Mechanical Simulation

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TruckSim 2022.0 New Features

This document lists notable new features in TruckSim version 2022.0.

VS Math Models

Powertrain Improvements

Series and Parallel Hybrid Models

The powertrain model adds two types of hybrid electric models to an existing hybrid model: one is *Series Hybrid* (also known as “REEV: *Range-Extended EV*) and the other is *Parallel Hybrid*. The series hybrid system involves an engine directly connected with a generator which charges the electric battery whereas separate motor(s) drive the wheels. On the other hand, in the parallel hybrid system, an engine and motor(s) are parallel structure that the engine and motor(s) drive the wheels through the transmission when a clutch is engaged while the wheels are driven by only motor(s) when the clutch is disconnected.

The existing hybrid model which involves a planetary gear is renamed as *Power-Split Hybrid* (`OPT_HEV = 1`) as distinguished with the new series hybrid (`OPT_HEV = 3`) and parallel hybrid (`OPT_HEV = 4`.)

Powering trailer axles

Articulated busses and some other combination vehicles are powered by driving trailer axles, rather than axles on the lead unit. When a powertrain is defined in a combination vehicle, a new parameter `POWERTRAIN_UNIT` specified which unit contains the powertrain. The default value is 1 (the lead unit), and the parameter is hidden from the Echo file and ignored if the vehicle does not include a trailer.

Trailers with Moving Parts

New options were added to support two kinds of connections for trailers that involve moving parts. One is for a ball or pintle hitch connected to a trailer with a hinged tow bar. These are used for truck dollies to avoid hitch loads on the pintle. Another is for articulated busses, which use an articulation system with a hinge connecting to the lead unit from a structure that is attached to the trailing unit with an articulation joint.

In support of these new connection options, the calculations made for hitch connections were redone. A new command `OPT_HITCH_TYPE` sets the type of hitch to 1 (generic or fifth wheel), 2 (ball or pintle hitch), 3 (ball/pintle connected to a massless tow bar, or 4 (articulation system). The first option (`OPT_HITCH_TYPE` = 1) provides the same model and associated outputs that were available in past versions.

Generic and fifth-wheel hitches (`OPT_HITCH_TYPE` = 1)

The generic hitch calculates rotations that occur on a fifth wheel in which a pitch hinge (Y rotation) is attached to the leading unit, an articulation hitch (Z rotation) is attached to the trailing unit, and the intermediate roll direction (X rotation) is defined by the vector cross product Z x Y. These angles, based on the rotation sequence Y-X-Z (also called 2-1-3) are not the same ones defined by ISO and SAE for defining sprung mass orientations; those start with yaw (Z rotation), pitch (Y rotation), and finally, roll (X rotation).

The generic hitch model calculates the 2-1-3 hitch angles based on differences in the sprung mass 3-2-1angles, then calculates moments based on those angles and their rates, applies the moments to the leading and trailing bodies using the hitch 2-1-3 axes.

Ball and pintle hitches (`OPT_HITCH_TYPE` = 2)

Ball and pintle hitches apply forces to connect a point in the rear of the leading unit with a point in the front the trailing unit. No moments are calculated from the angles. When the new type 2 hitch is specified, the moment calculations are skipped. Also, parameters, tables, and output variables associated with those calculations are not added to the VS Math Model.

Hinged tow bars (`OPT_HITCH_TYPE` = 3)

A new option (type 3) was added to support the simulation of trailers with hinged tow bars. This option adds a massless tow bar that is hinged in pitch, such that the vertical force (perpendicular to the bar) is zero. With this option, the VS Math Model calculates a relative pitch angle of the bar such that the normal (vertical) force is zero. The hitch still applies forces laterally and in the longitudinal axis of the hinged bar.

An additional parameter is defined with this option (LX_TOW_BAR) and outputs are generated as needed to animate the moving tow bar.

Articulation systems (OPT_HITCH_TYPE = 4)

Another new option (type 4) was added to support the simulation of articulated busses, where the hitch geometry is set to reduce the vertical space needed to separate the pitch and articulation joints. The distance is horizontal (rather than vertical as with most heavy-truck fifth wheels). This distance might be significant.

This option adds a massless structure to the trailer that articulates and connects to the leading unit with a hinge that allows relative pitch. The origin of the sprung mass coordinate system is moved in the X-Y plane of the trailer sprung mass such that the articulation point remains behind the hitch point the leading unit by the distance LX_ART (a new parameter for this type of hitch).

