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CarSim 2021.0 New Features

This document lists notable new features in CarSim version 2021.0.

VS Solver: Architecture

Improvements were made in the handling of VS Commands.

1. Parsing of VS Commands has been extended and reworked to provide more informative error messages, and to provide a foundation for more for more user-defined features.
2. The expression evaluator and calculator for the VS Commands has been re-written to improve performance.
3. The `DEFINE_VARIABLE` command has been extended to support the creation of new single-index arrays, e.g.,

   ```
   DEFINE_VARIABLE MY_ARRAY(10)
   ```

VS Solver: Models

Improvements were made in the CarSim Math Model.

Kingpin Rotation Angle Calculation

For suspensions which use a fixed kingpin axis and have steer angles defined in vehicle coordinates, the VS Math Model converts the steer kinematics from the suspension/steering tables into an equivalent rotation about the inclined kingpin axis. This kingpin rotation angle is then used as a constraint in the multibody suspension model.

This calculation was replaced beginning in version 2021.0 with a more efficient version that does not rely on iteration. Consequently, the model will no longer fail during the run with the error message, *"…there was a problem in kp_constraint: could not calculate the kingpin steer angle…*". Error handling for the new calculation method occurs at initialization, by checking the total inclination of the kingpin axis with respect to vertical and making sure it does not exceed 45 degrees.

The new calculation method produces slight differences in simulation results, but these are attributable to the accuracy of the new calculation compared to the previous iterative calculation, which would produce results only as accurate as its solution tolerance allowed.

Steering System Inertia Improvements

Beginning in version 2021.0, the VS Math Model can automatically calculate a suspension contribution term to the steering rotational inertia and add it to the user-provided steering system inertia value. This feature is enabled based on the setting of the parameter `OPT_I_GEAR_IN`:

- `OPT_I_GEAR_IN = 0`. The suspension contribution to steering system inertia is not calculated automatically. The user-provided value of `I_GEAR_IN` is used as-is. The user must calculate the suspension contribution themselves and include it in the specified `I_GEAR_IN`; alternatively, the user may decide to neglect the suspension contribution.
- `OPT_I_GEAR_IN = 1`. The kingpin geometry, steered unsprung mass and inertias, linkage kinematics, and steering gear kinematics are used to calculate an inertia term which represents the rotation of the steered unsprung masses around the left and right kingpin axes. This term is referenced to the steering gear input rotation and is added to the user-provided `I_GEAR_IN` value. In other words, the user-provided value is the steering system inertia not including the effect of the unsprung masses rotating about the kingpins. The total steering system inertia, consisting of the user-provided value plus the calculated value from the suspension, is output with the output variable `IstrGear`. It is, in general, not constant, due to the nonlinear kinematics; the Echo file value corresponds to the value at the time the Echo file was written.

Versions of the VS Math Model prior to 2021.0 are equivalent to setting `OPT_I_GEAR_IN` to 0 and neglecting the suspension contribution to the system inertia. Consequently, turning the suspension contribution on will cause differences in simulation results. This may require re-assessing and suitably adjusting steering system data such as damping and assist-force time constant.

The OPT_I_GEAR_IN option is supported in the GUI with a new checkbox on the **Steering System** screen.

Virtual Steering Axis Inertial Effects

The CarSim virtual steering axis front suspension, introduced in CarSim 2020.1, has been updated to include more detailed inertial effects.

First, the steering system now shares the steering rack acceleration with the multibody suspension system, allowing the suspension kinematics tables to constrain the unsprung masses in the multibody model more accurately. The steering rack acceleration calculated by the steering system is output with the new output variable Ay_Rack1. Consequently, users wishing to replace the steering rack with an external model will now need to provide the rack travel acceleration with the new import variable IMP_RACK_TRAVEL_ACCEL_1.

