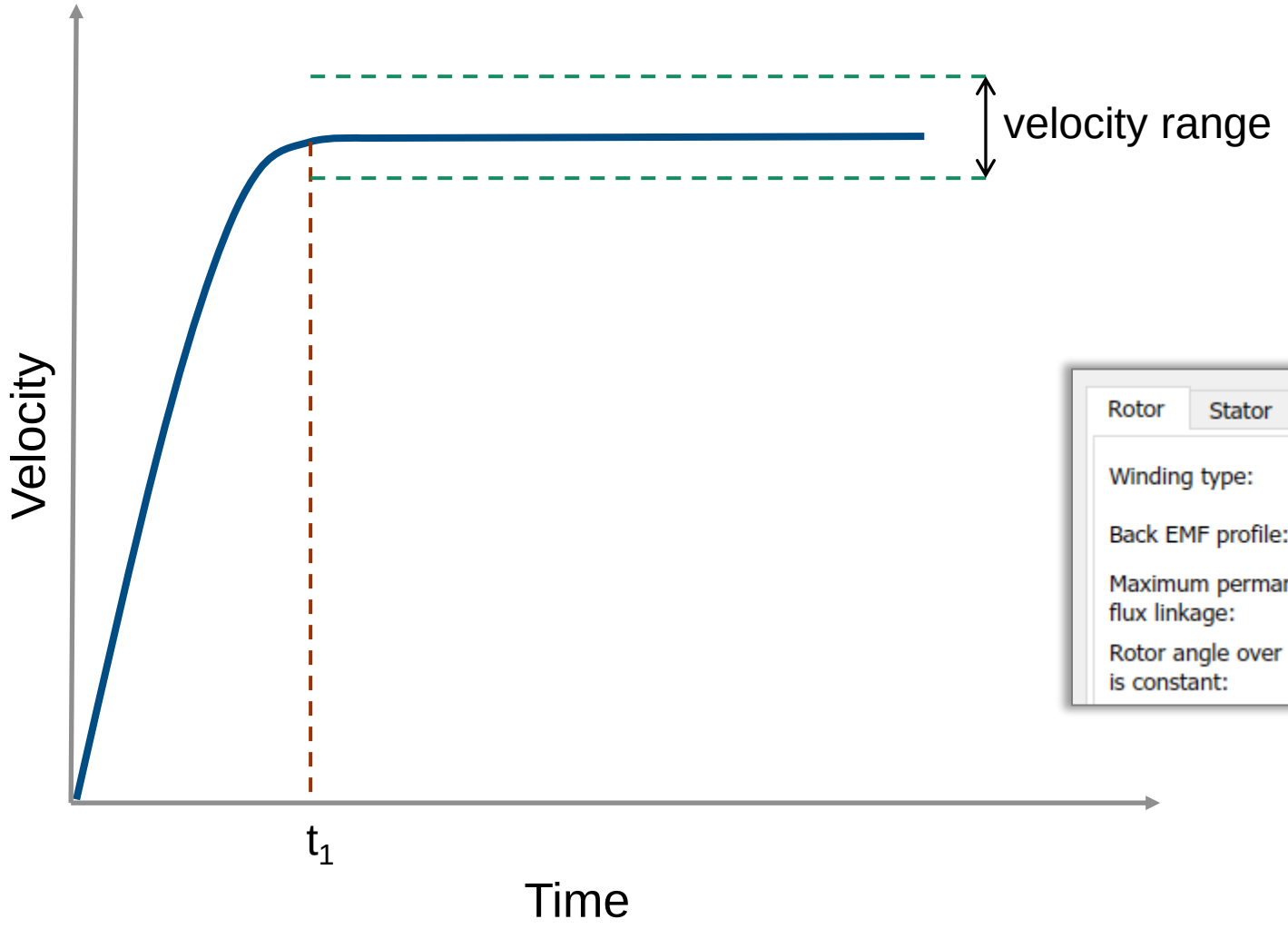
Driving Cycle Simulation

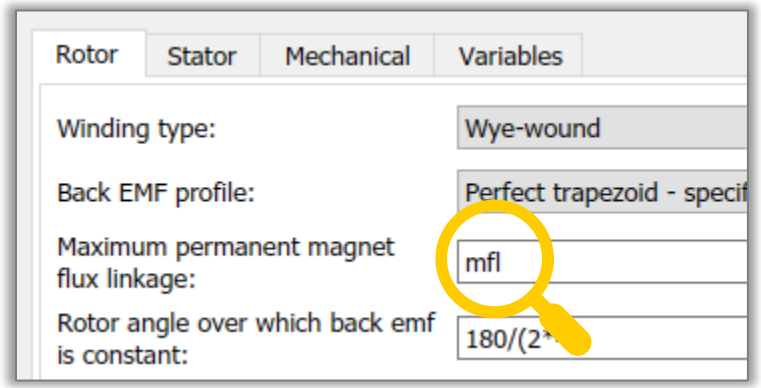


Stopping Distance



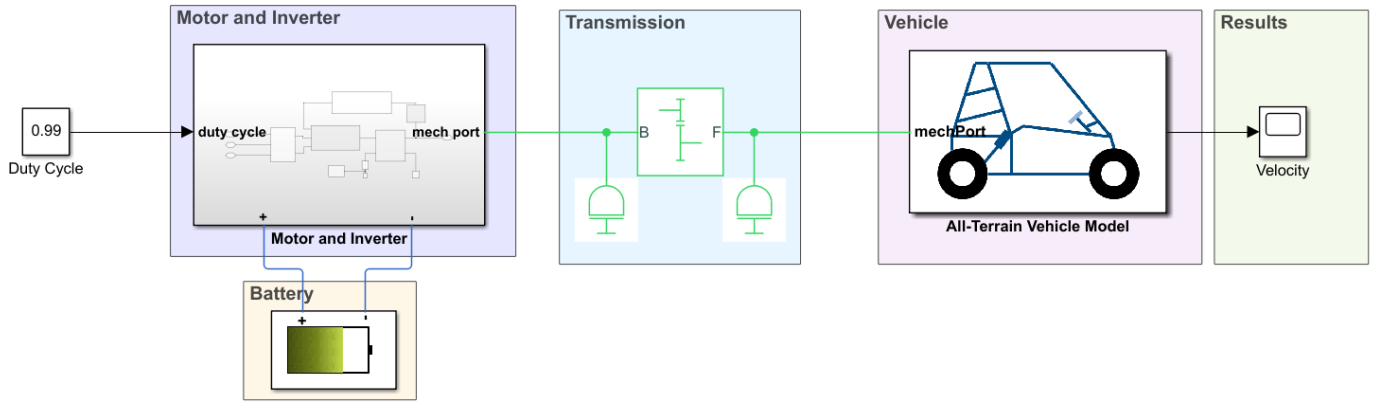
Estimating Vehicle Parameters





How to define the parameters?