Along with the new parameter, new outputs are generated as needed for this type of hitch. All the 2-1-3 moments calculation for the generic (type = 1) hitch are also applied with this type.

Wheel Center and 3-1-2 Definitions for the Independent Suspension

There is a new option for the generic/independent suspension model, keyword OPT_IND_KIN, available from a checkbox on the **Suspension: Independent System Kinematics** library screen.

When OPT_IND_KIN is on (=1), the longitudinal movement, lateral movement, dive, and camber kinematics tables are interpreted with definitions more closely matching physical measurements or general simulation outputs. Specifically, the wheel carrier is oriented relative to the sprung mass by a 3-1-2, steer-inclination-dive rotation sequence, where the steer and inclination are given by the toe and camber input tables. The wheel carrier is then translated by the translational input data, meaning that data gives the wheel center displacement. The option works by generating another set of kinematics tables which allow the model to match the position and orientation given by the input tables' alternate definitions. This capability is enabled by the built-in Independent Suspension Kinematics Utility (IKU), which handles the conversion calculations.

OPT_IND_KIN off (=0, the default) retains the previous behavior exactly. The effects of the option are readily compared with four new examples in the "* Independent Suspension Kinematics" category:

- Kinematics: Bounce (OPT_IND_KIN=0)
- Kinematics: Bounce (OPT_IND_KIN=1)
- Kinematics: Roll (OPT_IND_KIN=0)
- Kinematics: Roll (OPT_IND_KIN=1).

For more information, refer to the updated help file, **Help > Suspension Systems**, especially the new "Suspension Kinematics in the Math Models" section.

GPS Calculations

GPS coordinates are calculated and provided as output variables for the first vehicle unit and for moving objects. The conversion from global X and Y coordinates in the simulation model coordinate system to GPS have been based on the starting location of the vehicle, with updates occurring when there is a significant change in GPS latitude. Several improvements were made to accommodate simulations involving multiple vehicles and moving objects that might be separated by significant distances.

1. Simulations involving more than one vehicle running within a single VS Solver now include GPS outputs for all vehicles, rather than just the first vehicle.
2. The GPS conversion parameters `GPS_REF_LAT`, `GPS_REF_LONG`, `GPS_REF_X`, and `GPS_REF_Y` now retain their initial value, reflecting the value associated with the creation of the road or scene. Instead, when any reference point is reset for a vehicle or moving object, the run's log file will contain a line indicating the vehicle or moving object ID and the latitude/longitude at the reset.
3. The GPS reference point is now checked at initialization, to improve GPS output accuracy in cases where the initial location of the vehicle or moving object is past `GPS_RANGE_Y`.
4. Moving object GPS output calculations now account for the reference point reset implied by the parameter `GPS_RANGE_Y`, rather than always using the reference point established by `GPS_REF_LAT`, `GPS_REF_LONG`, `GPS_REF_X`, and `GPS_REF_Y`.
5. Moving object GPS output calculations now function if the X-Y coordinates of the moving object are specified directly. Previously, moving object GPS outputs were only produced if the moving object was set to follow a path.

Miscellaneous Features

- A new output variable `RRsurf_`*t* was added for each tire *t* (e.g., L2i for the left inner tire on axle 2, if there are duals). This is the rolling resistance coefficient due to the ground/road surface, which can vary with location.
- A new system parameter `OPT_ECHO_DEFAULT` is available to disable the identification with the indicator [D] in the Echo file for default values that were not set by reading an input file. This can be helpful in advanced applications, such as when a new run is made using an Echo file written at the end of a previous run. In this case, the [D] indicator never appears in the Echo files for the continuation run. The new parameter may be used to ensure the [D] indicator doesn't appear in other runs either, simplifying the use of text editors to compare files.
- New import variables to control steering systems were added for each axle. These are `IMP_DSTEER_CON_(`*`axle`*`)` and `IMP_STEER_CON_(`*`axle`*`)` for recirculating ball-type systems and `IMP_DSTEER_RACK_CON_(`*`axle`*`)` and `IMP_STEER_RACK_CON_(`*`axle`*`)` for rack and pinion systems. These variables define the position and speed of the steering gear output, which is provided as input to the non-linear kinematics for the wheels. Previously, the inputs to the wheel kinematic tables could be imported with separate variables for each wheel. Since separate variables for each wheel did not imply a single position for the steering output, information about the input gear could not be inferred. With a single import variable for each, the input information can be inferred. The separate variables are still

supported. You should use either the single variables for each axle or the individual variables for each wheel, but not both, depending on your needs.