Second, the multibody suspension system for the virtual steering axis now provides an inertia to the steering system. In particular, the inertia from the unsprung masses is referenced to the pinion rotation and added to the steering system inertia (I_GEAR_IN) to result in a new total steering system inertia, which is output with the new output variable IstrGear. The contribution from the suspension is, in general, not constant, due to the changing position and orientation of the wheel. Unlike the independent suspension and solid axle effect described above, this effect is always on; that is, OPT_I_GEAR_IN = 1 always for the virtual steering axis. This is primarily because the equivalent inertia term from the virtual steering axis suspension is a complicated expression based on the nonlinear 2D kinematics tables. Calculating the suspension contribution on your own and including it is much more practical for the systems with conventional kingpin axes.

The improvements to the virtual steering axis model for CarSim 2021.0 have two consequences:

1. The same data will produce different simulation results. This partly due to the steering system sending rack acceleration to the multibody suspension system, and partly due to the suspension sending inertia to the steering system.
2. Virtual steering axis datasets from the first version, CarSim 2020.1, may need to be updated. Some parameters to consider re-assessing are the rack damping, D_RACK, as well as the rack assist force time constant, TC_BOOST. In the case of Mechanical Simulation's example vehicles, the *B-Class Sports (VSA)*, and the *D-Class Sedan (VSA)*, we adjusted the rack damping coefficient to produce a similar damping ratio, given the increase in inertia. Before this adjustment, the steering systems seemed underdamped, and tended to oscillate. Greatly reducing the first order delay in the rack assist force (TC_BOOST) also reduced the tendency to oscillate.

Battery-Electric and Hybrid-Electric Powertrain Enhancement

The battery-electric and hybrid-electric powertrain model now supports multiple electric motors to allow one motor for every driving wheel. Two options are added to specify either one or two electric motors on each drive axle. An electric motor locates at the center of a conventional mechanical differential for one-motor case, while an electric motor is directly connected on each side of wheel for two-motor case. For example, a four-wheel (2-axle) passenger car can have one motor on the front axle and two motors on the rear axle.

The drive torque reaction for two-motor case can be selected to be either the wheel or the sprung mass. For an in-wheel motor, the drive torque reaction can be set to the wheel. The torque distribution between the front and rear, and between left and right motors can be set by a user parameter or external command through Simulink, VS Commands, etc.

All electric motors are involved in the battery state-of-charge calculation. Also, the electric motor(s) on the drive axle and differential clutch (LSD) can be used simultaneously.

Miscellaneous

1. Steering stops that were previously available only in torque-steer mode are now functional in angle control. Added output variables for steering stop torque (analogous to jounce and rebound stops)
2. A new import variable, `IMP_AT_CLUTCH`, has been added to control the automatic transmission lock up clutch. Previously, the clutch could only be controlled by table (`LOCK_AT_TABLE`) or by manipulating the clutch capacity on the fly (`IMP_M_LOCKUP_CLUTCH_CAP`).
3. The built-in electronic stability control has been extended to support multiple vehicles running within a single simulation. (This feature was mentioned in error in the 2020.1 release notes, as described in the 2021.0 backwards compatibility document.)
4. The built-in hybrid and electric vehicle powertrain model has been extended to support multiple vehicles running within a single simulation.
5. The VS Math Model will write a warning in the log file if it detects potential issues with the straight-line distance approximation of station that is used for X-Y spline segments.
6. The command `DEFINE_SUSP_X_DOF` that is used to add a longitudinal degree of freedom (DOF) to an independent/generic suspension was limited to axles 1 and 2 in 2020.1. It may now be used for independent/generic suspensions for axles 1-16, including simulations with multiple vehicles.

VS Browser: Graphic User Interface (GUI)

Procedures Screen

The Procedures screen was simplified slightly by replacing a set of four initialization-related checkboxes with a single one. As a result of changes in the past few years in the architecture of VS Math Models, the options to start the vehicle in approximate equilibrium (with the parameter `OPT_INIT_CONFIG` = 1) and with the wheel and powertrain spin rates synchronized to the vehicle speed (`OPT_INIT_SPEED` = 1) are always recommended when staring a simulation. Checkboxes to turn off these options were removed.

The remaining option, to locate the vehicle using Path station (`OPT_INIT_PATH`) is still an option that can be disabled if the user wishes to locate the vehicle by setting X, Y, and Yaw values directly.

