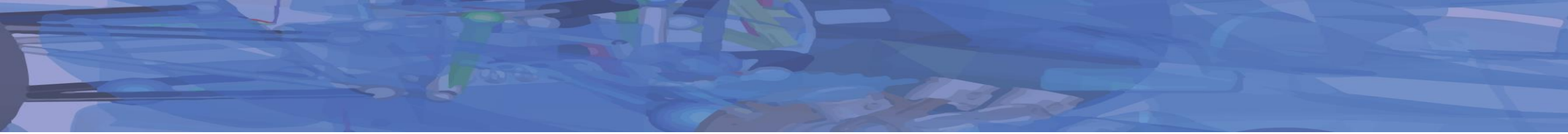

Dirt Late Model Racing Simulations in Dymola / Modelica

Nate Horn

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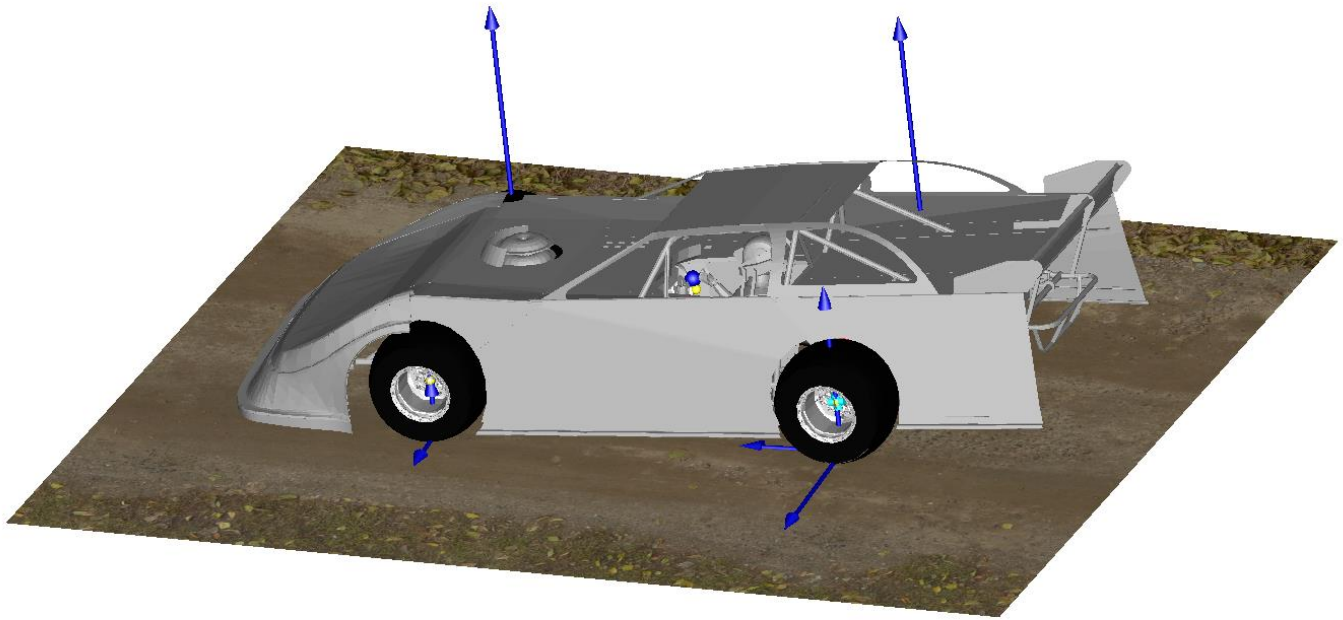
CLAYTEX

Dirt Late Model Racing Simulations

- Claytex Background
- VeSyMA Suite (Vehicle Systems Modelling and Analysis)
- My Background
- Dirt Late Model Racing
- The Simulations
- The Challenges



Who are Claytex?

- Users of Dymola and Modelica since 1999
- Dymola distributors since 2003 (Dassault Systemes partner since 2008)
- Major customers include Automotive OEM's, suppliers and Motorsport teams (Formula 1, NASCAR, Indycar)
  - First Formula 1 customer in 2004, currently support half the grid
  - First worked with Dallara in 2008 for IndyCar
  - First NASCAR customer in 2009, currently support all the manufacturers and top teams
  - Active in a number of other series
  - Supporting Motorsport inspired academic research programs
- rFpro system integrator since 2009
  - High fidelity graphics, audio and track models
  - Claytex offer complete tool chain to run the vehicle model
  - Support ADAS and autonomous vehicle development by feeding data to sensor models

Dymola

CLAYTEX

SOLUTIONS PARTNER

EDUCATION PARTNER Certified

rFpro

MathWorks Partner

VeSyMA Suite

- Suite of Modelica libraries for Vehicle Systems Modelling and Analysis
- First available in Dymola 2018
- Core platform enables performance, fuel economy and energy analysis
  - Drive cycle simulation
- Application specific extensions provide detailed models across many areas
  - Engines, powertrain, vehicle dynamics, driver-in-the-loop
- Open and extendible to easily connect libraries from other developers
  - Electrified Powertrain and Battery libraries from Dassault Systemes
  - Thermal Systems library from TLK Thermo

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My Background

- University of Iowa (B.S. and M.S.) in Mechanical Engineering
- Boeing Commercial Airplanes for 2 years
- Worked at Red Bull for 5 years until the operation shut down in 2011
  - Opportunity to collaborate with the Red Bull F1 team
  - First NASCAR team to use Dymola / Modelica
  - Introduced to Mike Dempsey (Owner of Claytex)
- Worked for 5 years at Chip Ganassi Racing (NASCAR program)
  - Vehicle Dynamics Group Leader
    - Simulation
    - Software
    - 7 Post Testing
  - Performance Group Manager
    - Add Aerodynamics
- Started at Claytex in February of 2017
  - Start up the US office

DLM Racing

DLM Racing
Industry / Cars / Tracks

- Started down this path to build a simulation package to use for demonstration purposes
  - Nobody in Motorsport want to share anything
  - I have background in this type of racing / simulation
- It also provided an opportunity for me to ‘use’ the VeSyMA suite as if I were a customer
  - Highlight areas for improvement
  - Feed these things into the Claytex ticketing system to be added / improved
- Push development forward in new areas

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DLM Racing

- Top prize payouts
  - as high as $1,000,000 (once)
  - down to $800 for local weekly racing events
  - ‘big’ races generally referred to as anything $5k or higher to win

- The Series
  - World of Outlaws
  - Lucas Oil Series
  - UMP
  - MARS
  - Corn Belt Clash
  - MLRA

DLM Racing

- Vehicle 2350 lbs (1066 kg)
- Engine/Transmission
  - Naturally Aspirated - Carbureted
  - V8 - 2 valves / cyl - Pushrod - Roller Cam
  - 420-440 cu inch (7.0-7.2L)
  - 900 HP (670 kW)
  - 9600 Peak RPM
  - 2 speed direct drive gearbox
- Front Suspension
  - Dual A-frame
  - Coil over
  - Rack and pinion steering

- Rear Suspension
  - Solid Axle “quick change”
  - 4 bar linkage on each side
  - Panhard bar
  - Torque reaction via lift arm
- Tires / Wheels
  - 15 inch diameter wheels
  - 14 inches wide
  - Multiple tire compounds legal (depending on series)
  - Tread patterns are ‘cut’ by team (depending on series)
  - Pressure 6-12 psi (40-80 kPa)
- Differential
  - Spool (locked LR to RR)