- A new output variable for dive angle was added for each wheel, `DiveG_`<wheel>. This is a general measurement of dive of the steered wheel hub (aka wheel carrier) which is available for all suspension types. The definition is the wheel spin change due to the suspension kinematics and compliance, measured with the outboard brakes locked.
- An extension to the driver controls is now supported for advanced users developing autonomous driving controls and ADAS. Activated by setting `OPT_DM_AUX` to 1. When activated, this feature produces output variables for a “bicycle model” steer angle to steer toward a path target offset (`LTARG`) different from the one used by the internal driver path follower model. See the Driver Controls help document for details on its operation and use.

VS Browser: Graphic User Interface (GUI)

Tool: Find links to the current dataset from any library

A new command was added to the **Tools** menu for searching: **Find All References to this Dataset in “Run_all.par” Files by Library...**

The existing **Find All References to This Dataset** option finds datasets that are immediately referenced by others. The search can be repeated, to find datasets that reference datasets that reverence the current dataset, but this form of manual repeating is time consuming.

The new search option takes advantage of `Run_all.par` files that are made automatically whenever a run is made, or VS Visualizer is used to view results. This has significant advantages:

1. Searching these files is rapid compared to searching the entire database. Even with large databases, the search is much less than a minute.
2. The searching finds all references where the current dataset was used in an existing run.
3. Results are filtered to show only cases where the current dataset referenced (no matter how indirectly) by datasets in a specified library.

For example, perform a search from a **Tire** dataset to find all the **Run Control** datasets that may somehow make use of the current tire dataset. Or, search for all vehicle datasets that used the current tire dataset in a run.

Support of New Joint Types

The new Hitch and Joint options are supported by changes to several screens.

1. The two Hitch screens (**Hitch: Joint Assembly** and **Hitch: Parameters**) both include a new checkbox to indicate that the hitch will generate torsional resistance, as needed for hitches of type 1 (generic or fifth wheel) and 4 (articulation system). If unchecked, the hitch will be either type 2 (ball or pintle) or 3 (pintle with hinged tow bar).

2. The **Vehicle: Trailer Sprung Mass** screen has a drop-down control to specify an additional moving part. The options are:
    a. Trailer hitch joint is at a single point (default)
    b. Trailer has a hinged tow bar
    c. Trailer has an articulation system

The type of hitch is set by combining the data from the two types of screens. The Hitch screen (whose Parsfile is read first by the VS Math Model) set the hitch type to 0 or 1. The Sprung Mass screen then leaves the hitch type intact (option a), converts a ball/pintle hinge to type 3 (option b), or converts a generic hitch to an articulation system (option c).

Powertrain: Hybrid/Electric System screen

Powertrain: Hybrid/Electric System screen is changed to support three types of hybrid electric (Power-split, Series and Parallel hybrid) and pure electric systems. As VehicleSim used to support only one type of hybrid (power-split) and pure electric in the previous versions, this screen used to distinguish them by a checkbox (Show EV parameters only.) The new screen replaces the old checkbox with a new drop-down menu which involves four types of hybrid/electric system. The checkbox status in the data from the previous versions is automatically assigned to the new drop-down menu item.

The hybrid/electric system used to be installed by Powertrain screens (e.g. **Powertrain: Rear-Wheel Drive** screen, etc.) using keyword, `OPT_HEV`. From this version, Powertrain screens only define `OPT_HEV = 0` when IC (Internal-Combustion) powertrain is selected while **Powertrain: Hybrid/Electric System** screen defines `OPT_HEV = 1` through `4`.

Miscellaneous Changes

- Users can now specify the results output directory of an FMU with self-contained mode enabled.
- The **Animator: Wheel Indicators** library screen can now support wheels on up to 20 axles (the previous limit was 9).
- Various vehicle screens with Miscellaneous blue links can now link to **Animator: Reference Frame** datasets (in support of adding moving parts to the animated vehicle).
- Many minor changes were made to fix bugs, correct typos, improved consistency, etc.

