Annex V – AU - ROAMS, A FAST RUNNING MOBILITY SIMULATOR UTILIZING GEOTIFF TERRAIN MAPS

Note: This Annex appears in its original format.

ROAMS, a Fast Running Mobility Simulator Utilizing **GeoTIFF Terrain Maps**

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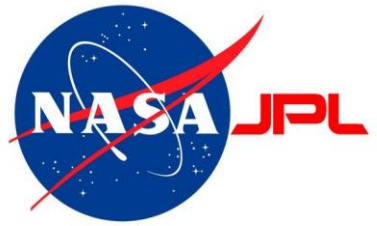
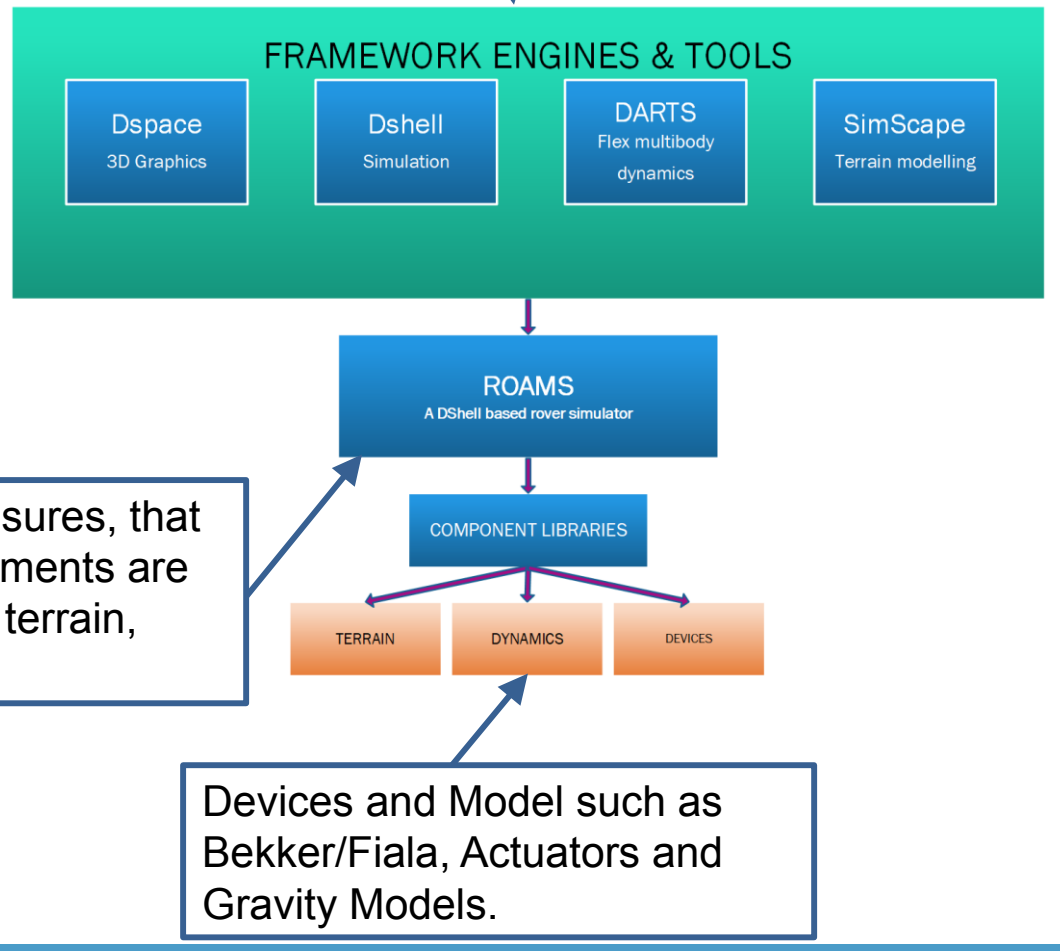


ROAMS

- Rover Analysis, Modeling and Simulation (ROAMS) is a Physics Based Simulation Tool for Simulations of Rovers
- Minimal Coordinate Formulation
- Recursive Algorithm Based on Spatial Operator Algebra
- Python for Vehicle Modeling
- C++ for Core Computations