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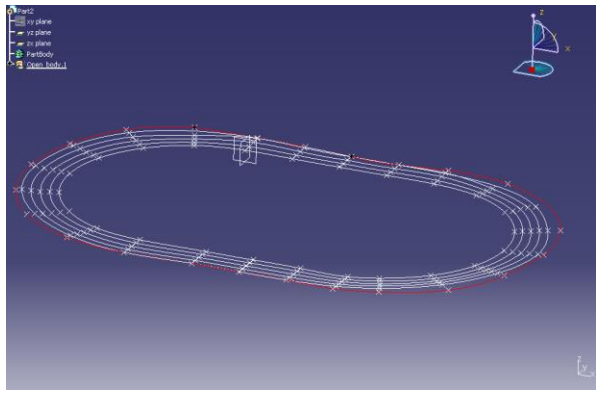
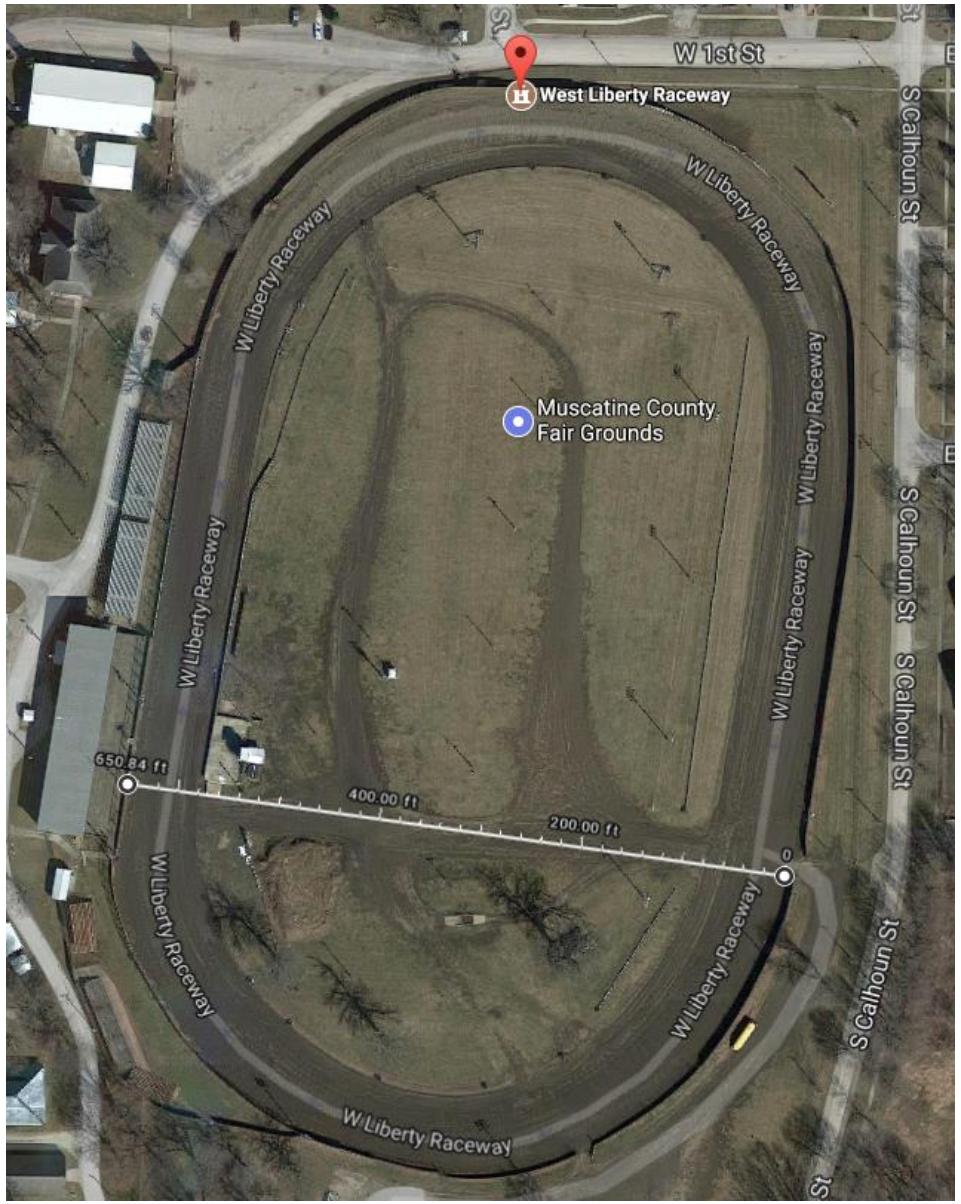
DLM Racing

- West Liberty
  - ½ mile in length
  - 5 degree banking
  - Wide corners
  - Wide racing surface

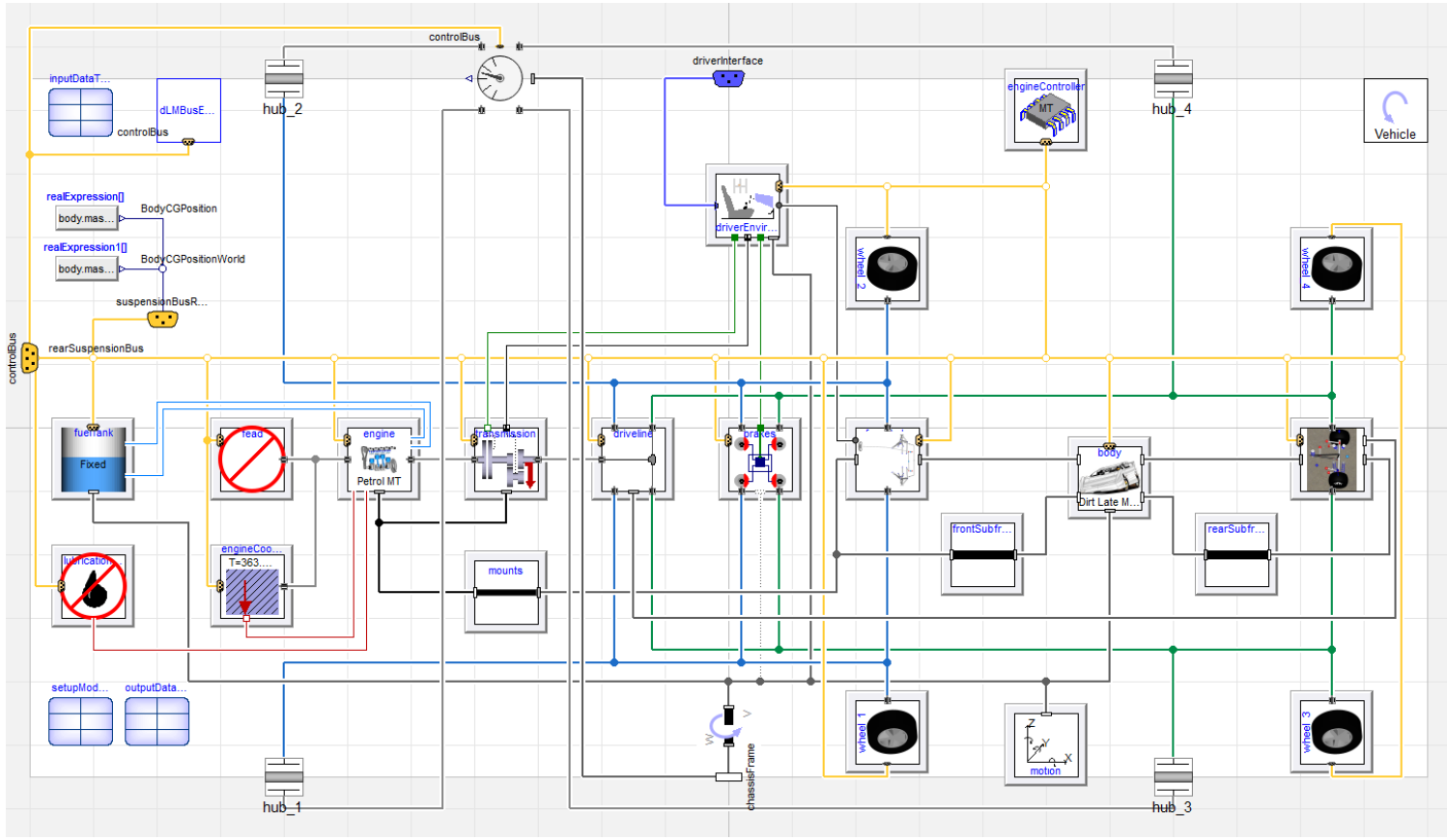


- Our ‘home’ track in college
- Fast laptime during qualifying: 18.73 seconds
- Winner slow laptime in feature: 22 seconds
- Over 3 seconds of laptime falloff is common