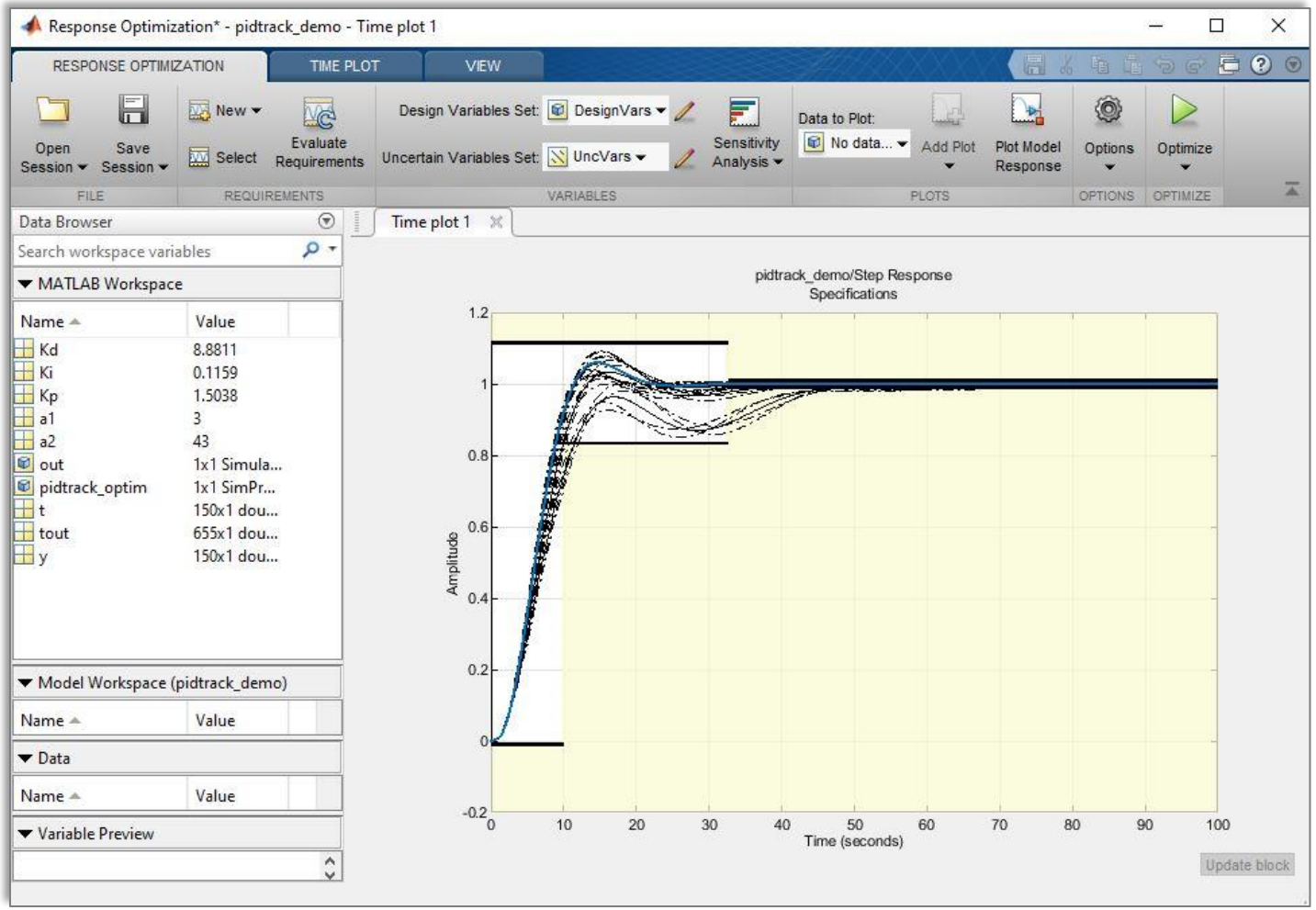
- ✓ Build the vehicle model
- ✓ Define the problem
  - ✓ Optimize the flux linkage
- ✓ Define the cost function
  - ✓ Bound the vehicle velocity (10 m/s – 12 m/s)

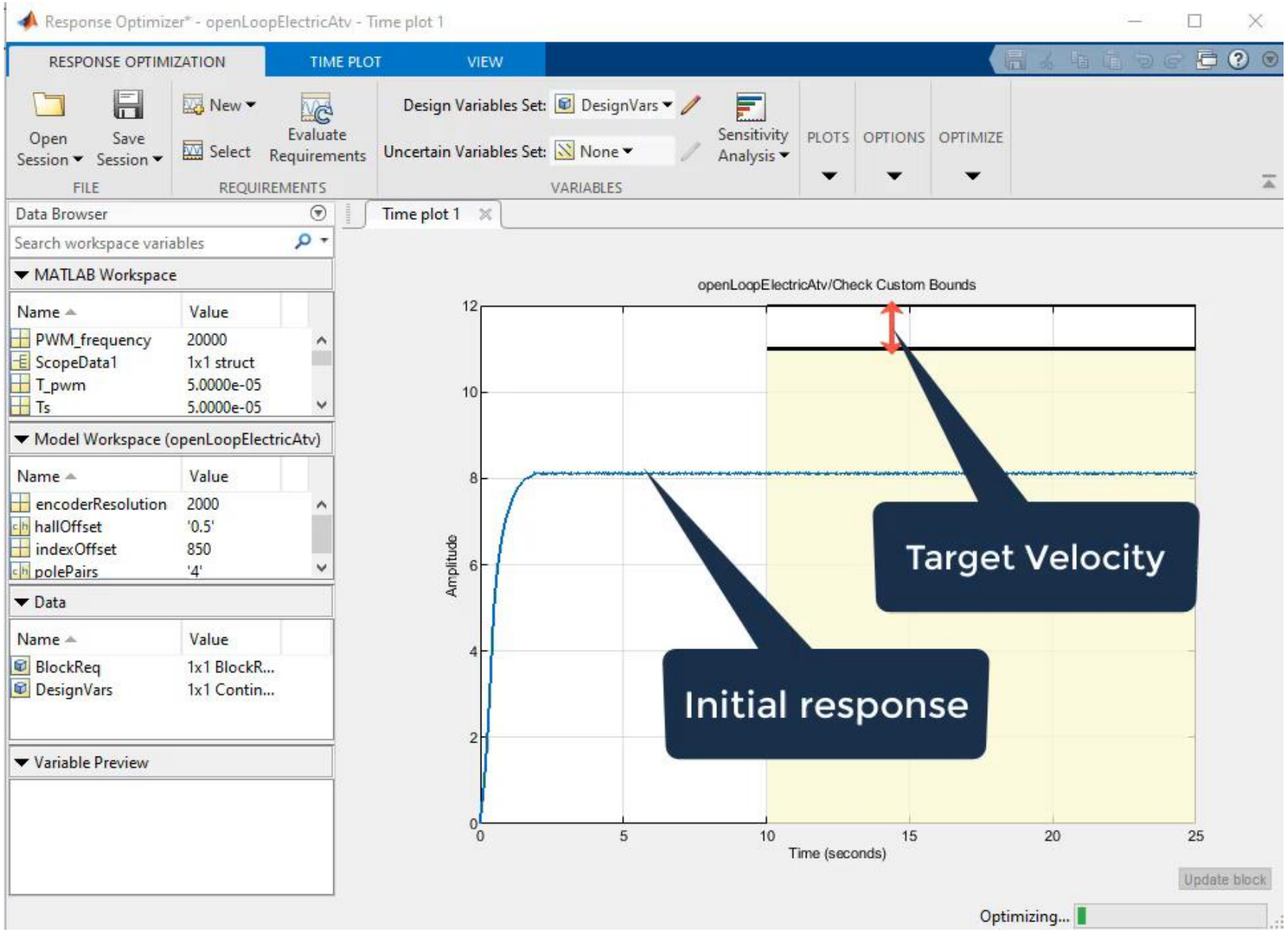


Response Optimization

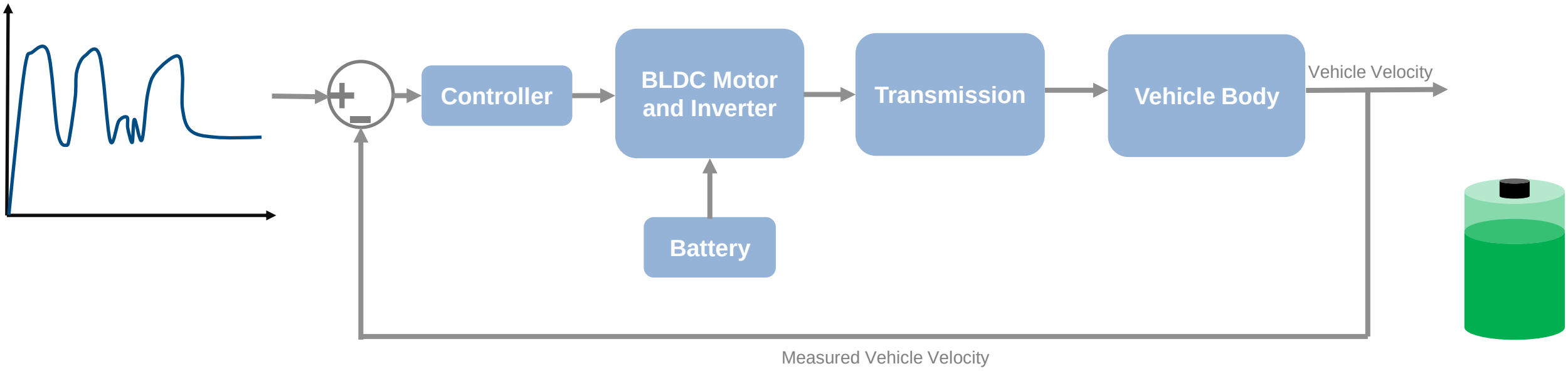
Optimize model response to satisfy design requirements