High res ROAMS graphics of components

Sets up the Multibody Model, the Terrain, Graphics and Handles the Dynamics

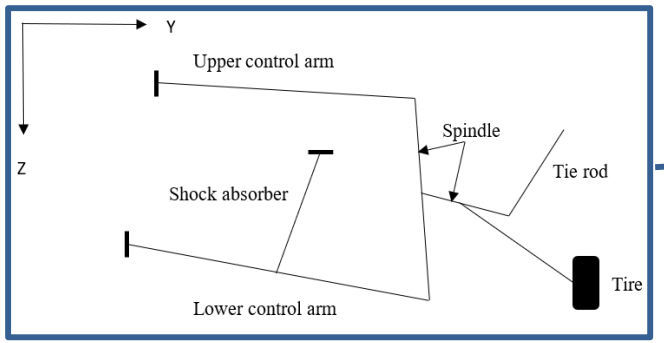


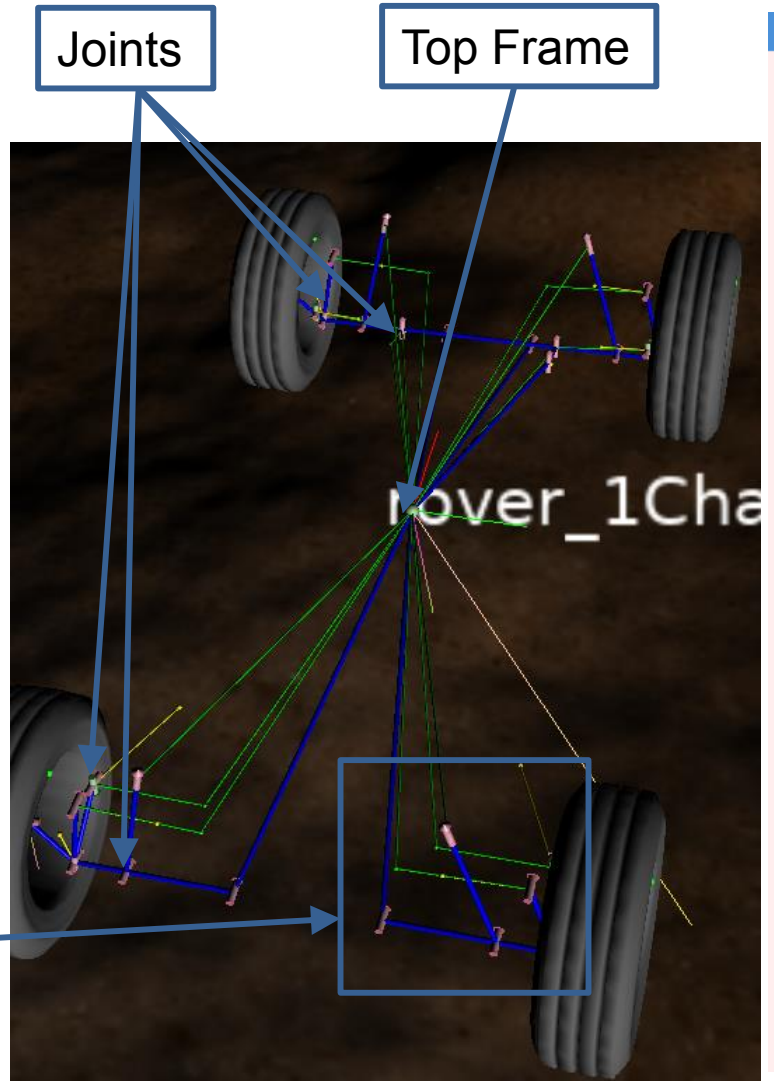
The Rover module ensures, that the simulation requirements are met (terramechanics, terrain, vehicle ect.)

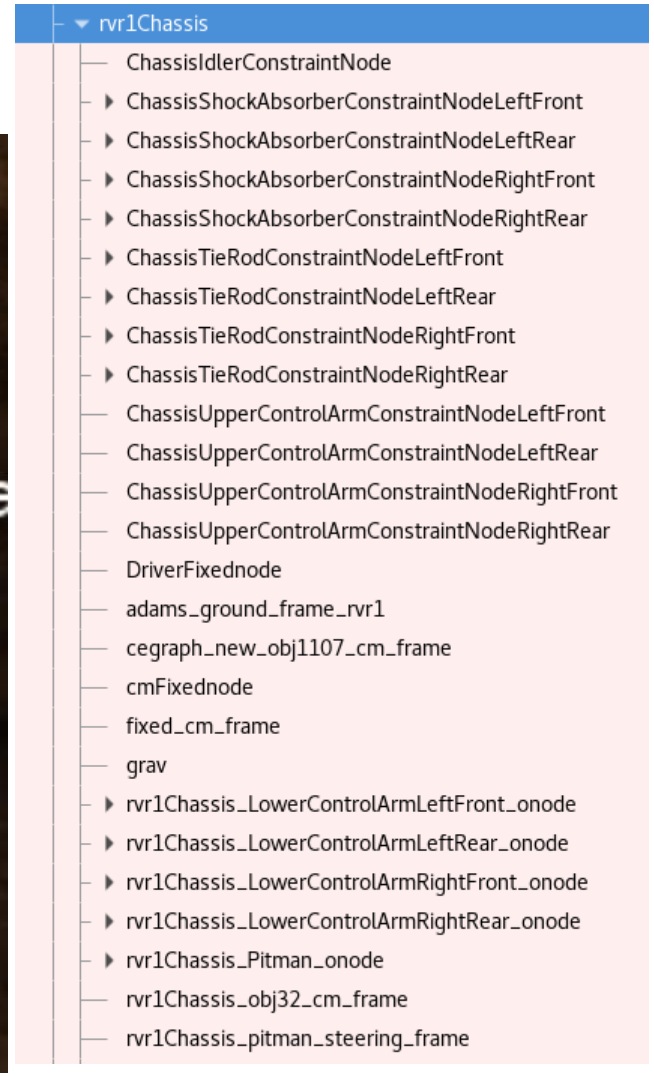
Devices and Model such as Bekker/Fiala, Actuators and Gravity Models.