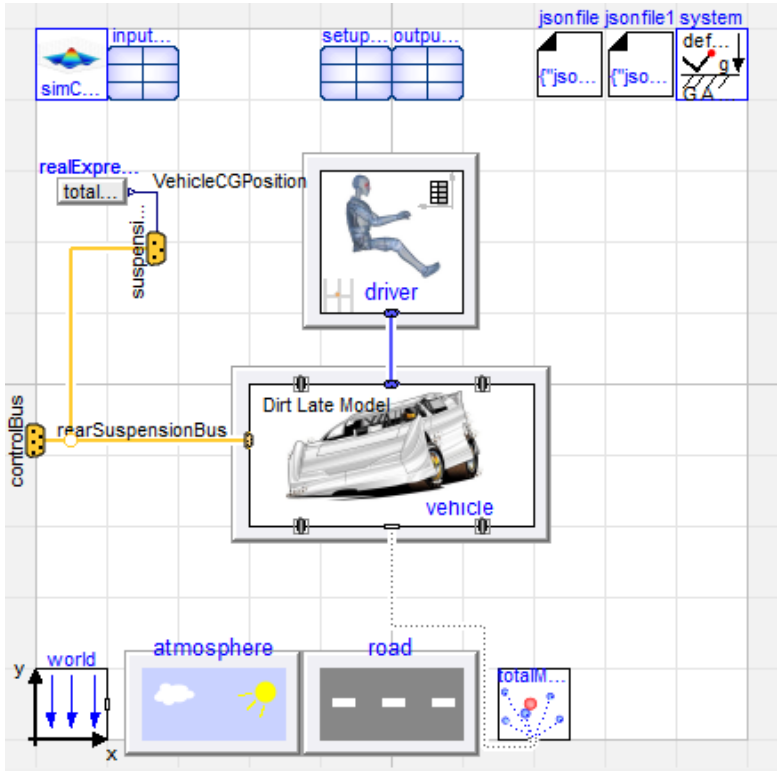


The Simulations - Same Vehicle Model

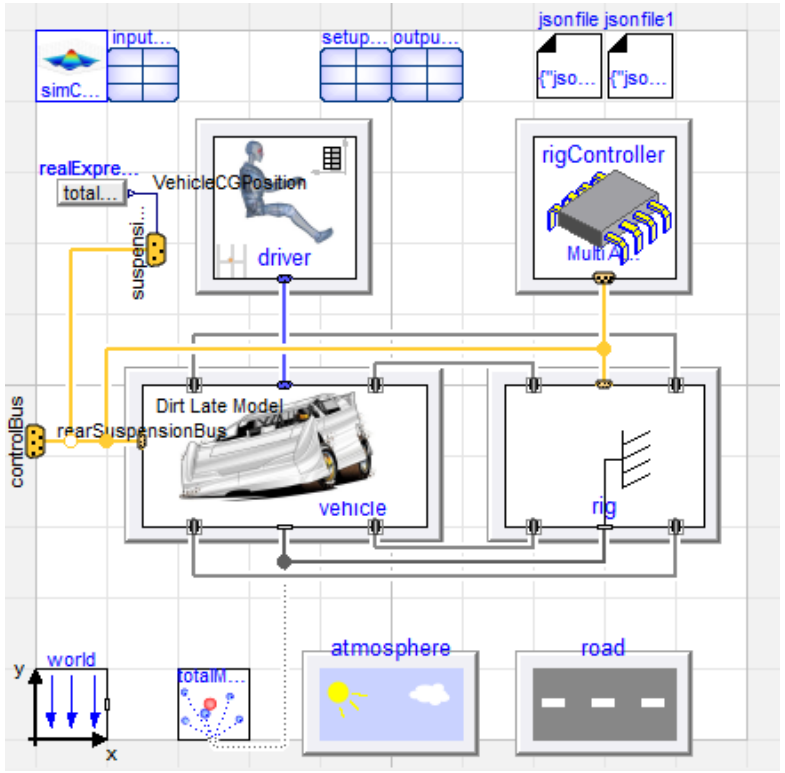
- Started with the VeSyMA - NASCAR vehicle
  - VehicleInterfaces Library standard
  - Swapped to Rack and Pinion steering
  - Built custom rear suspension model
  - Started with a VeSyMA aero model and customized
    - Estimated the aerodynamic model inputs based on limited information
  - Created a custom setup event (starting from NASCAR example)
- Added STL of a Body for visual reference



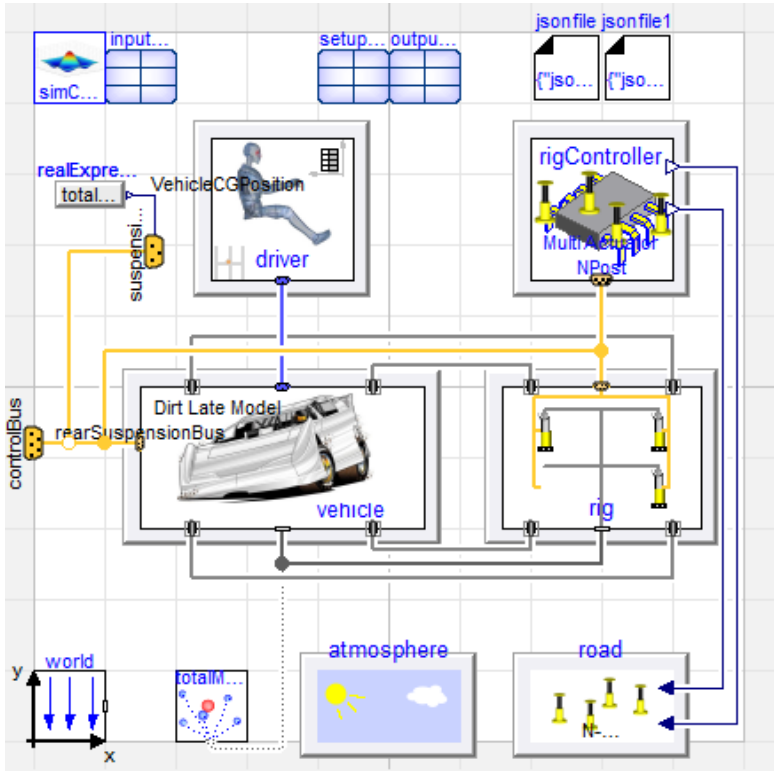
The Simulations - Same Vehicle Model



‘MassCheck’



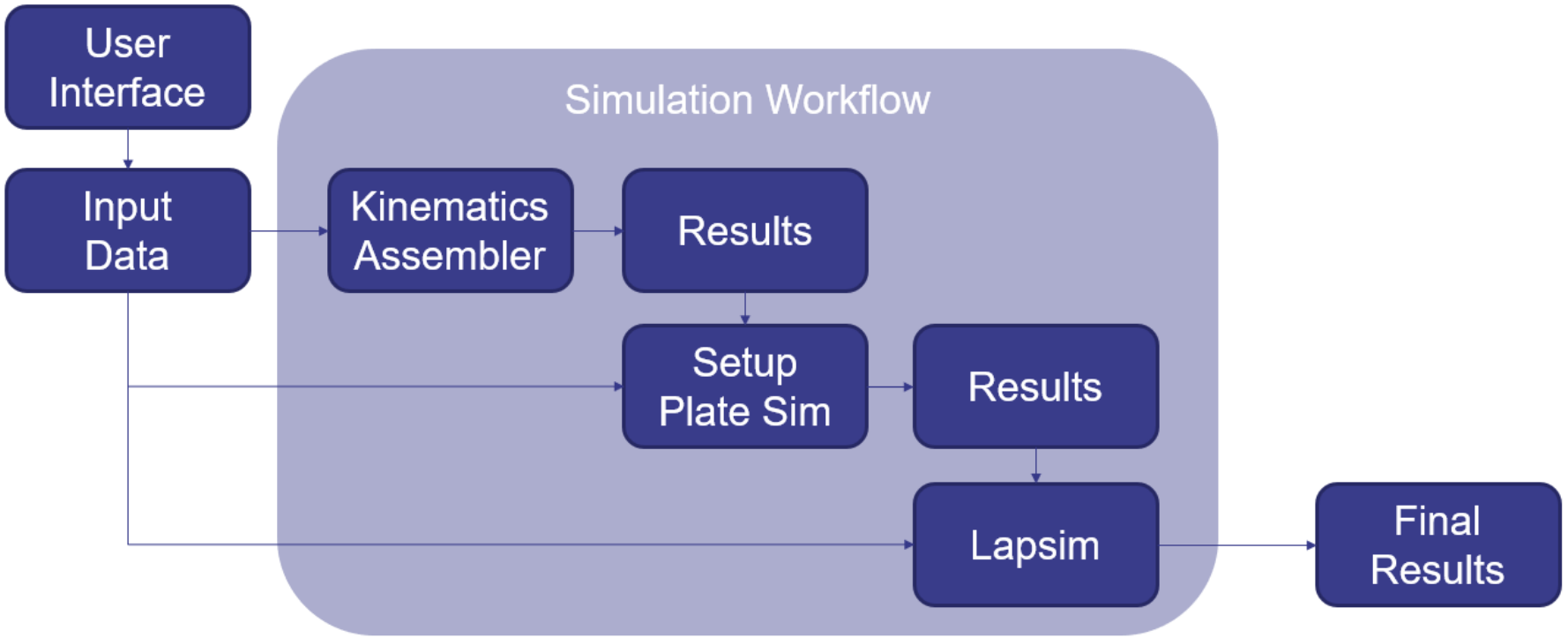
‘Body Fixed KnC’



‘Swept Sine 7P’