Tire (External) Screen

On the Tire (External) screen, a new drop-down menu for the **Temperature mode** (with root keyword `DELFT_TYRE_TVM`) has been added under **Siemens MF-Tyre/MF-Swift v2020.2** tire model. The detail of setting is described in the separate Tire Models document.

Powertrain: Front and Rear Differential Screens

On the Powertrain: Front and Rear Differential screens, a new drop-down menu is added to select one of three cases: **Not electric**, **One electric motor on center**, and **Two electric motors, one on each side**. The new screen layout enables to set the electric motor(s) and differential clutch (LSD) simultaneously. The detail of setting is described in the separate Powertrain System document.

Powertrain: Transfer Case Screen

On the Powertrain: Transfer Case screen, a new drop-down menu is added to select one of three cases: **Mechanical**, **Electro-mechanical (hybrid)**, and **Full electrical**. The new screen layout enables to set mechanical and/or electrical torque distribution to rear axle. The detail of setting is described in the separate Powertrain System document.

Other Tools: Stacks

RT Platforms

From version 2021.0 CarSim supports new Real-Time system: Linux-RT (from dSPACE release 2020B) on dSPACE SCALEXIO including DS6001.

On the NI Linux RT now you can run parallel solvers with LibVIEW and VeriStand.

FMU for Linux System

From version 2021.0 CarSim can generate the FMU running on Windows, Linux or on both systems.

VS Scene Builder Proving Ground Tile

A new proving ground tile has been created for the VS Scene Builder. This tile provides a complete environment with nine testing areas, including: a five mile circle track, a hill grade surface, an on-grade split-mu surface, a split-mu surface, a rough road section, a 1000m straight, a 500m skid pad, a handling course, and an urban multi-lane environment. Use the over 600 built-in paths or create your own in the VS Scene Builder.

VS SDK

The VS SDK was created in conjunction with the 2019.1 release with the goal of supporting end-users who are building tools around a VehicleSim product using the VS API.

For the 2021.0 release, the VS SDK has been simplified for the benefit of software developers who do not routinely work with a VehicleSim product.

NVIDIA DRIVE Sim Constellation Integration

Mechanical Simulation has partnered with NVIDIA to integrate the CarSim vehicle dynamics model with NVIDIA DRIVE Sim Constellation. The first release is with DRIVE Sim version 1.14 and compatible with CarSim going back to version 2020.0. The CarSim plugin allows users to take full advantage of the NVIDIA DRIVE Sim environment while using their own custom vehicle models as defined by CarSim.

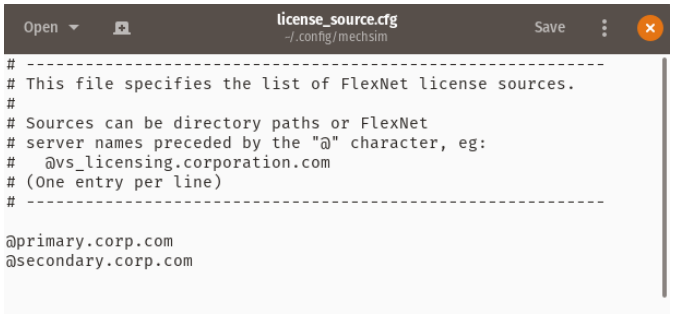
For more information regarding the CarSim plugin for NVIDIA DRIVE Sim and to request a copy, please contact CarSim support.

VS Driving Simulator Preview

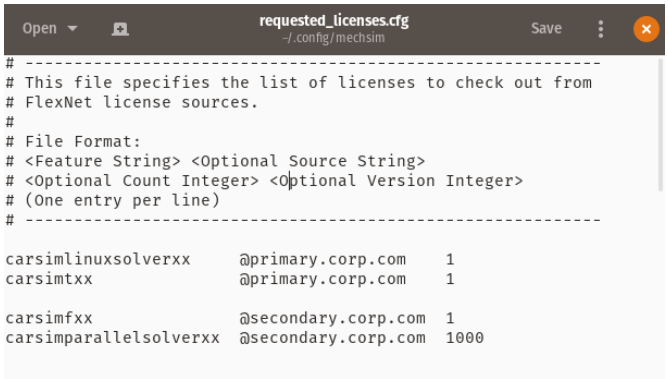
A link will be made available on the user section of our website to download a preview of the new VS Driving Simulator. This is a Windows desktop application that utilizes VS Connect, the VS Visualizer, and select Logitech hardware to allow users to perform driver-in-the-loop testing. This software will be the foundation for new driving simulator products moving forward.