Model

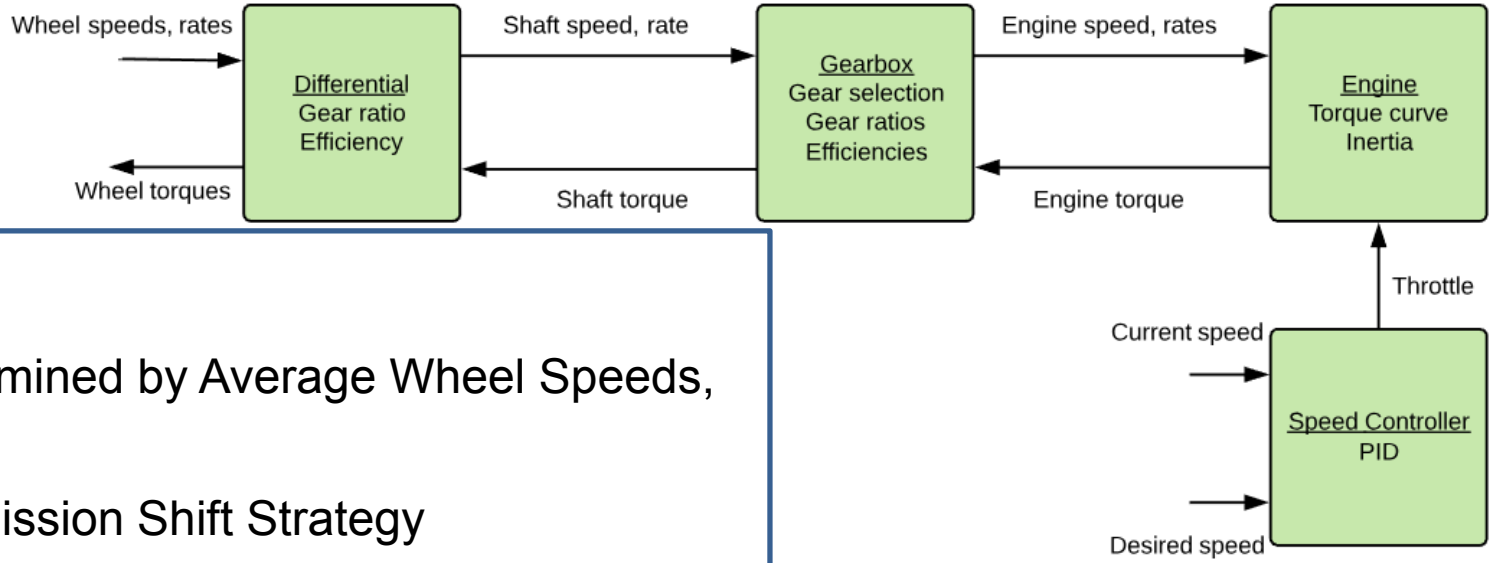
- Multibody System Treated as a Tree Topology System (Graph Theory)
- Top Frame of Tree: Chassis
- Top Assembly: FED vehicle
- Subassemblies: Suspension, Steering
- Drivetrain and Rollbar Implement Forces on System
  - Dynamics Included in Chassis