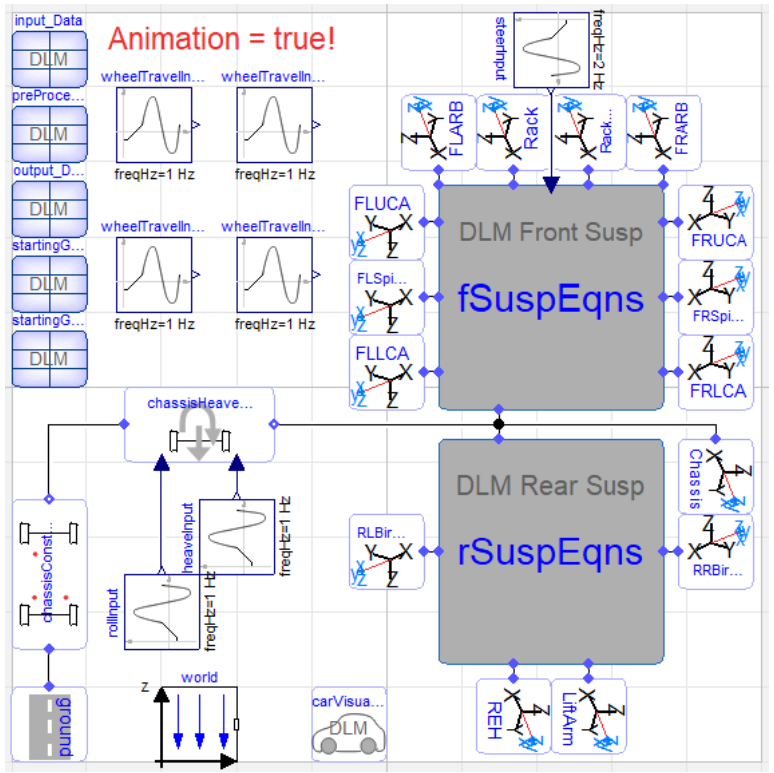
The Simulations - Workflow

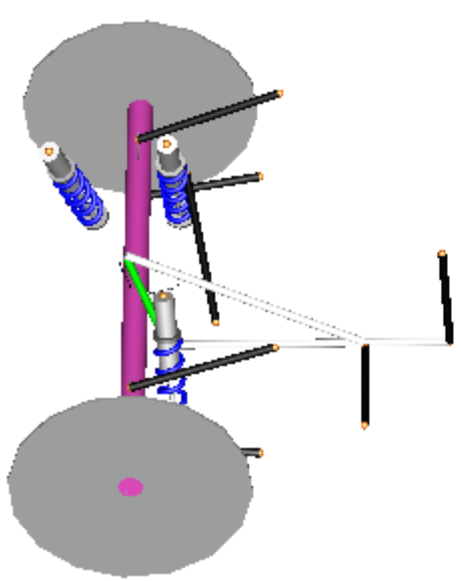
- Representative workflow for a racing application

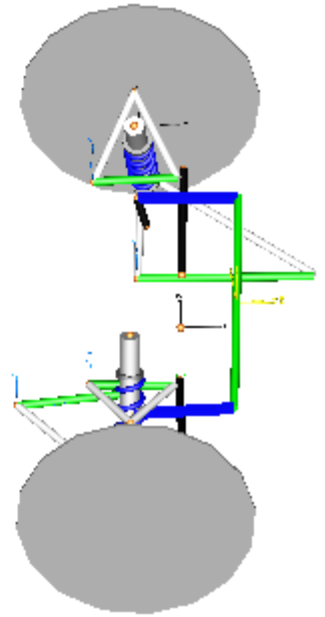


The Simulations - Kinematics Assembly

- Algebraic model to assemble components
  - Inputs in local part coordinates
  - Outputs in vehicle coordinates

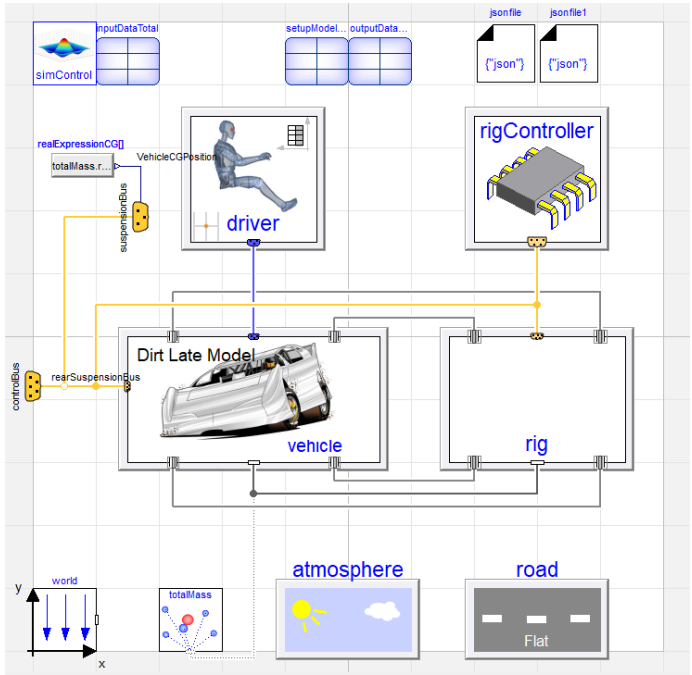


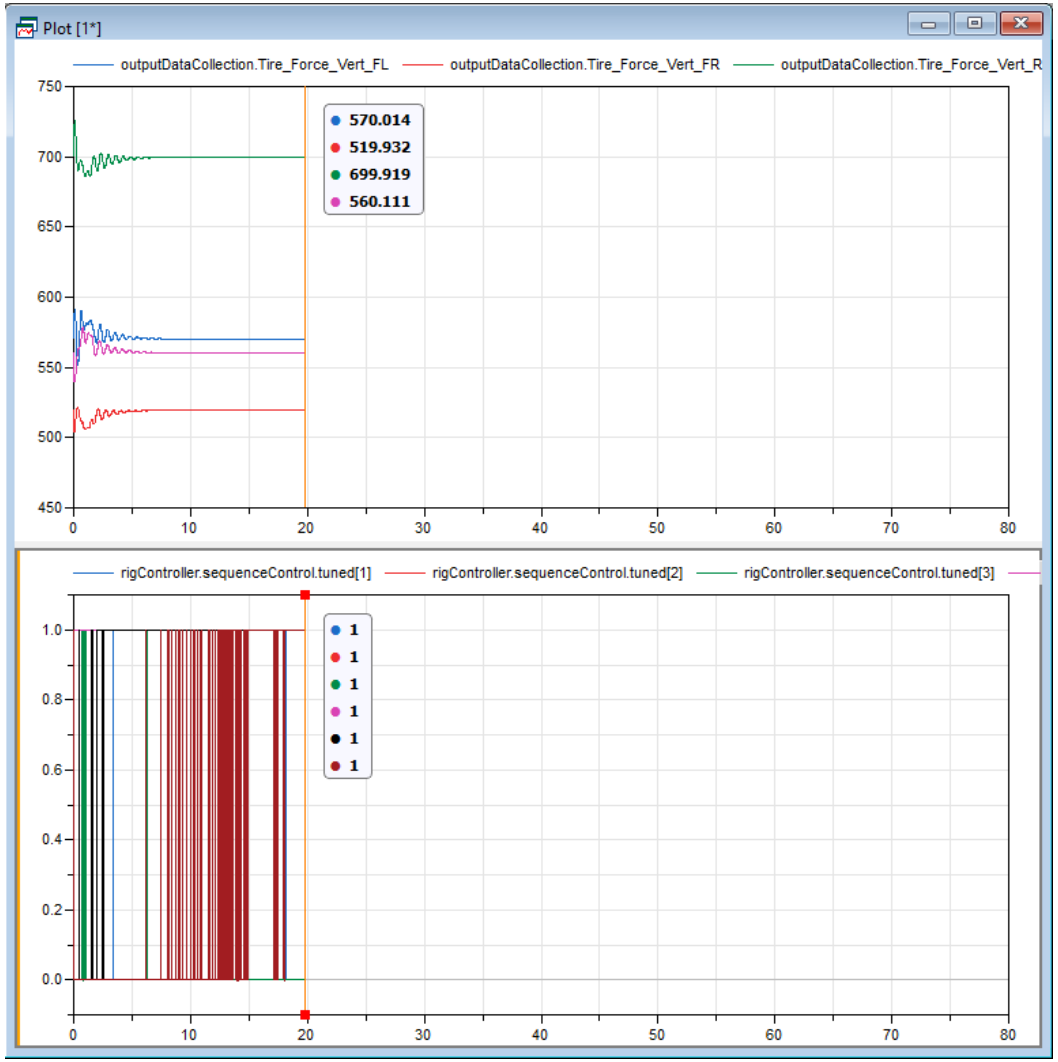




The Simulations - Setup Event

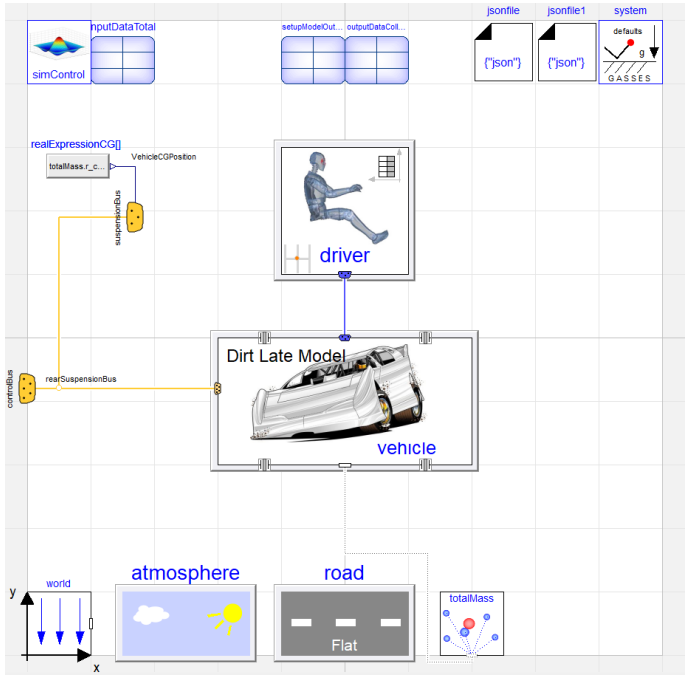
- Closed loop adjustment simulation
  - Adjusts camber shims (camber angles)
  - Adjusts tierod lengths (toe angles)
  - Adjusts body CG x and y position (front and ls weight %)
  - Adjusts spring preloads (ride height and cross weight)
  - Adjusts ARB droplink length (ARB preload)