- Time-domain
- Frequency-domain
- Custom constraints
- Cost functions




Response Optimizer* - openLoopElectricAtv - Time plot 1
RESPONSE OPTIMIZATION
TIME PLOT
VIEW
Open Session
Save Session
FILE
New
Select
Evaluate Requirements
REQUIREMENTS
Design Variables Set: DesignVars
Uncertain Variables Set: None
Sensitivity Analysis
VARIABLES
PLOTS
OPTIONS
OPTIMIZE
Data Browser
Search workspace variables
MATLAB Workspace
Name
Value
PWM_frequency 20000
ScopeData1 1x1 struct
T_pwm 5.0000e-05
Ts 5.0000e-05
Model Workspace (openLoopElectricAtv)
encoderResolution 2000
hallOffset '0.5'
indexOffset 850
polePairs '4'
Data
BlockReq 1x1 BlockR...
DesignVars 1x1 Contin...
Variable Preview
Time plot 1
openLoopElectricAtv/Check Custom Bounds
Amplitude
Time (seconds)
Target Velocity
Initial response
Update block
Optimizing...

Driving Cycle Simulation



Team Introduction:

- Team Kshatriya is the official BAJA SAE team of Vellore Institute of Technology, Vellore.
- Founded in 2006 by a group of students, Team Kshatriya, was the first all student motorsport team in India.
- Design, manufacture and test single-seater All Terrain Vehicles, while keeping in mind all the regulation of the completion.
- Amongst the longest running m-BAJA team of India and has been participating in BAJA SAE India since its inception, a legacy of 15 years.

1. Performing the full 4WD vehicle simulation

- AIM:
  - The goal was to understand how a 4WD ATV accelerates compared to a RWD ATV

- METHOD:
  - Model the driveline of RWD and 4WD ATV while keeping all the other factors similar in the simulation environment and then compare the performance with the help of Data Logger

1. Performing the full 4WD vehicle simulation

- Limitations and Further Development:
  - Tire model can be improved with the support from tire manufactures providing data
  - Road/soil interaction with the tire can also be done to increase model fidelity
  - Engine model data can be crosschecked with actual dyno-test data

- Testing:
  - Use sensors/transponder to measure time accurately
  - Keep the test location and environment same for all iterations of a test cycle

2. Study of Steering Ratio and Lateral Dynamics

- AIM:
  - The goal was to understand how the ATV will respond on a range of different steering tests and compare the results of various steering ratios

- METHOD:
  - Model the ATV using a 3-DOF blockset and Kinematic Steering blockset
  - Setup different steering test and measure the net lateral load transfer at various speeds

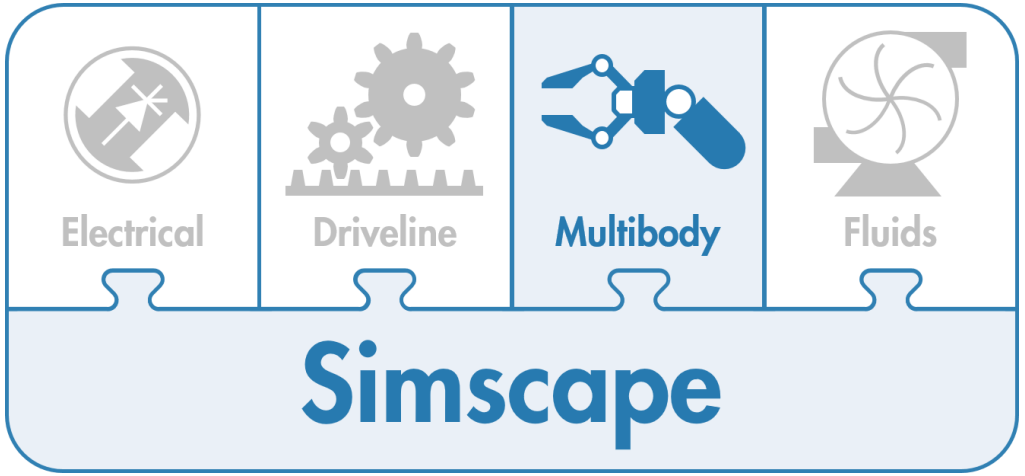
2. Study of Steering Ratio and Lateral Dynamics

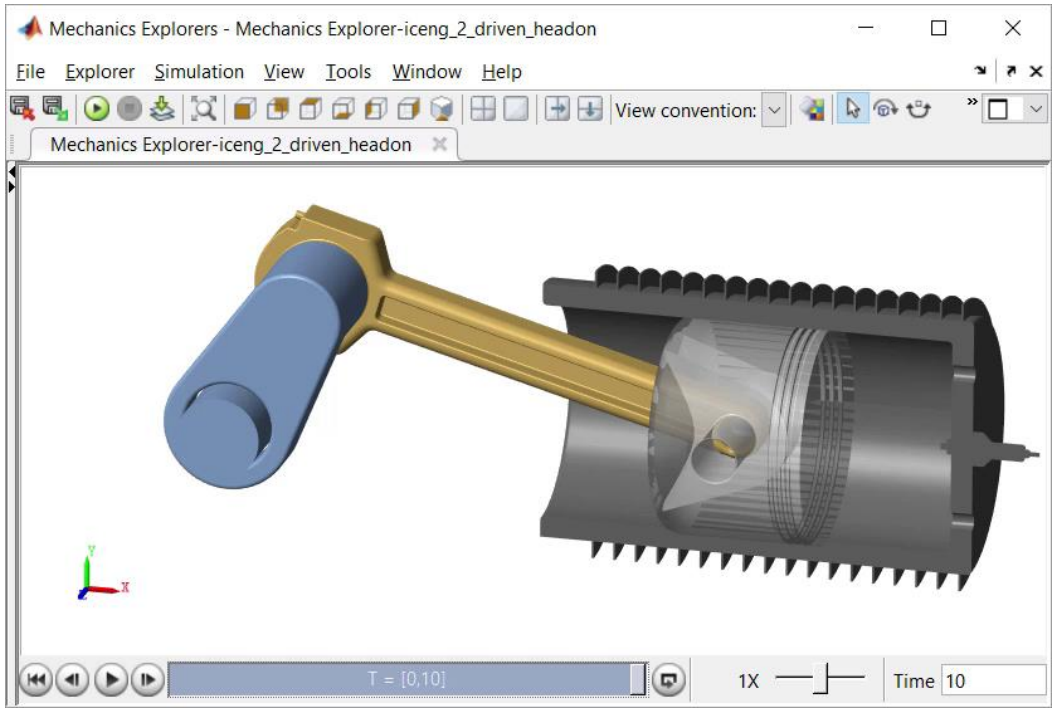
- Limitations and Further Development:
  - The current model only accounts for a corner taken at a constant velocity.
  - Roll and pitch of the ATV can be included in the model with a higher DOF blockset
  - Tire model can be improved with the support from tire manufactures providing data
  - Road/soil interaction with the tire can also be done to increase model fidelity