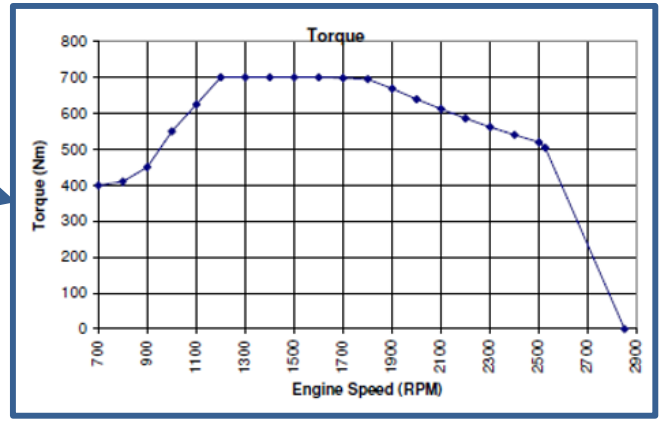




Drivetrain



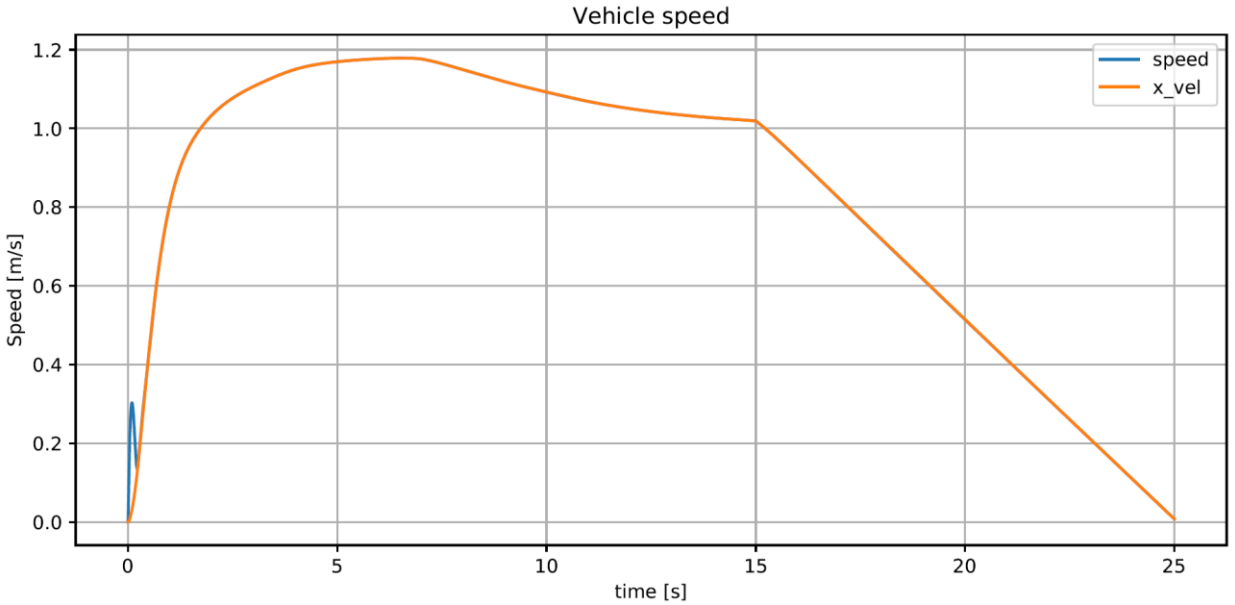
- Semi Kinematic Approach
- Gearbox Input Speed and Rate Determined by Average Wheel Speeds, Rates and Axle Gear Ratio
- Gearbox Gear Determined by Transmission Shift Strategy
- Engine Input Speed and Rate Determined by Gearbox Gear Ratio
- Engine Torque Curve Utilized to Determine Engine Torque
- Speed Controller Determines Throttle Level
- Inertia Accounted for by: $T_{EngineOut} = T_{FullThrottle}$*Throttle – J*α
- Gearbox Output Torque Determined by Gear Ratio and Efficiency
- Differential Output Torque Determined by Gear Ratio and Efficiency
- If Locked: Torques Scaled by Wheel Speeds

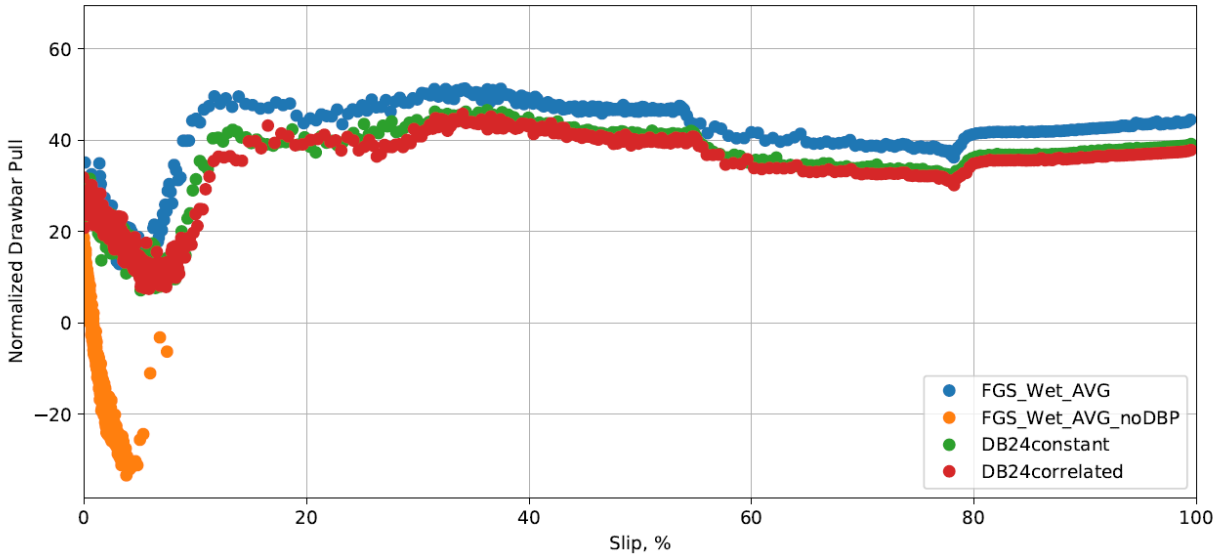


Drawbar Pull

- Throttle is a Number Between 0 and 0.9
- The Lowest Gear is Selected. Differential is Locked
- Initially, the Speed of the Tractor is 1 [m/s]
- Throttle is Ramped Up from 0 at a Rate of 0.06 [1/s]
- From 15 to 20s the Speed is Decreased