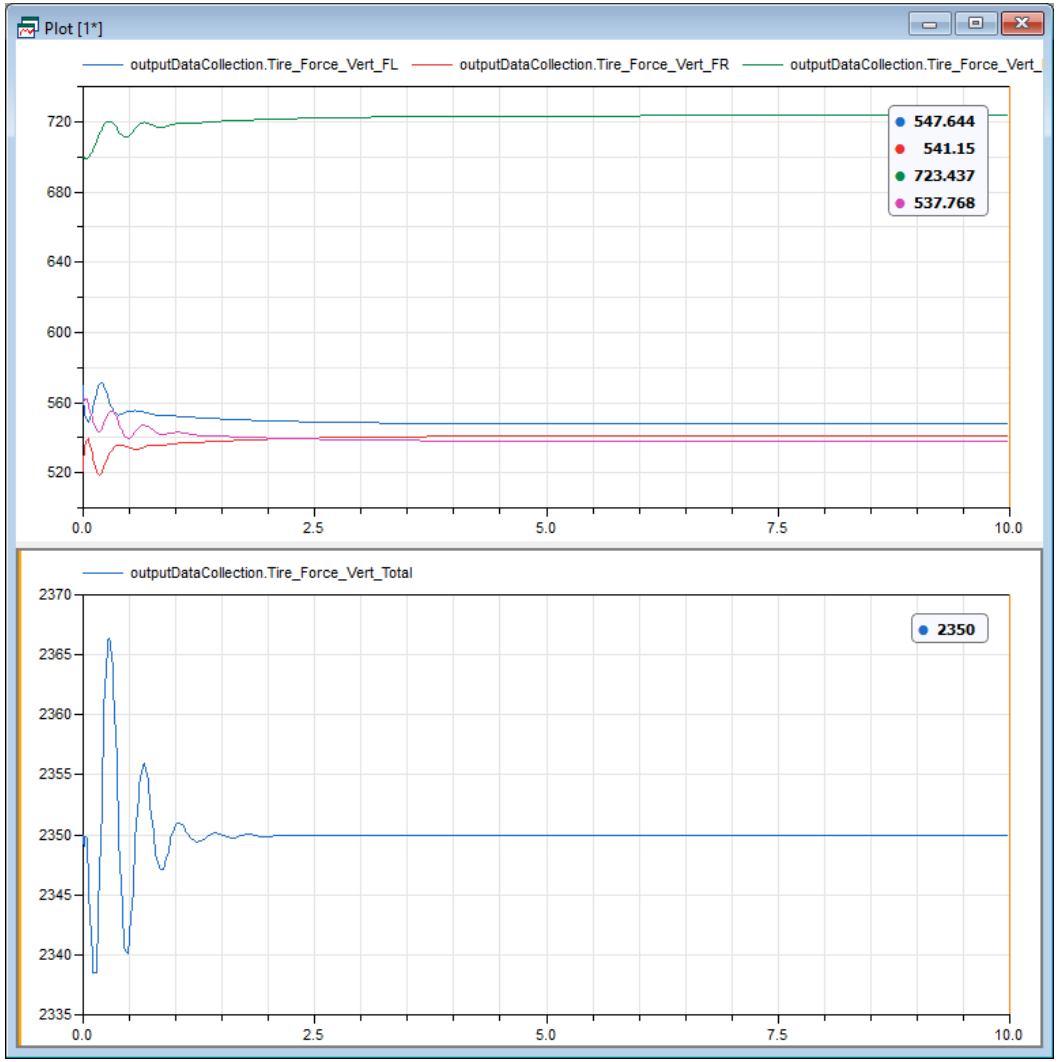




The Simulations - Mass Check

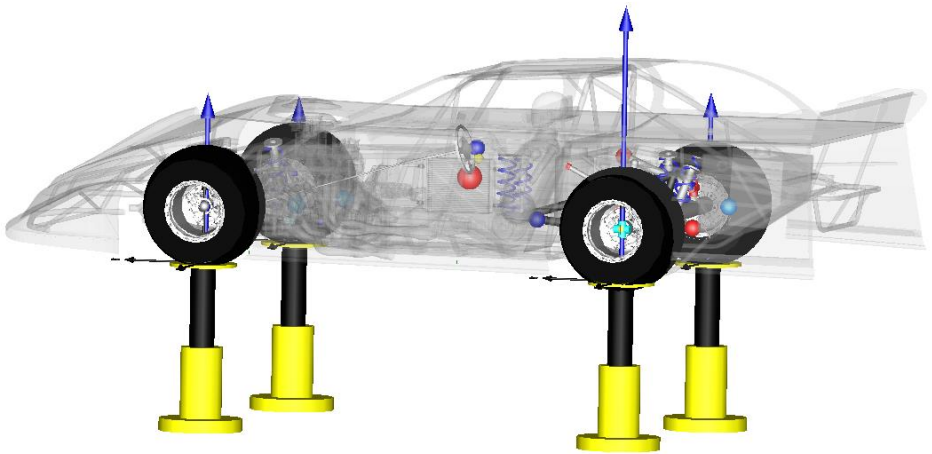
- Simple simulation to check the results of a Setup sim
  - If adjustments are properly applied to car it will remain static for the entire sim… if there are errors in transferring data across the car will oscillate
  - In this example, the car oscillates and settles with different wheel loads… indicating there is an issue