- Testing:
  - Use sensors/transponder to measure time accurately
  - Set same track as the ones used on the model
  - Map the steering and pedal response of the driver and use the same for testing
  - Keep the test location and environment same for all iterations of a test cycle

Simscape Multibody
Overview

- Enables multibody simulation of 3D mechanical systems
  - Assemble bodies and joints including import from CAD
  - No need to derive and program equations
- With Simscape Multibody you can:
  - Refine requirements for mechanical system
  - Discover integration issues early
  - Design control algorithms and logic
  - Test embedded software without hardware prototypes

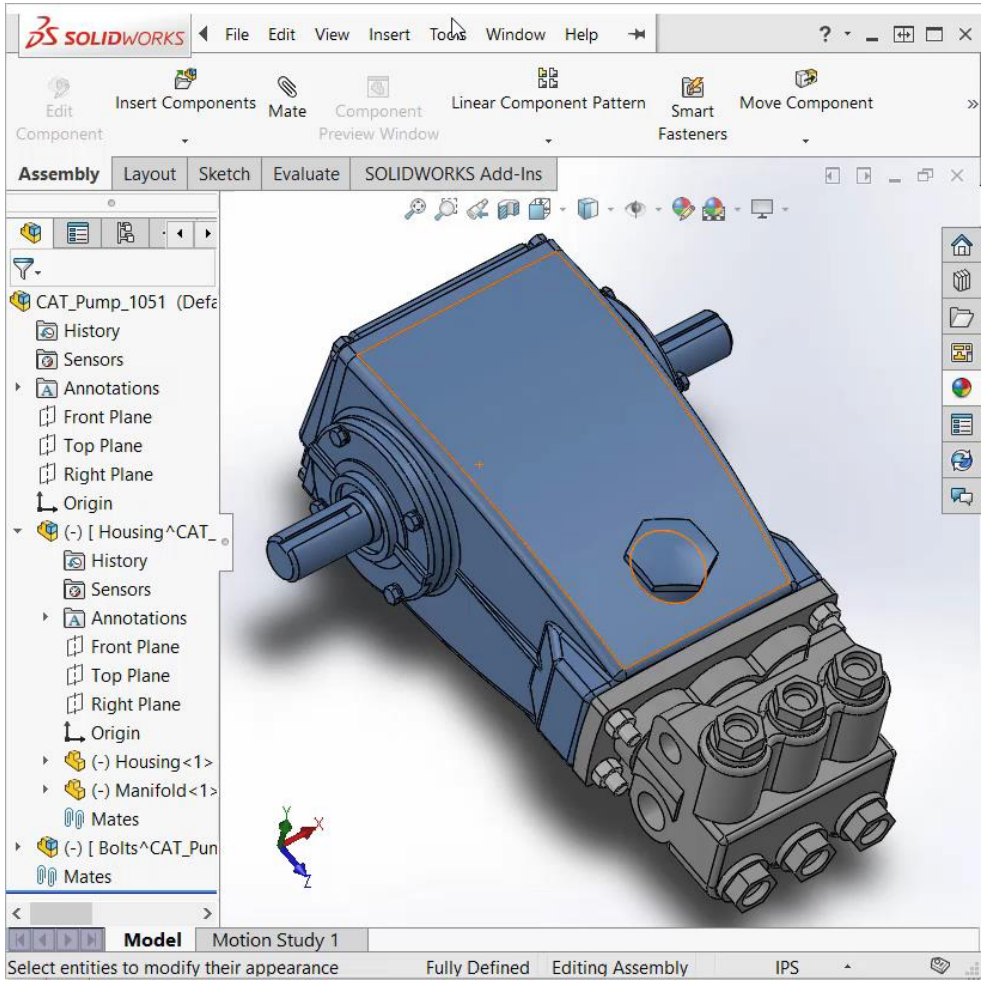




Simscape Multibody Modeling Environment

Part Definition, CAD Import, Constraints, Forces, Visualization

- Import CAD assemblies
  - Part definitions
  - Converts mate definitions to joints
  - SOLIDWORKS, Inventor, Onshape, and PTC Creo® (Pro/ENGINEER®)
- Import CAD Parts
  - CATIA, NX, SolidEdge, and others
  - STEP files



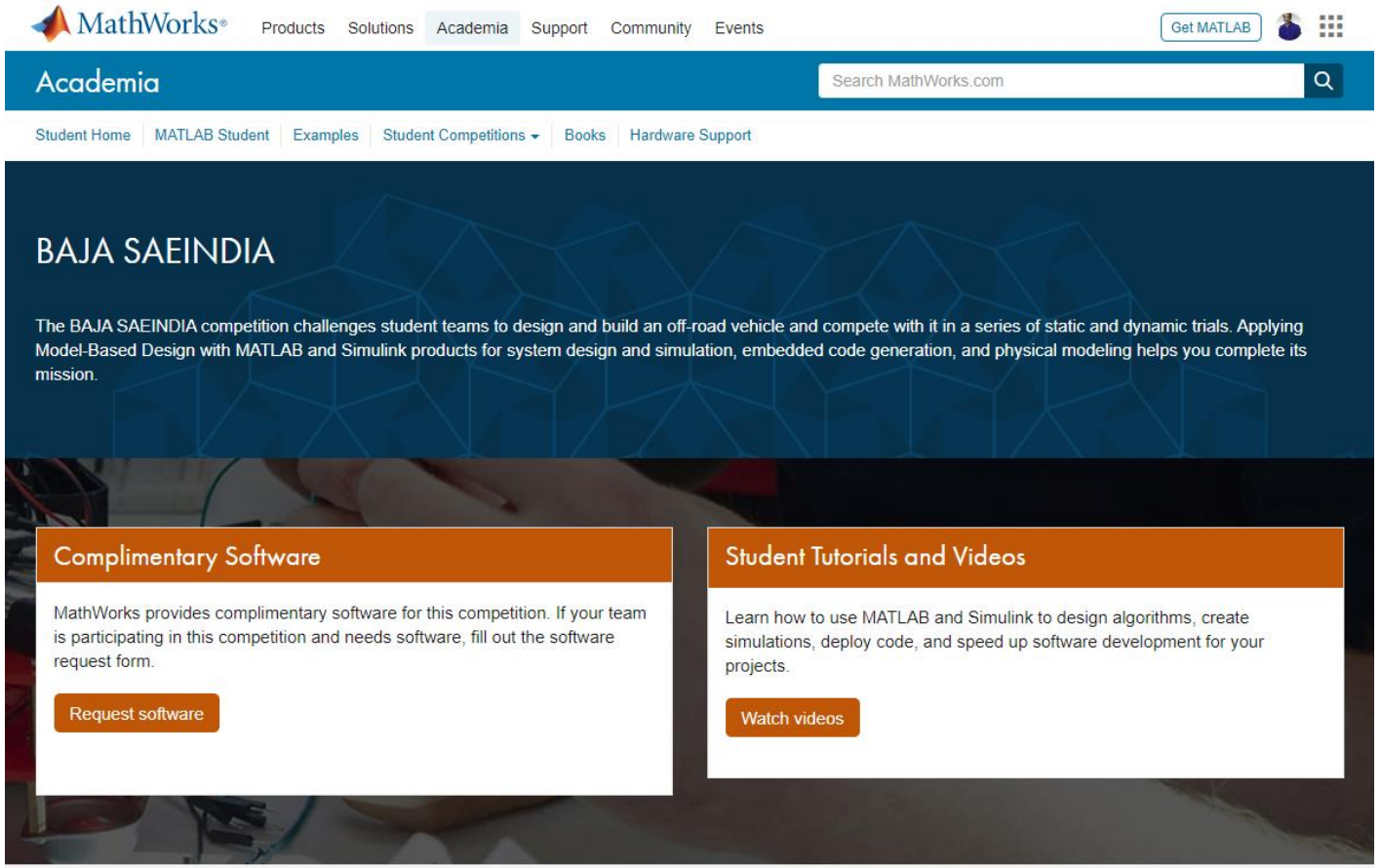
Recap: Which Tools To Use?