VS Visualizer

Added new option to scale plots non-symmetrically by pressing the "alt" key while dragging with the middle-mouse-button (or left+right mouse buttons). In this mode, moving the mouse up/down zooms vertically, moving left/right zooms horizontally. There is also an option on the plot window right-click context menu ,"Asymmetric mouse zoom", to switch which mode is default (active w/o the Alt key).

VS Solver Wrapper (Command Line Interface)

Support of VS Solver Wrapper with a command-line interface has been improved to provide more options when using external software to provide automation.

- VS Solver Wrapper can now execute simulations using Simulink completely using the command line interface. Simulink will be automatically launched when the `SIMULINK_MODEL_FILE` keyword is detected in the "`all.par`" input file. For more information, see VS_SolverWrapper.pdf.
- VS Solver Wrapper can execute simulations of an FMU using the command line interface. An FMU must be FMI version 2.0 and self-contained that includes all input files and binary solvers: vehicle solver 32/64 bit for Windows and Linux 64 if running on Linux 64, `simfile.sim`, `Run_all.par`, events parsfiles, vs_terrain file, external tire files, see VS_SolverWrapper.pdf.
- VS Solver Wrapper can now load and run External Tire model datasets. Previously these were referenced through absolute path, due to third-party requirements. They are now referenced through relative path, with the absolute path being determined dynamically through the PROGDIR simfile parameter.

Live Animation Solver Wrapper

CarSim and TruckSim have a new wrapper program, named wrapper_live_animation, which uses VS Connect to provide live animation data to VS Visualizer while the simulation run progresses. An example dataset that demonstrates this wrapper is included with CarSim and TruckSim.

This wrapper accepts command line parameters to control the run and VS Connect network connection. For a list of available command line options, use the Windows' Command Prompt to execute the following:

```
wrapper_live_animation_Release_Win32.exe -?
```

Both 32- and 64-bit versions are provided.

The wrapper also accepts keyboard input during the simulation to control the simulation (speed up, slow down, pause), as well as other options. See on-screen help when the wrapper is run for more details.

Source code (C++) and Visual Studio 2015 project files are included with this wrapper so that it can be modified or used as the basis for integrating CarSim and TruckSim solvers into external simulation programs with support for VS Connect data synchronization and live animation with VS Visualizer.

This wrapper can be found in the `Extensions\Custom_C` folder of your CarSim or TruckSim database. It is also included in the VS SDK in the folder `Libraries\vs_connect\example`.

Documentation

The following document was added to the **Help** menu:

1. High Performance Computing (HPC) and VehicleSim

The following Reference Manuals have been updated:

2. VS Browser (GUI and Database)
3. VS COM Interface
4. VS Commands Reference Manual
5. VS Commands Summary
6. VS Math Models Reference Manual
7. VS Visualizer Reference Manual

The following Screen documents have been updated:

8. ADAS Sensors and Target Objects
9. Animator: Wheel Arrows and Other Indicators
10. CarSim and TruckSim Brake System
11. CarSim and TruckSim Suspensions
12. Driver Controls
13. External Models and RT Systems
14. Powertrain System
15. Powertrain for Electric and Hybrid Electric Vehicles (BEV/HEV)
16. Trailer Hitches
17. TruckSim Steering Systems
18. Vehicle Screens and Outputs

The following Technical Memos have been updated:

19. High Performance Computing (HPC) and VehicleSim
20. HPC Licensing
21. VS Camera Sensor Simulink Block
22. VS Solver Wrapper

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

23. dSPACE RT Guide
24. Windows DS for CarSim and TruckSim

Database

New and Updated Examples

Kept one significant figure in steering system inertia

Round the steering System Inertias to one significant figure which serve as a good estimate to this property.

External ABS with I/O Channels: Ports screen

Since version 9.0 TruckSim has shipped with a **Run Control** dataset indicated as using the **I/O Channels: Ports** screen. This screen supports up to 20 **I/O Channels: Import** datasets and up to 20 **I/O Channels: Export** datasets. For the 2017.0 release the linked **Models: Simulink** dataset was accidentally changed to use the same Simulink model and I/O array as the non-multi-port External ABS example. For the 2022.0 release, the example has been restored to use the **I/O Channels: Ports** screen. A new Simulink model has been added to support this screen.

Series and Parallel Hybrid Electric examples

Several new hybrid electric powertrain examples are added under *** Series and Parallel Hybrid** category.