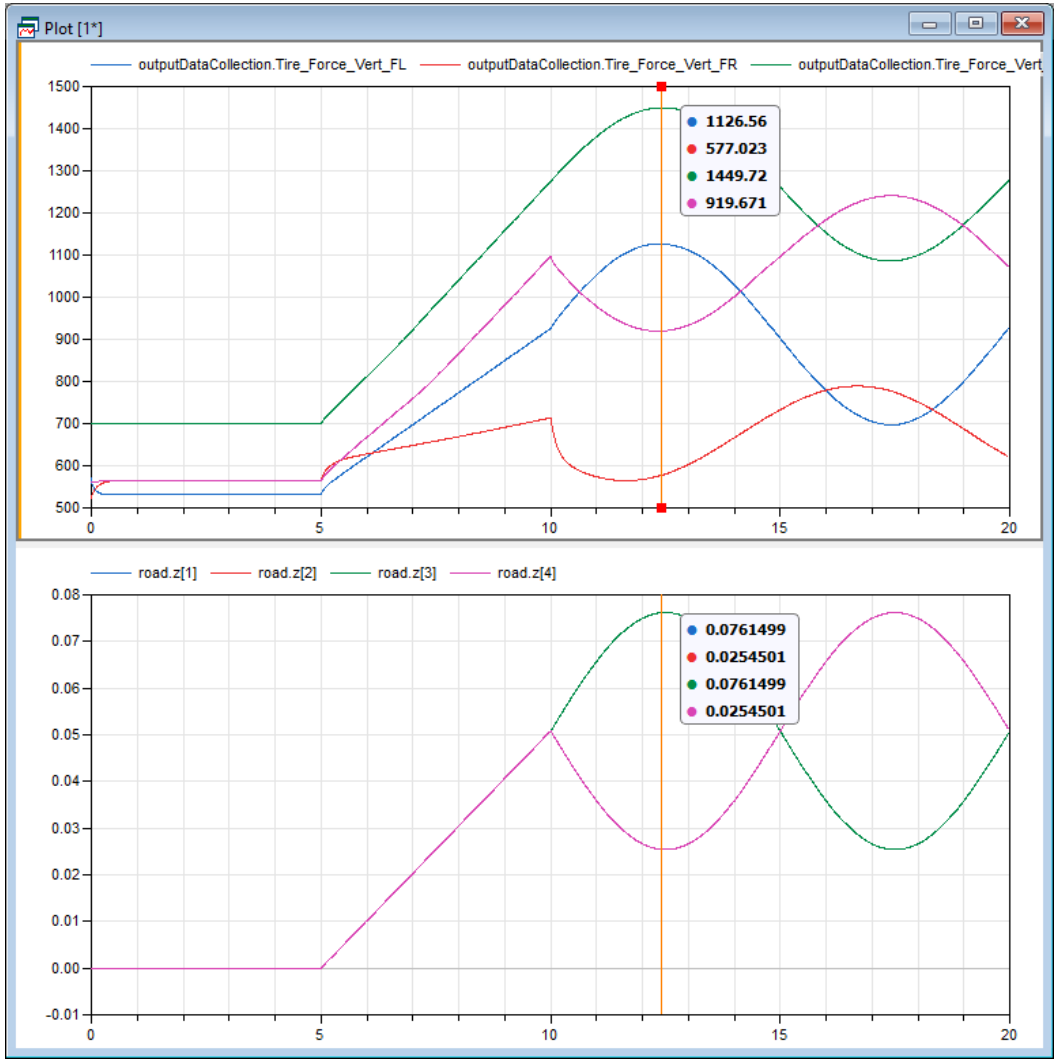




The Simulations - Pulldown Rig

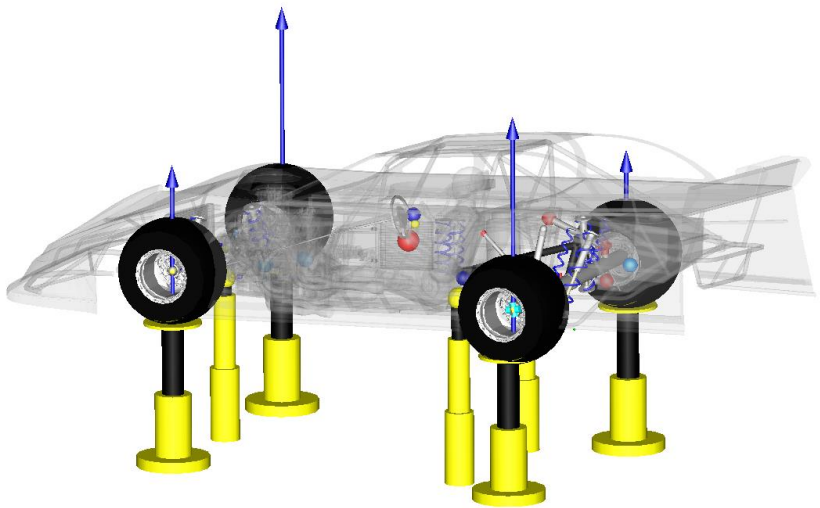
- Pulldown rig (‘pushup rig’)
  - General low frequency analysis
  - Wheel rates
  - Roll rates
  - Camber gain
  - Damper to wheel motion ratios

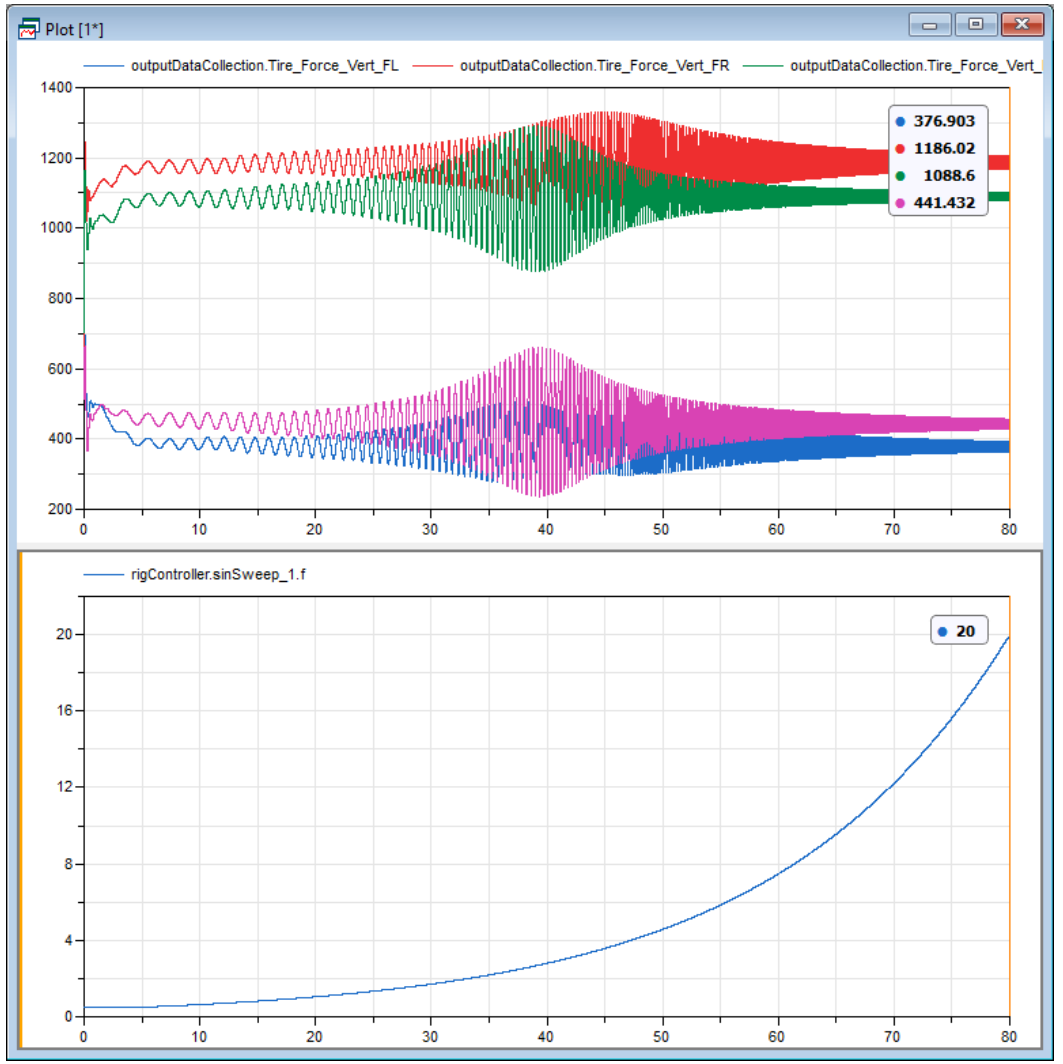




The Simulations - 7 Post Swept Sine

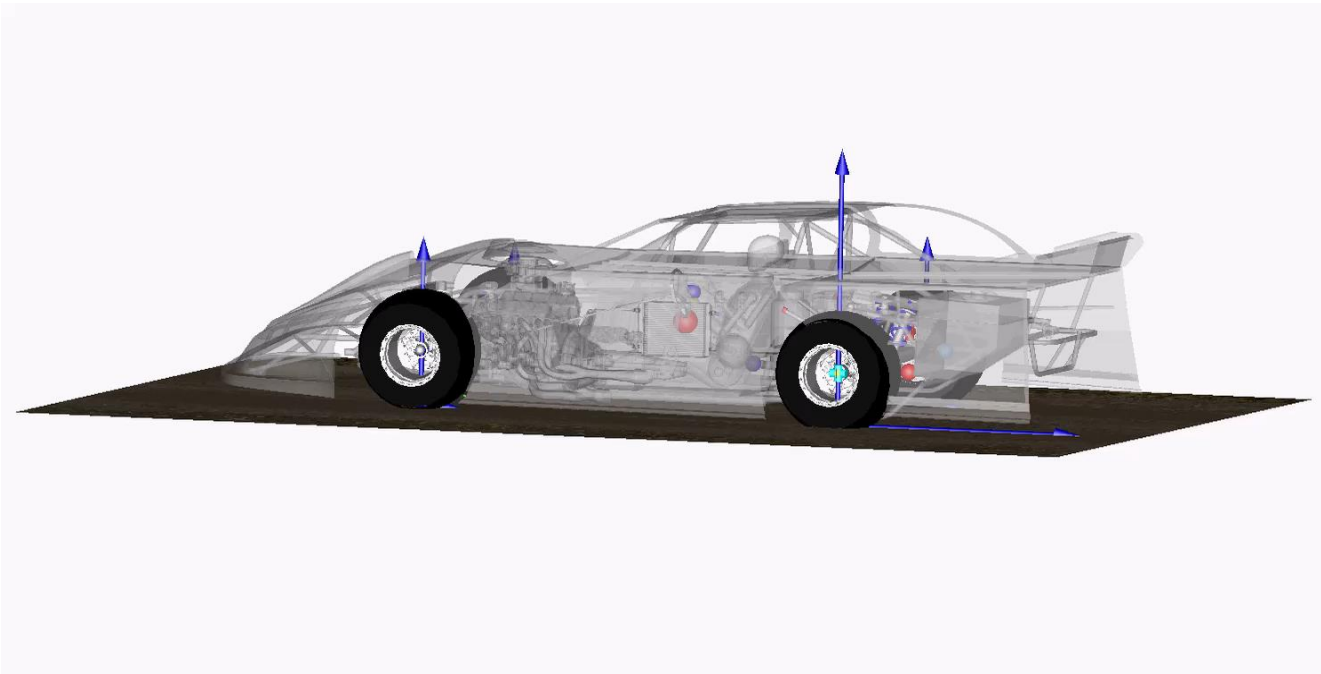
- Modal analysis on a 7 post rig
  - Extract Body modes
    - Heave
    - Pitch
    - Roll
    - Other?
- Tire vertical load variation
  - Optimize Damping