Software Tool	When To Choose
MATLAB + Simulink	• System equations are already known or can be derived • *"**Need a calculator** to solve my equations and process results"*
Simscape	• Model **mechanisms** (motors, shifter actuators, etc.) • Model **multidomain systems** (mechatronic, fluid, thermal) • Reduce visual complexity: model **without deriving equations**
Simscape Multibody	• Model **3D rigid body systems** (suspension, steering, etc.) • Import kinematic models from **CAD** and add dynamics

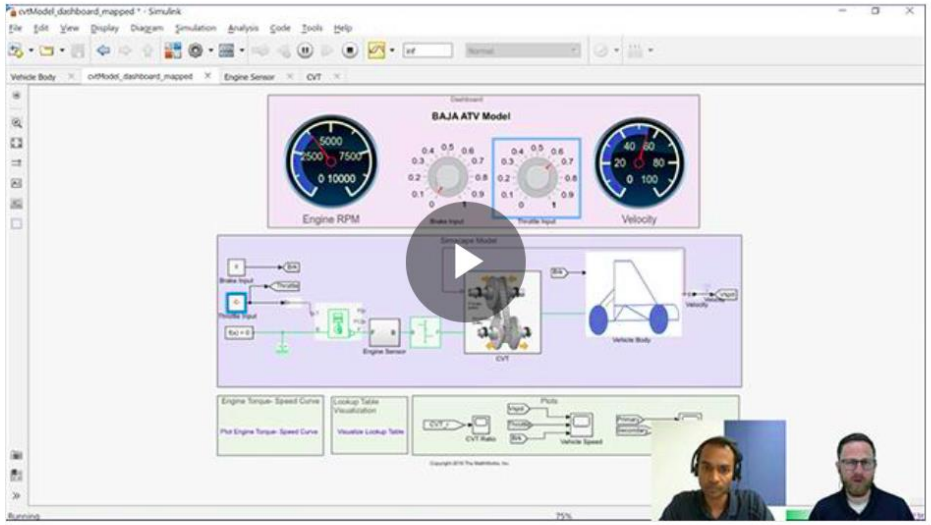
… and you can combine them all!

Complimentary Software for BAJA SAEINDIA Teams

Link: https://www.mathworks.com/academia/student-competitions/baja-saeindia



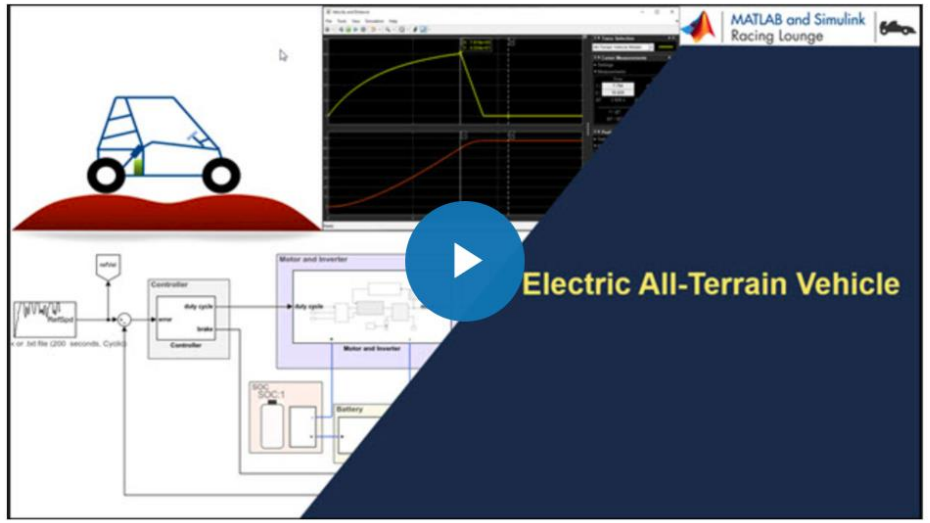
Tutorial Videos for BAJA Competition



Description | Related Resources

Modeling of a Continuously Variable Transmission (CVT) BAJA All-Terrain Vehicle (ATV)

Link: https://www.mathworks.com/videos/modeling-a-vehicle-with-continuously-variable-transmission-1554467867519.html