Licensing

An improvement has been made to the way the license feature selections can be configured with the `cs-lm-cli` utility. This change will allow users to specify a source preference for each individual feature being checked out. For example, in the `license_source.cfg` file, given the following data:



This will allow the `requested_licenses.cfg` file to be configured as such:



With this configuration, `carsimlinuxsolverxx` and `carsimtxx` features will be selected from the `@primary.corp.com` license source, while the `carsimfxx` and

`carsimparallelsolverxx` features will be selected from the `@secondary.corp.com` license source.

Documentation

The following documents have been added to the **Help** menu:

1. Database Upgrade Guidelines (Release Notes sub-menu)
2. Initialize a Vehicle Using Imported Variables (Technical Memos sub-menu)
3. Modular Vehicle Models (Technical Memos sub-menu)
4. VS Table Tool Introduction (Reference Manuals sub-menu)
5. VS Table Tool Usage (Technical Memos sub-menu)

The following Guides and Tutorials have been updated:

6. CarSim Formula SAE / SAE Baja
7. Introduction to CarSim

The following Reference Manuals have been updated:

8. System Parameters in VS Math Models (former title: System Parameters in VS Solvers)
9. VS Browser (GUI and Database)
10. VS COM Interface
11. VS Commands
12. VS Commands Summary
13. VS Math Models (former title: VS Solver Programs)
14. VS SDK
15. VS Visualizer

The following Screen documents have been updated:

16. Aerodynamics
17. Animator: Camera Setup
18. Atlas GPS Tool (in Paths, Road Surfaces, and Scenes sub-menu)
19. Electronic Stability Control (ESC) (in Controls sub-menu)
20. Driver Controls (in Controls sub-menu)

21. Data Groups (in Generic Data Screens sub-menu)
22. External Models and RT Systems (in Model Extensions and RT Systems sub-menu)
23. Home: The Run Screen
24. Import and Export Variables (in Model Extensions and RT Systems sub-menu)
25. Parallel VS Math Models (in Tools sub-menu)
26. Paths and Road Surfaces (in Paths, Road Surfaces, and Scenes sub-menu)
27. Powertrain
28. Powertrain for Electric and Hybrid Electric Vehicles
29. Preferences (in Tools sub-menu)
30. Procedures and Events
31. Run Control Screen
32. Steering Systems
33. Suspension Systems
34. Tire Models
35. VS Scene Builder (in Paths, Road Surfaces, and Scenes sub-menu)
36. VS Terrain (in Paths, Road Surfaces, and Scenes sub-menu)

The following Technical Memos have been updated:

37. Example: Camera Sensors
38. HPC Licensing
39. Initialization in CarSim and TruckSim
40. Modular Vehicle Models
41. Numerical Integration in VS Math Models (former title: Numerical Integration in VS Solvers)
42. Simulations with Multiple Vehicles

The following Real-Time and DS System documents have been updated:

43. DS6001 Network Settings
44. NI RT Target Systems
45. VI-Grade Integration Guide

Database

New and Updated Examples

The following subsection titles correspond to categories for new examples that all share the prefix "* CS 2021.0," e.g., *** CS 2021.0 – Electrically Driven Wheels**