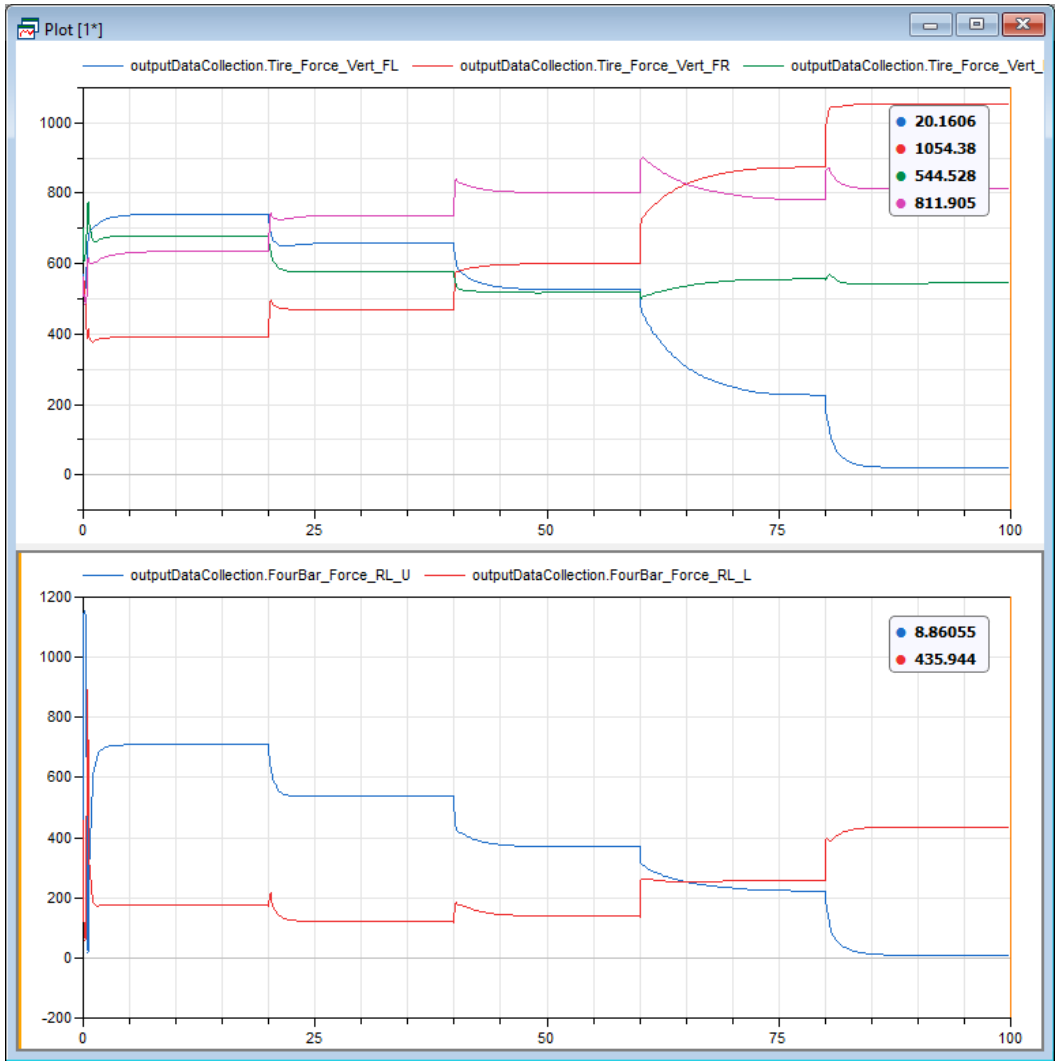




The Simulations - Quasi Static

- Single State target… divided up into 5 steps
  - Note that the upper ‘four bar’ load is approaching zero at this point on the track



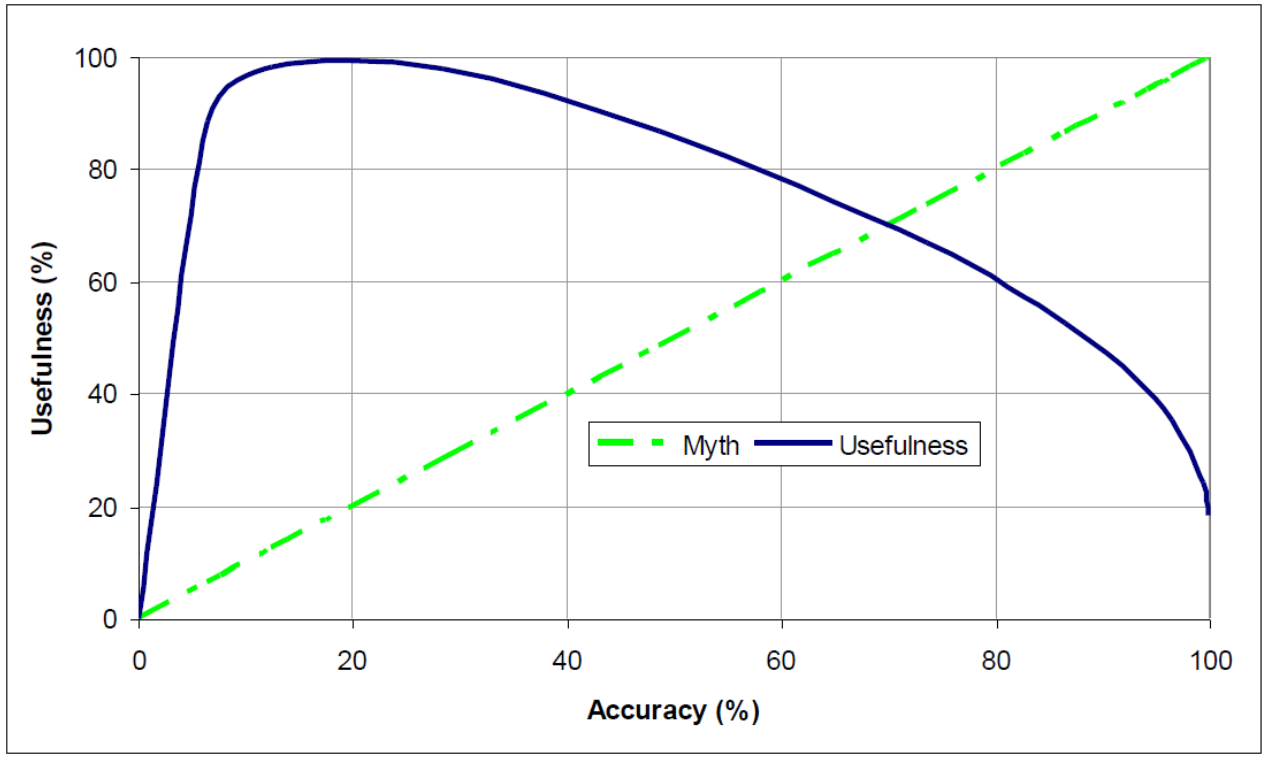


The Challenges

- Input data…
  - Reasonable spring and damper input data
  - Questionable accuracy on vehicle geometry
  - Questionable aerodynamic data
  - Questionable tire models
  - Questionable track geometry

The Challenges

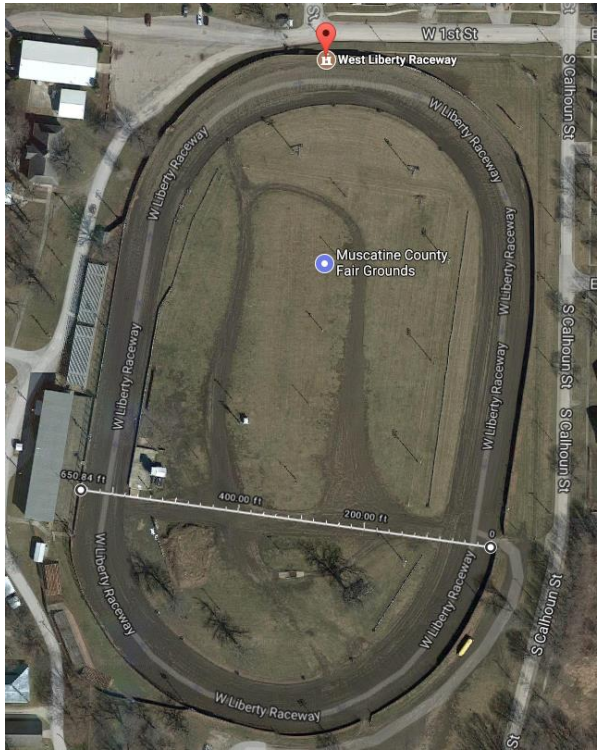
- Validation data is even more scarce
  - Geometric data
  - Low frequency data (Pulldown / K&C)
  - Higher frequency data (7P)
  - On-track data
- Alternative methods
  - iPhone logging of acceleration data has proven useful
  - GoPro video is often enlightening
- “Bad data is worse than no data”
  - I would argue that some insight is better than no insight



** Credit: Damian Harty’s 2017 NAMC Keynote Presentation

The Challenges - Validation Data

- West Liberty
  - ½ mile in length
  - 5 degree banking
  - Wide corners
  - Wide racing groove



- Fast time during qualifying: 18.73 seconds
- Winner slow lap in feature: 22 seconds

- 3 second falloff over the course of an event is common.