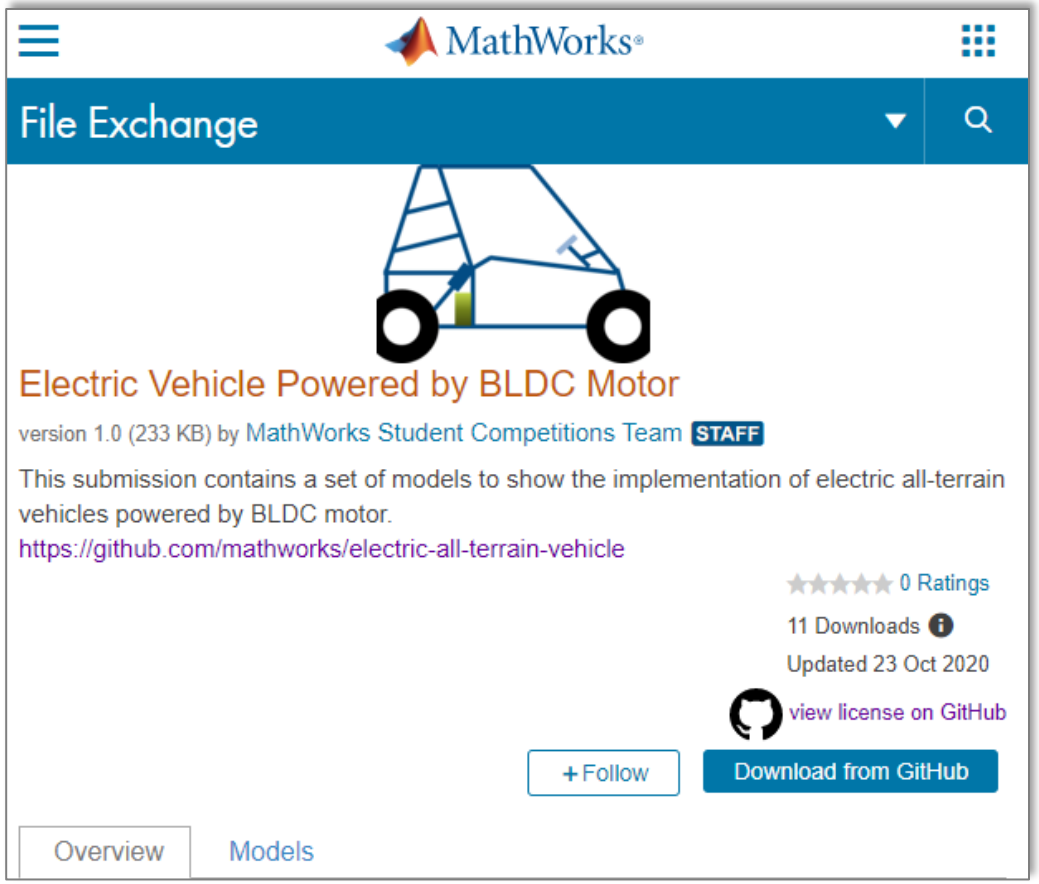


Description | Full Transcript | Related Resources

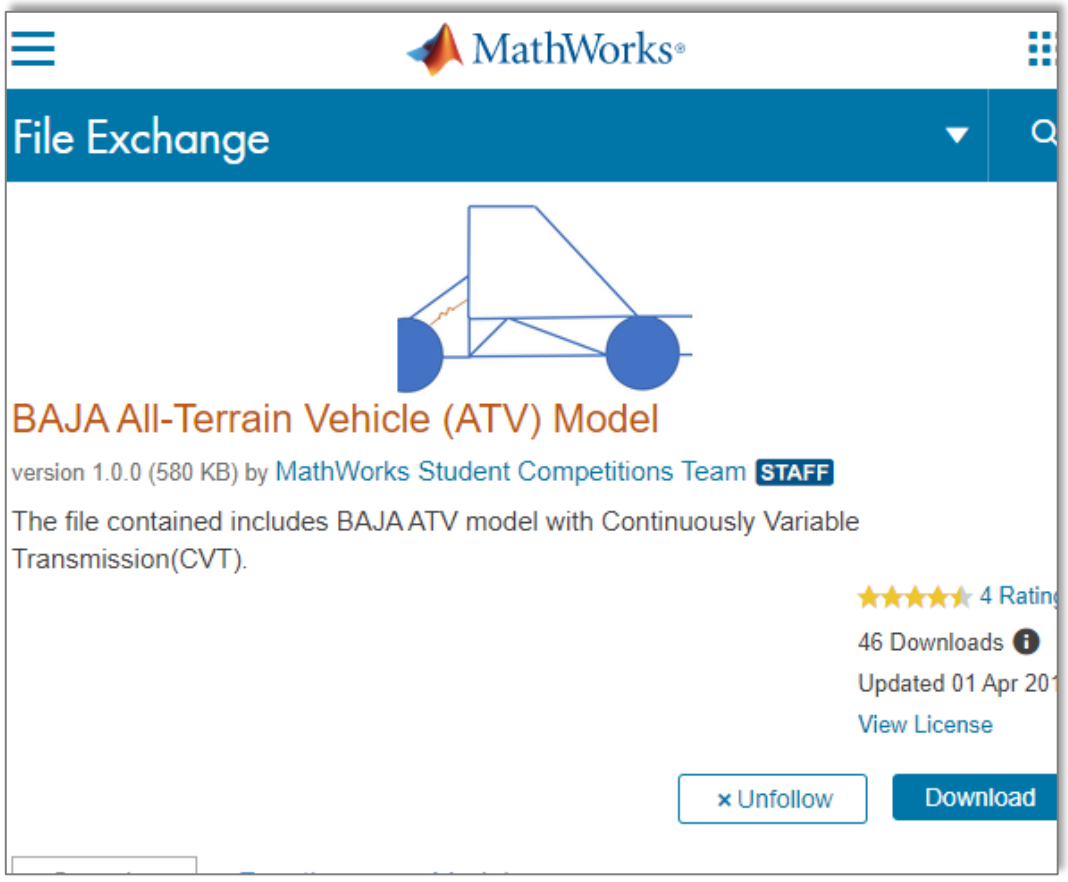
Model and Simulate an Electric All-Terrain Vehicle with Simscape

Link: https://www.mathworks.com/videos/model-and-simulate-an-electric-all-terrain-vehicle-with-simscape-1618894089707.html

File Exchange Links

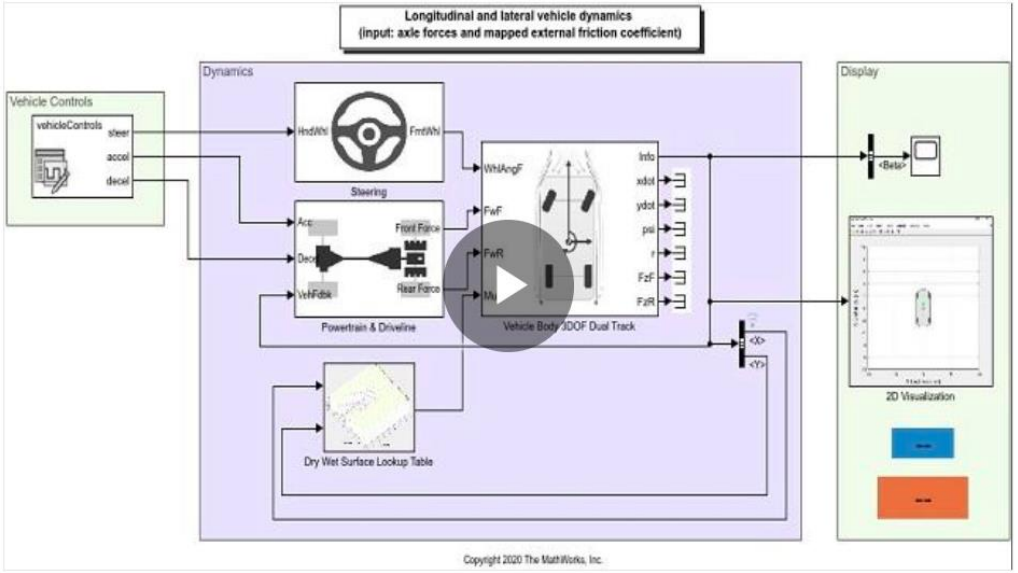


Link:
https://www.mathworks.com/matlabcentral/fileexchange/81623-electric-vehicle-powered-by-bldc-motor



Link:
https://www.mathworks.com/matlabcentral/fileexchange/70576-baja-all-terrain-vehicle-atv-model

Tutorial Videos for BAJA Competition



Link: https://www.mathworks.com/videos/matlab-and-simulink-racing-lounge-simulating-longitudinal-and-lateral-vehicle-dynamics-1576843468042.html

Vehicle Path Tracking Using Pure Pursuit

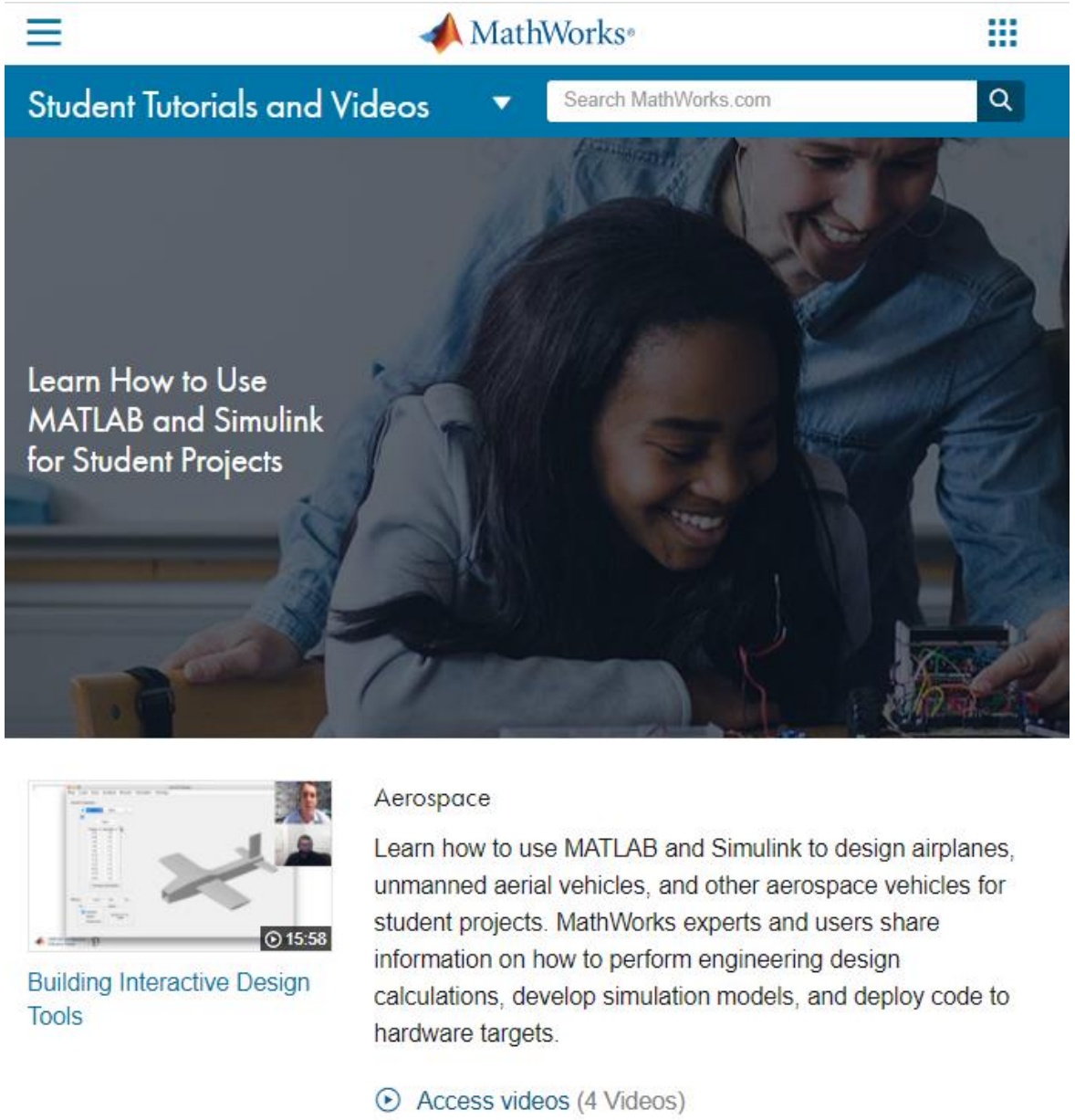
Link: https://www.mathworks.com/videos/vehicle-path-tracking-using-pure-pursuit-controller-1595330917925.html