Hinged towbar dollies and updated vehicle data for rigid towbar dollies

Demonstration of the new hinged towbar feature consists of two parts: (1) New vehicle configurations, and (2) Update or replacement of existing vehicle examples. Partly as result of this activity, TruckSim 2022.0 has all new dollies representing 1-axle, 2-axle, and 3-axle configurations, in both rigid and hinged towbar variants. An example of a turntable ball race-type coupling is also included and applied to 1-axle and 2-axle dollies.

New runs are in the categories *** Double and Triple Road Trains** and *** Rigid Truck and Dog Trailer Combination**s.

Articulation system joint and power on trailing unit

Articulated bus examples are used to demonstrate two new features in the modeling available in TruckSim:

1. Powertrains may be installed on a trailer in a combination vehicle (as an alternative to the lead unit). An articulated bus example powers the axle on the trailing unit.
2. Some articulated busses use articulation systems in which a pitch hinge that connects to a leading unit is located some distance in front of an articulation hinge.

ACC Perception Logic Update

The adaptive cruise control (ACC) perception logic in the ego vehicle used within the ACC Euro NCAP examples and ADAS and Active Safety examples has been updated. This perception update determines if the sensed object ahead of the ego vehicle is in the lane of the ego, or not; this is especially useful on curved roads to help reduce false-positive detections.

The four-lane (*ACC, 4-Ln Road, Fwd and Opp. Traffic*) and five-lane (ACC, 5-Lane Road, 3 Lanes Fwd Traffic) ADAS and Active Safety examples with ACC have included the same ACC perception logic updates, as included in the ACC Euro NCAP examples. The four-lane example now includes a heads-up-display (HUD) indicator in the VS Visualizer for when a vehicle has been detected in the same lane as the ego vehicle. This same logic is included in the five-lane example, though the in-lane detection indicator is not shown in the VS Visualizer.

ACC Tour Bus Example

An ACC example in the ADAS and Active Safety Category has been added with a Tour Bus (*ACC Bus, 4-Lane Rd., Fwd, Opp Traffic*) that demonstrates the in-lane detection logic for the ACC, to reduce false positives. A visual indicator of when the ACC logic perceives a vehicle in the lane of the Tour Bus is shown in the VS Visualizer.

ACC Euro NCAP Updates

Euro NCAP adaptive cruise control (ACC) tests have been included for the first time, in TruckSim. These tests mimic the Euro NCAP ACC tests in CarSim and they utilize the Euro Van, which is similar to the euro-ncap-commercial-van-test-and-assessment-protocol-v10.pdf document which can be found on the Euro NCAP website, in the Test and Assessment Protocols section (https://www.euroncap.com/en/for-engineers/protocols/general/).

Vehicle-to-Vehicle Communication Examples

Two Vehicle-to-Vehicle (V2V) Communication examples have been added. In one example — *V2V, Severe Braking Ahead, w/Collision* — two small vehicles abruptly stop on a highway, forcing a large, tall truck to also stop abruptly. The ego vehicle with ACC and AEB senses the large truck stopping, but cannot stop in time, so it collides with the truck. The second example — *V2V, Severe Braking Ahead, Avoid Collis.* — includes communication of the lead truck's longitudinal acceleration sensor data to the ego truck (like the way data would be communicated using modern V2V communication), such that the ego truck can determine severe braking ahead, even before the ACC and AEB are able to perceive the severe stop. With this V2V data communicated to the ego truck, it can stop without colliding with the lead truck.

Tractor-Trailer Platoon Examples

Several autonomous Tractor-Trailer Platooning tests have been added as examples to the TruckSim Database. Simple control logic and data exchange between the platooning trucks achieve a close spacing distance as the platoon undergoes a variety of obstacles. These examples have been modeled using both the Parallel Solver method (solvers assigned to each truck run in parallel) and Singler Solver method (one solver models the whole platoon).

Addition of Two-Axle Rental Trailer with Example

A new double-lane-change (DLC) example has been added, that includes a Euro Van with a two-axle rental trailer connected. This example is like the Euro Van DLC example with a one-axle rental trailer. Both examples contain updated trailer Animator Shape File art.

New Animator Resources

New Animator Shape Assemblies have been added for the three-Axle Sleeper Cab, Flatbed Trailer, Shipping Container Hauler, and 53-ft. Box Trailer.