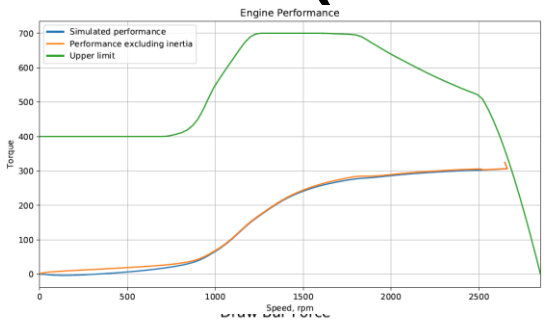
Video 2

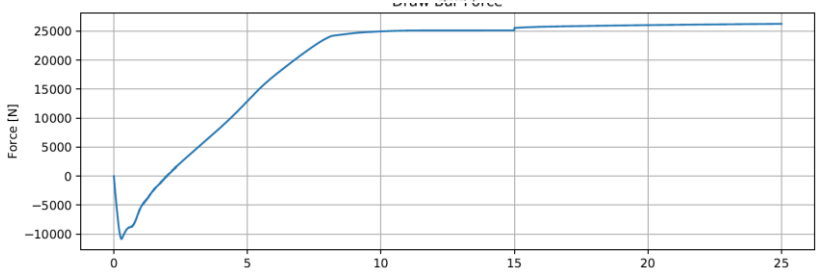


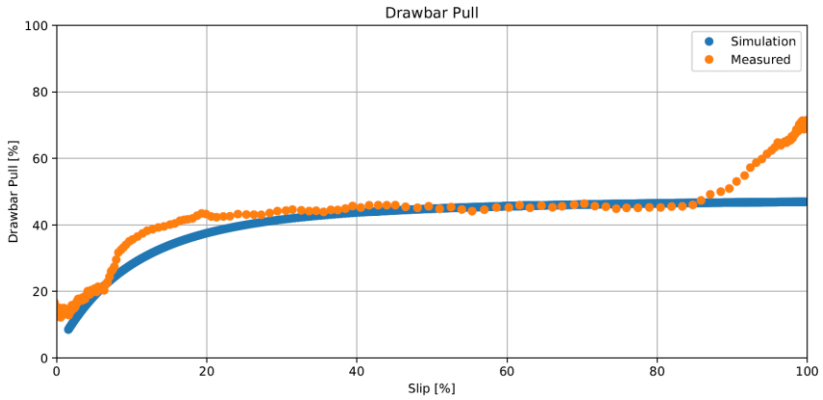


Compared to measurements (FGS)

- Simulation is Performed with Average Bekker-Wong Parameters
- Brake Applied at 15 sec to Achieve 100 % slip
- Inertia Effects are Accounted for in Both Test and Simulation
- TOP 2-2-604: Available power at the test vehicle is measured in as many gear combinations as possible from zero to full speed. Each speed is held long enough to obtain steady state conditions, i.e. both speed and drawbar pull are stabilized