Student Competition Tutorials and Videos

Learn how to use MATLAB and Simulink to solve competition tasks

» Get started now

https://www.mathworks.com/academia/student-competitions/tutorials-videos.html



The Winner's Circle

See how students are winning competitions worldwide with MATLAB and Simulink

» Explore student projects

https://www.mathworks.com/academia/superstar-students.html

The Winner's Circle

Cool projects. Raw talent. The right tools. With these ingredients student competition teams are winning competitions worldwide and shaping the future of automotive design, aerospace engineering, robotics, and many other technical fields

Get support for your team

Robotics

Government College of Engineering Aurangabad

MathWorks Modeling Award- DD ROBOCON India 2019

We used MATLAB & SIMULINK for

- Modelling and Simulation of Dynamic behaviour of autonomous robot
- Analysis of gaits and the algorithms for autonomous robot
- Designing the control system.
- Calculating trajectory of Shagai with different angles and velocities for manual robot
- Transition of autonomous robot to different zones according to color of zone.

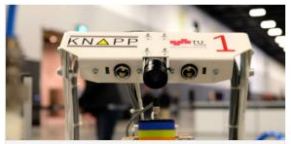
» Our facebook page
» Our Instagram page

Eindhoven University of Technology

1st Place - Soccer Middle Size League RoboCup 2019

Tech United, the robot soccer team from Eindhoven University of Technology, won 1st Place in the RoboCup Soccer Middle Size League 2019 in Sydney, Australia. The team uses MATLAB and Simulink to develop and generate real-time control software for their robot soccer players. This allows the team to rapidly develop complex software, ranging from vision to real-time motion control to strategy software.

» Team website
» Watch a recap of the final match



Technische Universität Graz

2nd Place - Logistics League RoboCup 2019

Team GRIPS achieved 2nd place at the RoboCup Logistics League competition 2019 in Sydney. MATLAB and Simulink were used in the parameter tuning process for several control loops. The team plans to integrate MATLAB even more in the software stack by connecting to the Robot Operating System (ROS). This will enable the team to conveniently implement more sophisticated control algorithms.

» Team GRIPS Website
» Team GRIPS Facebook page
» RoboCup Logistics League

Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)

2nd Place - Soccer Small Size League RoboCup 2019

ER-Force is a RoboCup Soccer Small Size League team that came in second place in this year's international event in Sydney, Australia. They used MATLAB to develop, simulate, and optimize their motion control systems for their autonomous soccer robots.

Efficient and precise motor control is crucial in the competitive RoboCup environment and

Shattuck Public School

2nd Place BEST Award – Frontier Trails BEST Regional Robotics Championship 2018

The team at Shattuck Public School used Simulink to provide a simulation of their robot structures to help them design and build an effective robot. This year's goal was to build a robot that might help clean up the oceans, and it was an exciting challenge.

Eastwood/Cornerstone Schools, Montgomery, AL

3rd Place Game Winners – South's BEST Regional Robotics Championship 2018

Gears, Inc. Robotics team, from Eastwood/Cornerstone Schools, won the Simulink Design Award at the South's BEST Regional Robotics Championship. They used Simulink and Stateflow to program their robot's drive and control functions, allowing it to collect trash from a simulated ocean environment. The award was given based on the design and sophistication of the Simulink model, as well as

Student Competition Communities

Overview

Video series - Facebook Group

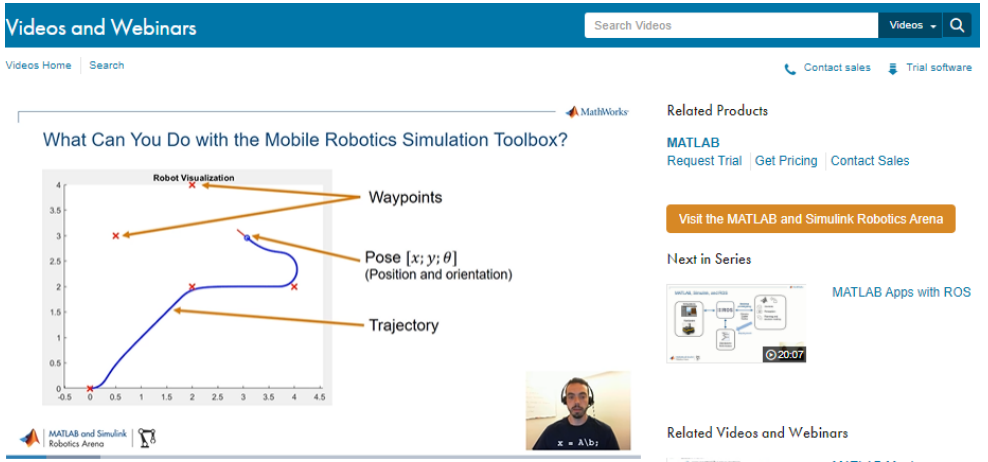
Video series - Facebook Group

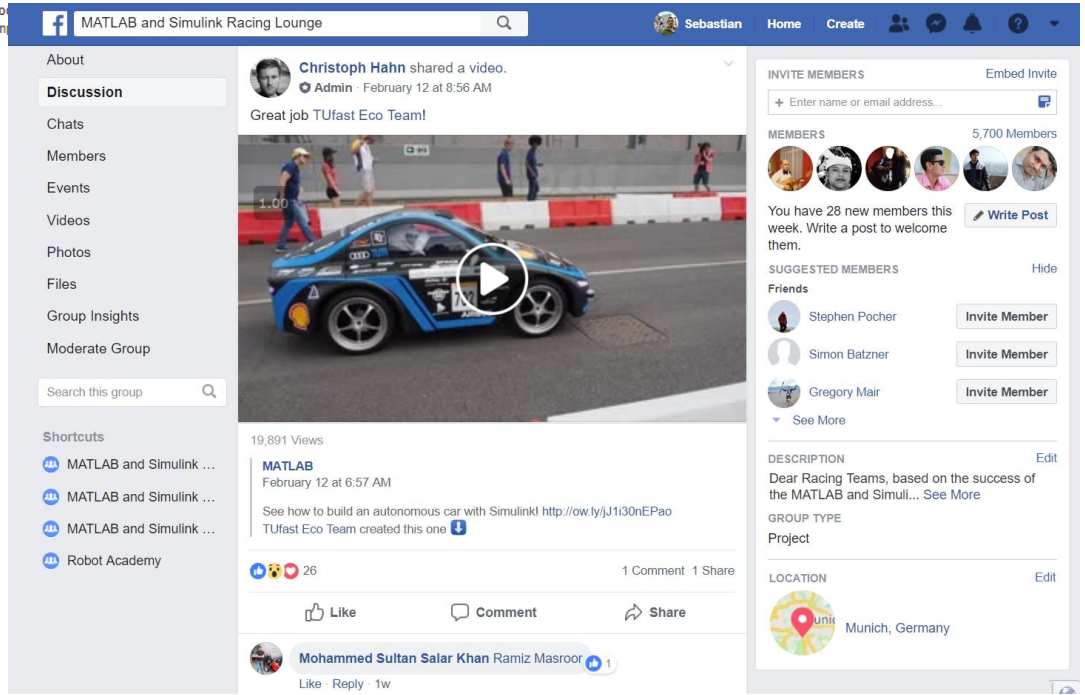
Student Lounge blog
(for all competitions)