Entry	Imperial	SI
Speed	90 mph	40.2 m/s
Radius	425 ft	129.5 m
Lat Curvature	0.002353 1/ft	0.00772 1/m
Bank Angle	5 deg	5 deg
Lateral Accel	1.27 G	12.50 m/s^2
Longitudinal Accel	-0.2 G	-1.96 m/s^2
Vertical Accel	0 G	0.00 m/s^2

Mid Corner	Imperial	SI
Speed	85 mph	38.0 m/s
Radius	325 ft	99.1 m
Lat Curvature	0.003077 1/ft	0.010095 1/m
Bank Angle	5 deg	5 deg
Lateral Accel	1.49 G	14.58 m/s^2
Longitudinal Accel	0 G	0.00 m/s^2
Vertical Accel	0 G	0.00 m/s^2

Exit Corner	Imperial	SI
Speed	90 mph	40.2 m/s
Radius	425 ft	129.5 m
Lat Curvature	0.002353 1/ft	0.00772 1/m
Bank Angle	5 deg	5 deg
Lateral Accel	1.27 G	12.50 m/s^2
Longitudinal Accel	0.4 G	3.92 m/s^2
Vertical Accel	0 G	0.00 m/s^2

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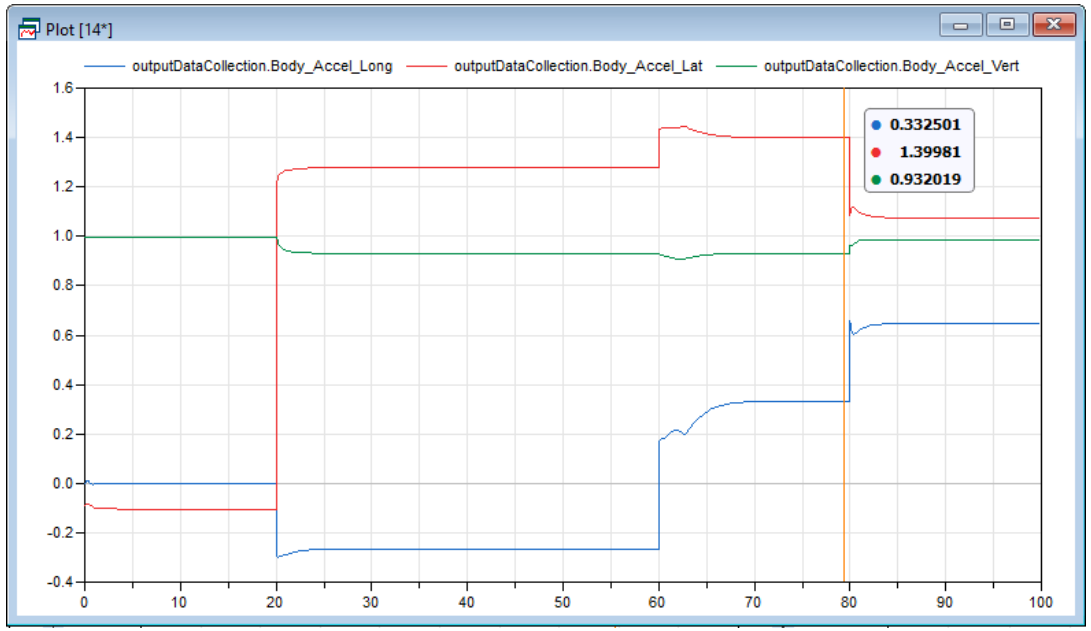
The Challenges - Validation Data

- Logged data vs ‘accelerometer’ reading in the simulation model



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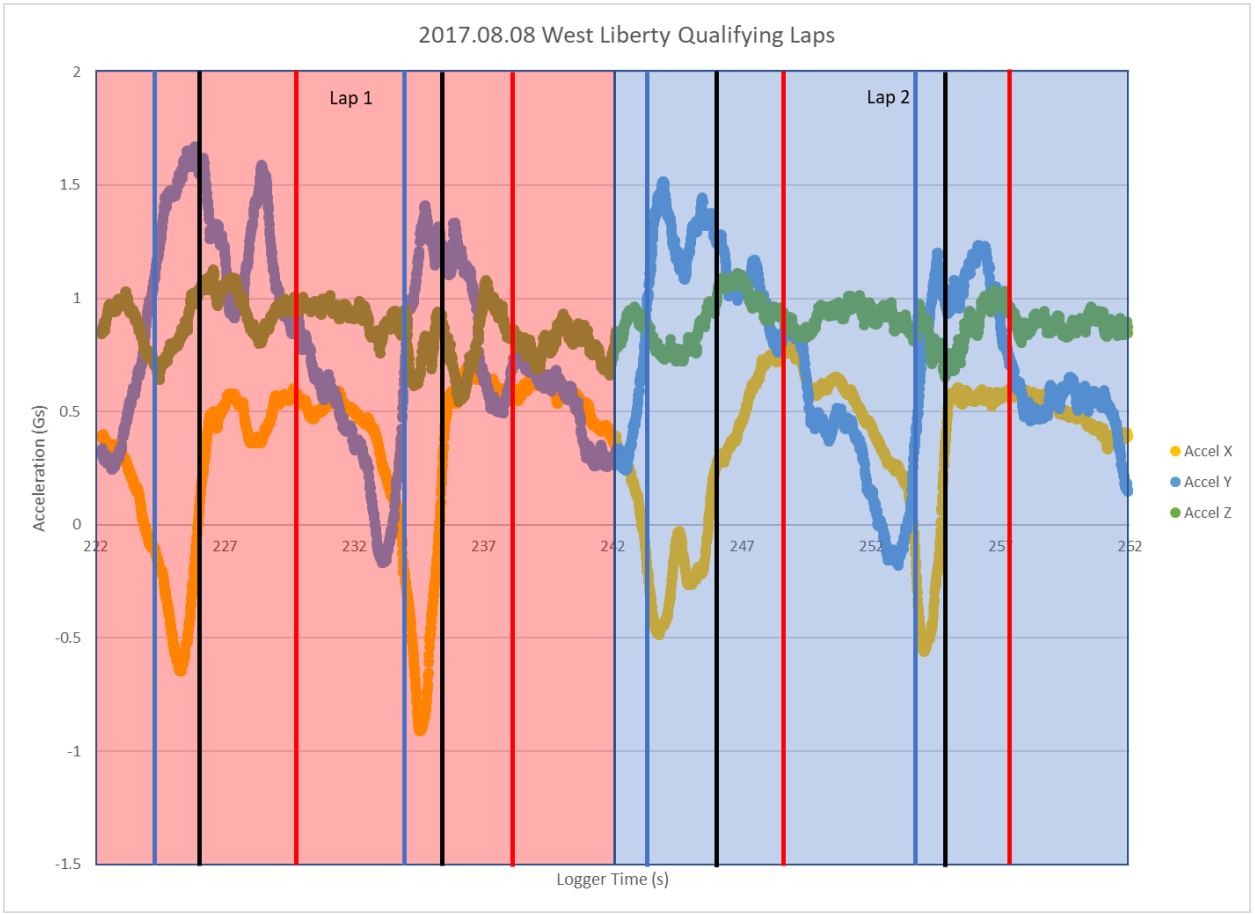
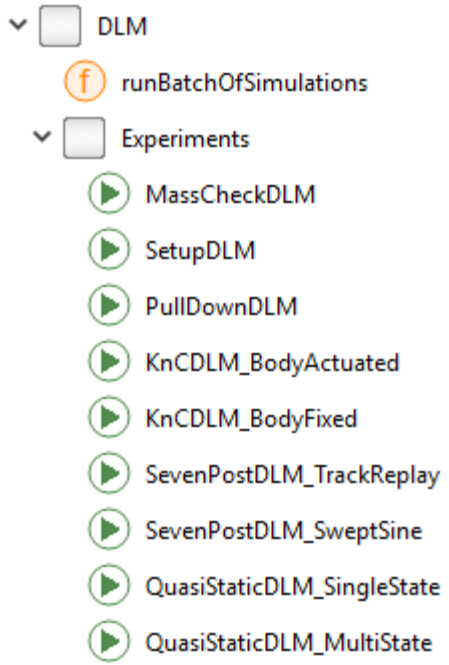
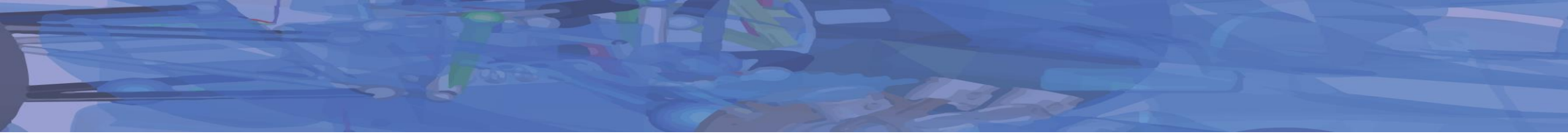


DLM Racing Simulations - Summary

- VeSyMA was used to construct a suite of dirt late model simulations with Dymola / Modelica
- This project demonstrates the power of Dymola / Modelica as well as the usefulness of VeSyMA
- An experienced Dymola user, utilizing VeSyMA can build a set of simulations like this efficiently
- Even though many assumptions were made, the resulting simulations were useful
- Are these simulations perfect? No.
- Are these simulations helpful? Absolutely.





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Questions / Thoughts / Comments?

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