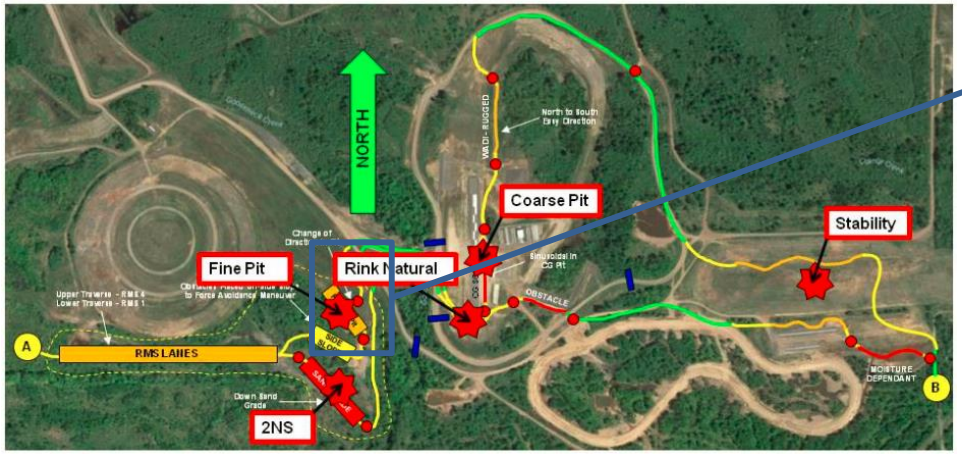


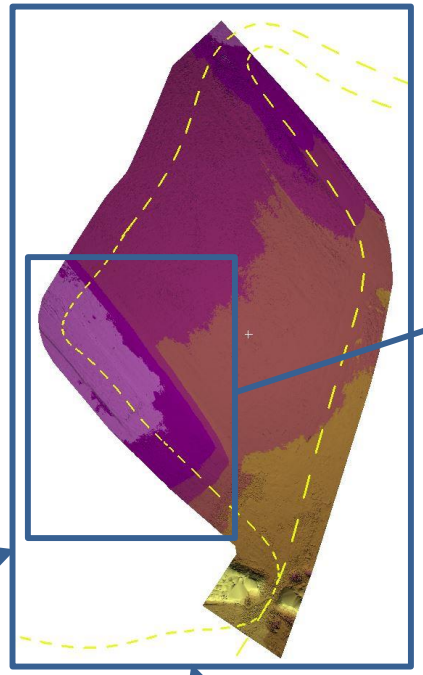


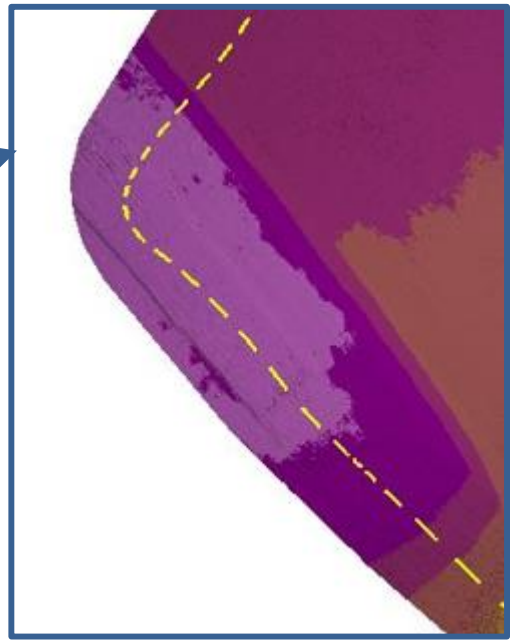


Traverse Y7

- Desired Speed vs Allowable Speed
- Both Hard Surface and Soft Soil
- Up Slope
- 90 Degree Turn