Student Communities

Engagement

- **100+ videos** for automotive and robotics
- **19k+ members** across 2 Facebook groups
- Dedicated e-mails:
  - roboticsarena@mathworks.com
  - racinglounge@mathworks.com

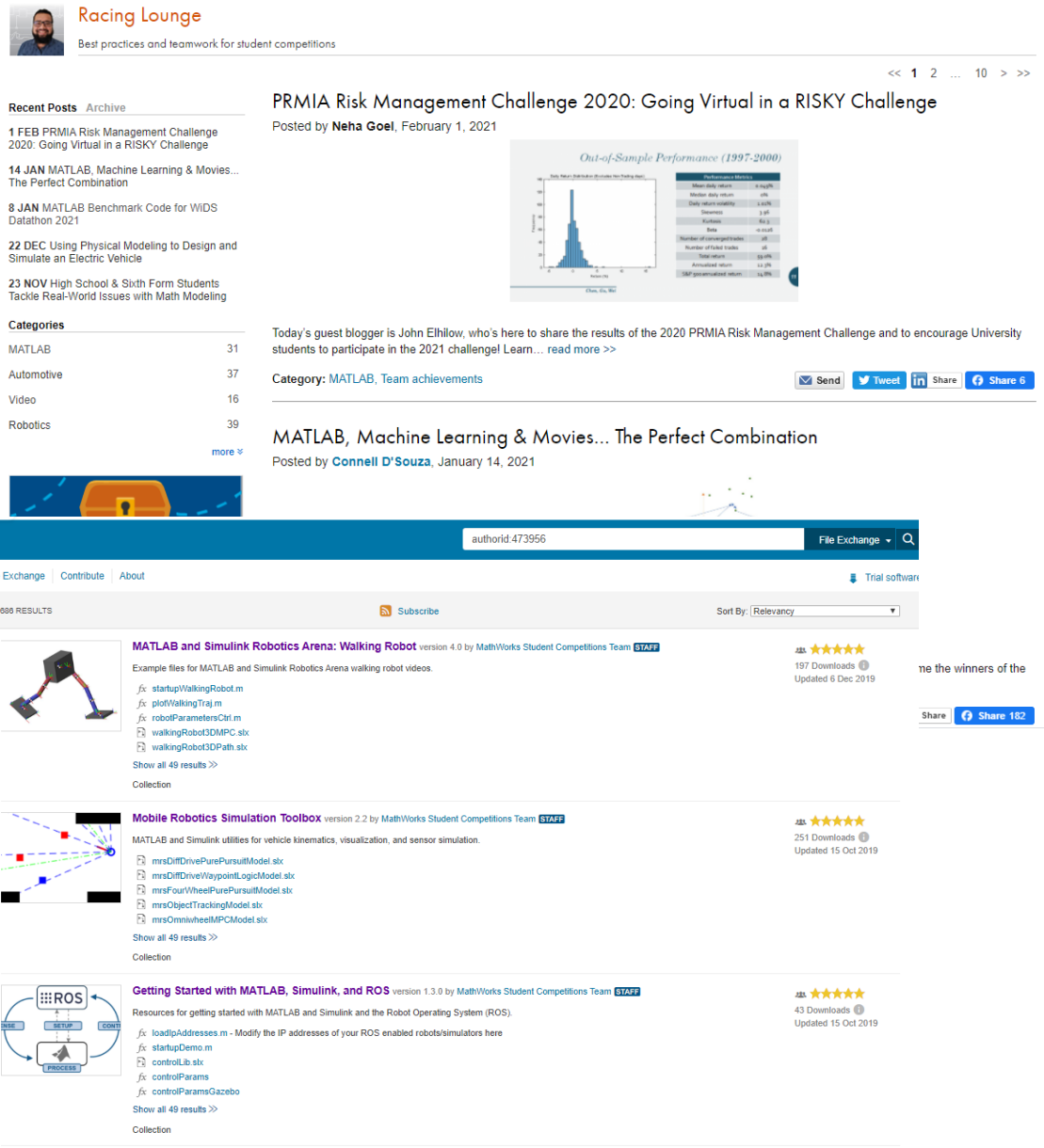




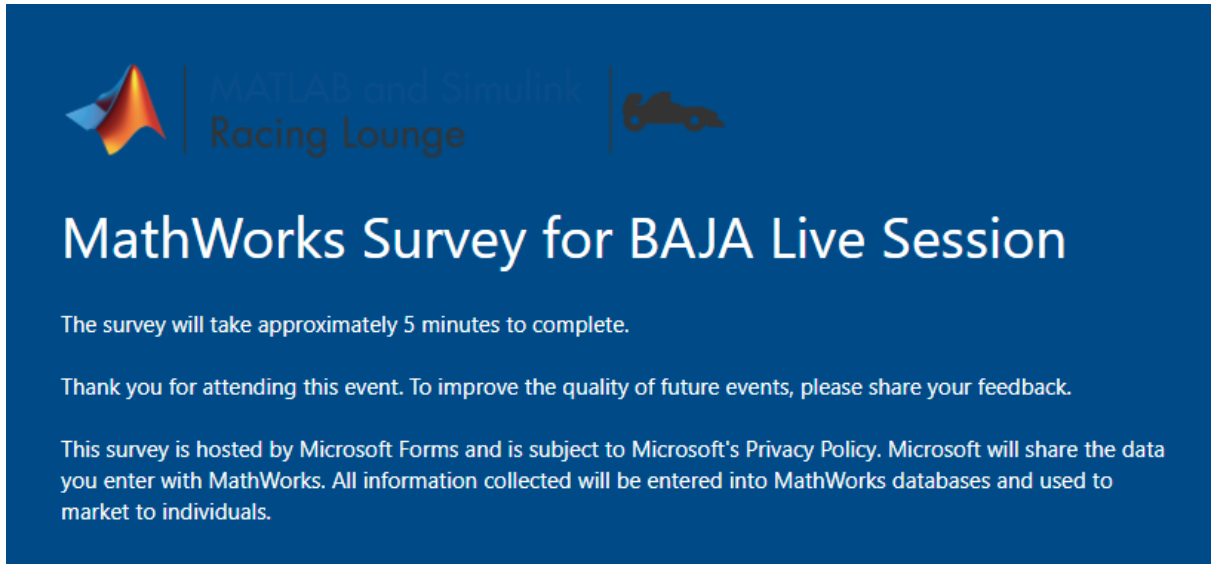
Student Communities

MATLAB Central

- **50+ blog posts** on [Racing Lounge blog]
- **50+ File Exchange entries** from [MathWorks Student Competitions Team]
- **MATLAB Answers** tags
  - [roboticsarena]
  - [racinglounge]



Survey Form



Link: https://forms.office.com/r/W4YjJSPqYZ

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