Combined ADAS Features

CarSim 2021.0 has added three examples which combine multiple advanced driver assistance systems (ADAS) into one ego vehicle, per example. The nominal 'FCW & AEB: Animated Deer' and 'ACC, 5-Lane Road, 3 Lanes Fwd Traffic' examples were created in past versions of CarSim without as many combined ADAS features. The new 'FCW, AEB, ACC, & LKAS: Animated Deer 'example in the '*Combined ADAS Features'* category includes forward collision warning (FCW), automatic emergency braking (AEB), automatic cruise control (ACC), and Lane Keeping Assistance System (based on Path Detectors). The new Comb. ADAS: Hwy. w/Traffic, Strong LKAS, and Comb. ADAS: Hwy. w/Traffic, Weak LKAS examples in the '*Combined ADAS Features'* category includes forward collision warning (FCW), automatic emergency braking (AEB), automatic cruise control (ACC), Blind Spot Detection (BSD), Lane Departure Warning (LDW), and Road Departure Mitigation (RDW). One of these examples includes strong LKAS control parameters which does not activate LDW or RDM, and one contains weak LKAS control parameters, which activates LDW and RDM due to the ego vehicle wandering in its designated lane.

Electrically Driven Wheels

The CarSim vehicle models support electrical motors at each drive axle, including one motor per wheel (i.e., two per axle).

Data Changes related to Steering System Inertia

To demonstrate the new suspension contribution to steering system inertia (see page 2), the following vehicles have received updates to their steering system data:

- Compact pickup truck
- Offroad (Baja-style) pickup truck
- Compact utility truck
- Lifted (solid front axle) pickup truck

Using the new version of these vehicles with existing procedures produces different simulation results due to the updated data.

New Datasets to Highlight New Animator Assets

Two new datasets have been added to highlight new or updated animator assets taken from TruckSim. These visual assets can also be used as traffic objects after linking to them with an Animator: Shape File Link dataset. The assets are:

- Improved Cab shape for 3A Sleeper Cab lead unit
- New flatbed trailer
    - New trailer body

    - New landing gear
    - New axle and air suspension components
    - New mudflaps
    - New 41k lbf Coiled Steel payload
- New shipping container trailer
    - Front, Mid, and Rear components for different length containers
    - Containers can be added as part of the object (for traffic) or as custom payloads (Ego vehicle)

New Datasets to Show New Proving Ground Tile

The new proving ground scene is demonstrated with the following examples:

- CS 2021.0 - New Proving Ground > Hill Start Assist (Manual Trans)
- CS 2021.0 - New Proving Ground > Lift Throttle in Curve
- CS 2021.0 - New Proving Ground > Sine Bumps - Out of Phase
- CS 2021.0 - New Proving Ground > Split Mu Braking Test w/ ESC
- CS 2021.0 - New Proving Ground > Split Mu Hill Climb @ GVWR
- CS 2021.0 - New Proving Ground > Split Mu Hill Climb w/ Driver Only
- CS 2021.0 - New Proving Ground > Top Speed Test
- CS 2021.0 - New Proving Ground > Trailer Oscillation Test
- CS 2021.0 - New Proving Ground > Urban Test Area

These examples don't show all available sections of the new proving ground, which has nine testing areas including a five mile circle track, a hill grade surface, an on-grade split-mu surface, a split-mu surface, a rough road section, a 1000m straight, a 500m skid pad, a handling course, and an urban multi-lane environment. Additional reference paths, for other test sections, are set up in the Scene: External Import dataset for the proving ground, which you can view there. You can also open the VS Scene Builder to view the new proving ground's tile, where over 600 paths are available for export.

VS Table Data Examples

A new example that utilizes the VS Table Tool, was added, for CarSim 2021.0. This example is in the new '*VS Table Data'* Category and titled 'Baseline DLC (VS Table Engine Map)'. Also added to the '*VS Table Data'* Category was the 'Baseline DLC (VS Table dZ rough road)` example, which was first introduced in the CarSim 2020.1 release.

The 'Baseline DLC (VS Table Engine Map)' example effectively VS Commands, to load header and binary files, created using the VS Table Tool, that represent the same C-Class Hatchback Engine Map data found in the 'Baseline' example from the '*Quick Start Guide Example*' Category. This new 'Baseline DLC (VS Table Engine Map)' example, and the earlier 'Baseline DLC (VS Table dZ rough road)` example, are explained with more detail, in a new Technical Memo for the 2021.0 software release, titled 'VS Table Tool Usage'.