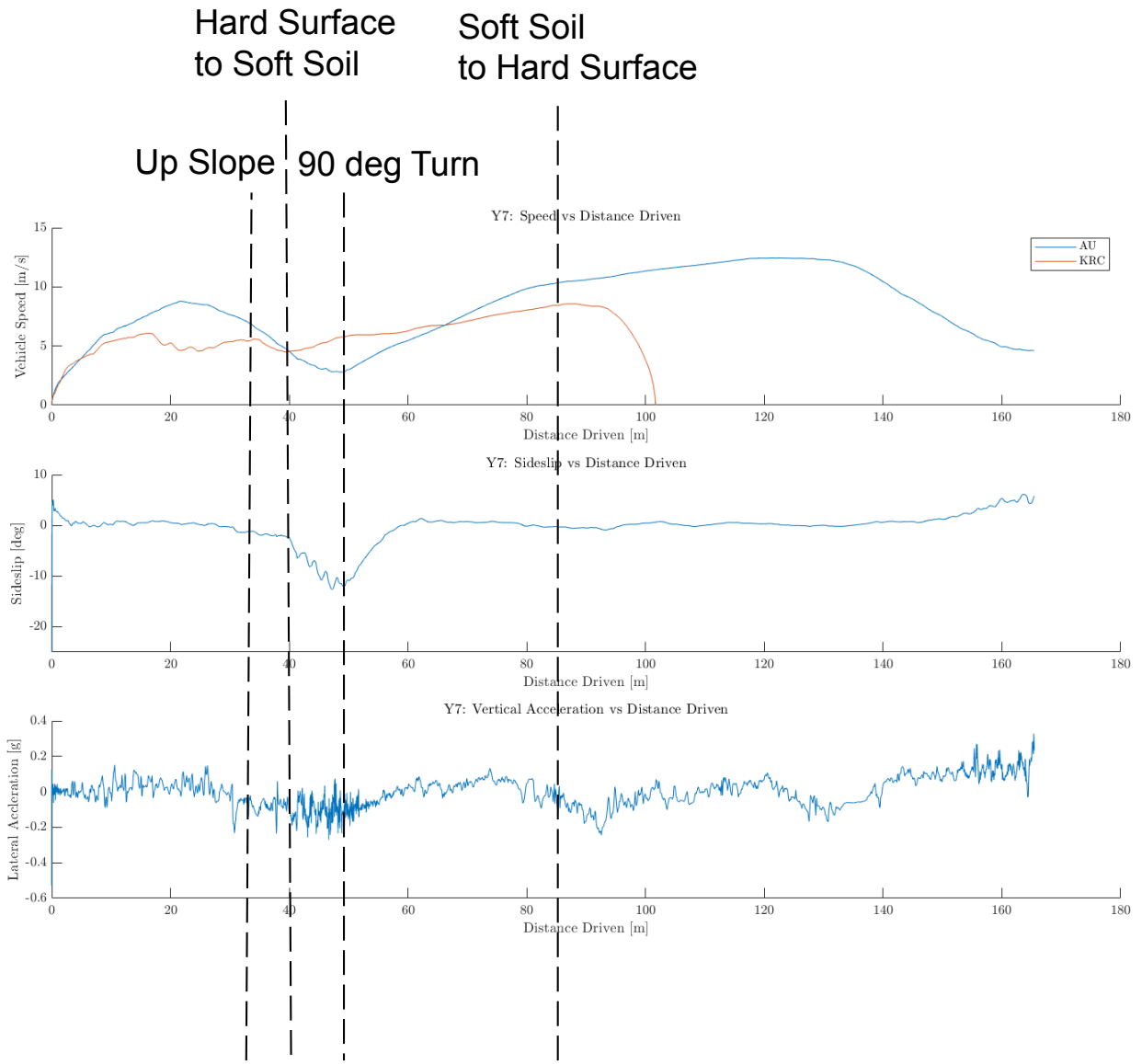




Traverse Y7

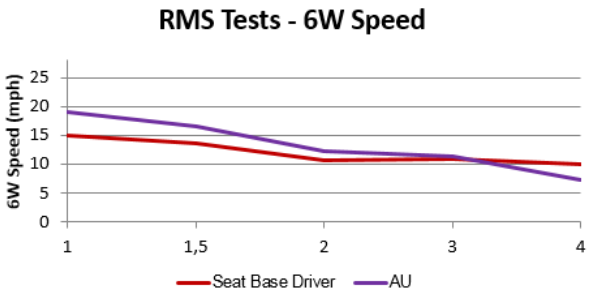
Video

- Change Soil Contact Type during Runtime
- Speed Limited by 90 deg Turn
- …



Traverse Y8

- Desired Speed vs Allowable Speed
- RMS
- Side Slope
- Obstacle Avoidance on Side Slope
- Hard Surface



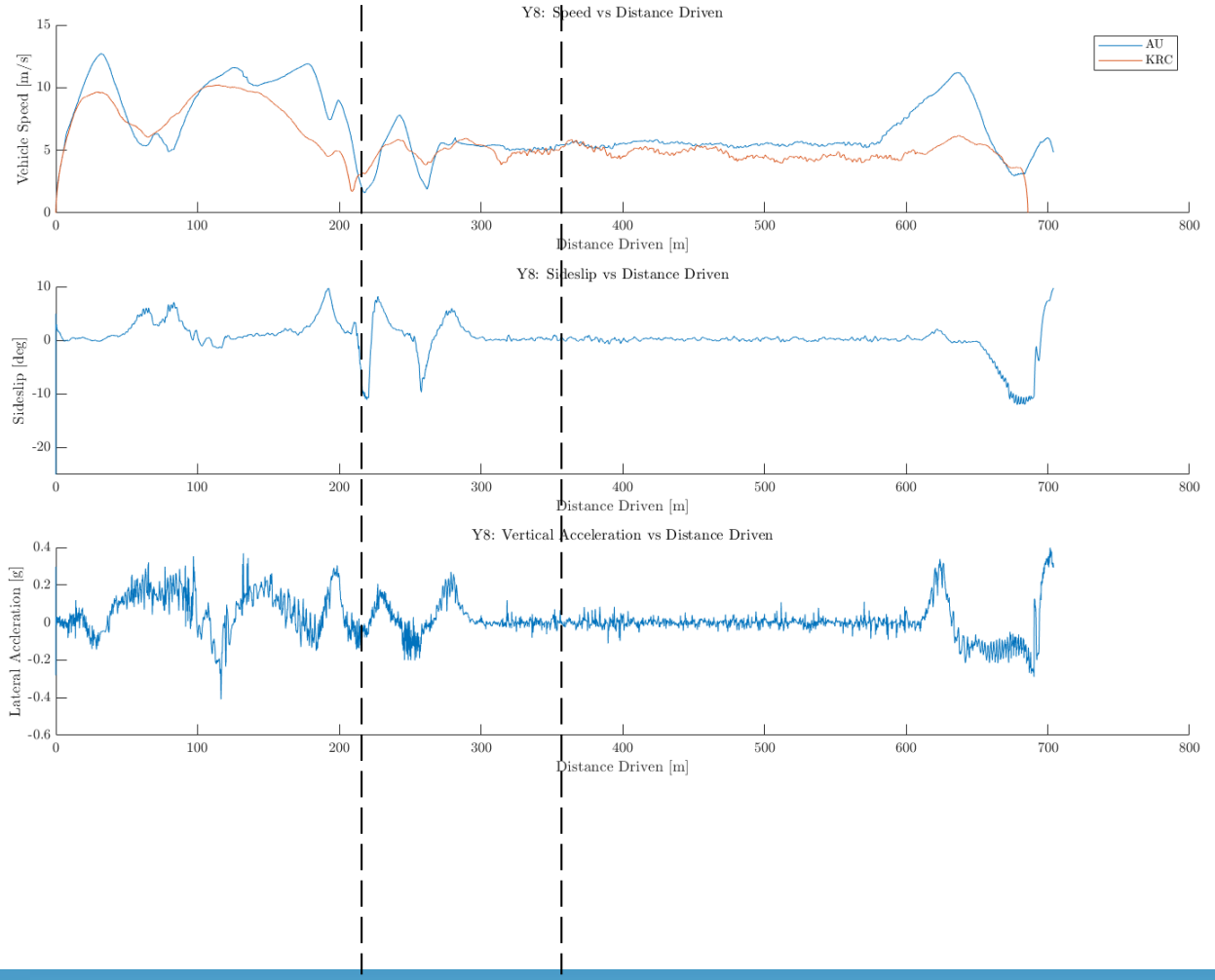
Traverse Y8

Video

- At RMS: Limited by 6 W Speed
- At Side Slope Obstacle Avoidance: Large Slip
- …

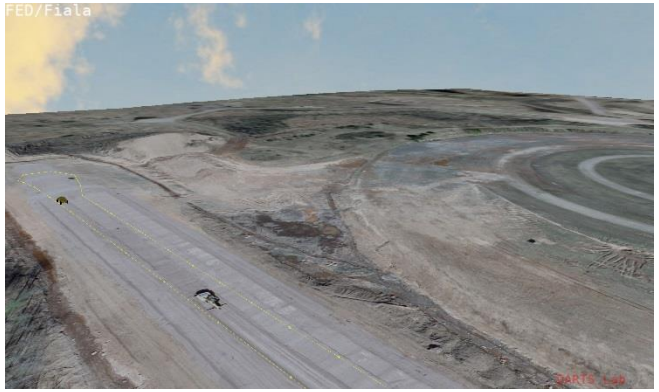
Side Slope Avoidance

RMS 2.0



Traverse

- Load in High Resolution Area of Operation
- Load in High Resolution Texture
- Drive on Area of Operation
- New Soil Type Does Not Require Stop in Simulation
- Realtime Simulation Demonstration
- Terrain Based on Geotiff



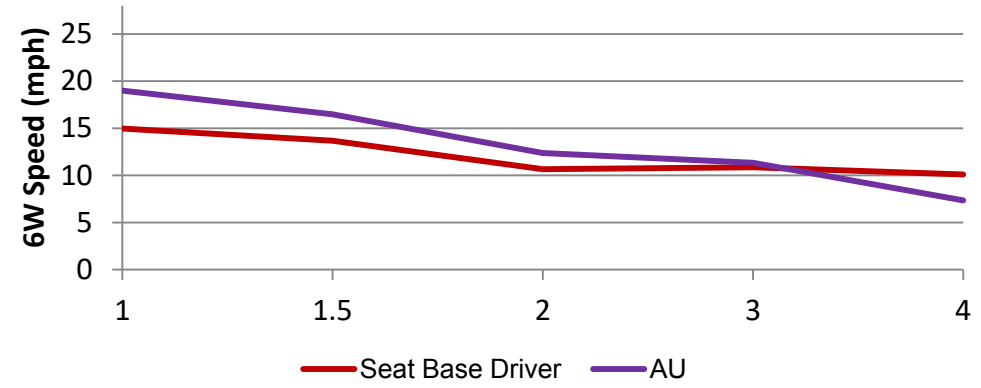
Video

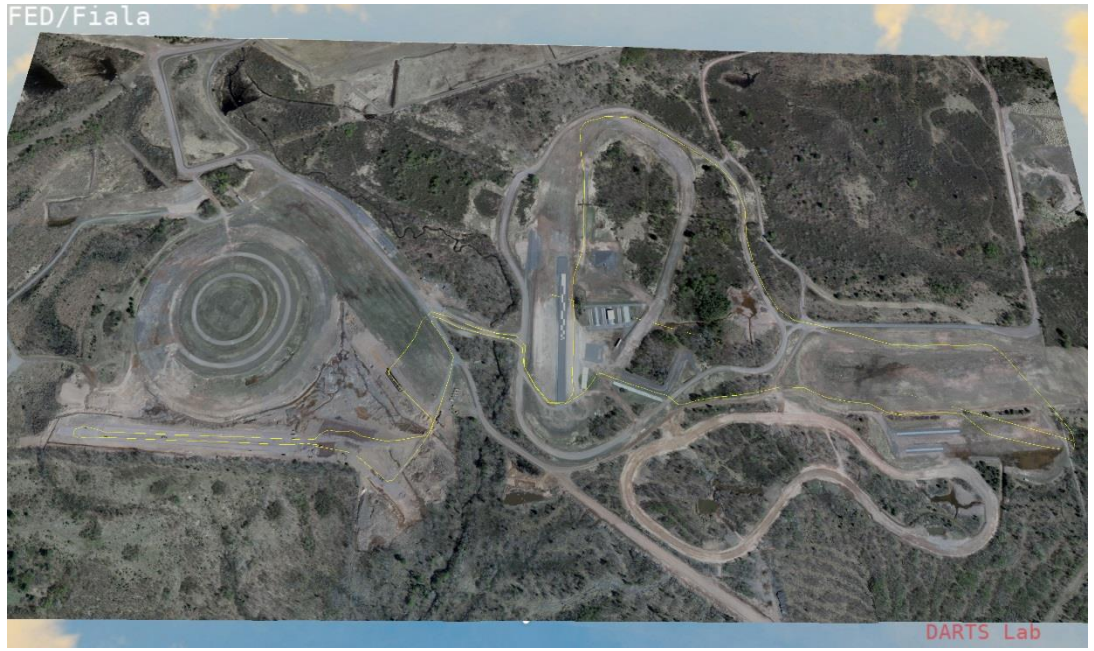
Plot/video/figure

Closing comments

- Improvements:
- Suspension
  - Shock Absorber
- …

- Strengths:
- Terrain
  - Large Data Sets
  - Drive on Entire Area of Operation
  - Change Soil Properties During Runtime
  - Change Soil Contact Type During Runtime
  - Fast Computational Time





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