Payloads

In VehicleSim (VS) Math Models, a *payload* is a body with inertia properties, which is rigidly attached to the sprung mass of the underlying vehicle. It can represent cargo, people, vehicle components, fuel loads, or anything else that adds to the inertia properties of the sprung mass.

Role of Payloads in the Vehicle Model

If the properties specified for the sprung mass exactly match those of the vehicle to be simulated, then payload masses and inertias are not needed. Otherwise, payloads can be used to quickly create various vehicle configurations that represent a single vehicle under different loading conditions. The payload can even be given negative mass properties to simulate a vehicle that is lighter than the baseline.

The mass and other inertia properties of each payload are combined with the sprung mass in the model during the initialization that takes place after all the input Parsfiles have been read, but before the simulation starts. The effect is the same as if the sprung mass properties were specified taking the locations and inertia properties of the attached payloads into account.

For example, Figure 1 shows part of an Echo file listing the sprung mass information, followed by payload information. The unladen sprung mass parameters all end with the suffix `_SU` (sprung mass, unladen). In this case, seven payloads were installed on the sprung mass (see line 149), and calculated properties are shown for the sprung mass with the payloads attached. Those parameters end with the suffix `_SL` (sprung mass, laden).

VS Vehicle Models include a command `DEFINE_PAYLOADS` with the form:

`DEFINE_PAYLOADS` *n*

where *n* is an integer or formula that is evaluated to provide an integer value (see line 170 in the figure). If *n* is less than 1, the command does nothing. If *n* is greater than 0, then the command adds payloads to the VS Math Model, up to a limit of 99 total for the vehicle.

In the VS Math Models, each payload is represented by the coordinates of its mass center, its mass, and its six moments and products of inertia (see lines 173-182). For combination vehicles, a parameter indicates which sprung mass contains the payload.

The existing number of payloads is provided with a system parameter named `NLOAD` (line 169). `NLOAD` is the total number of payloads. With combination vehicles, `NLOAD` is the sum of the number of payloads added to each sprung mass.

LastRun_ECHO.PAR #

```
130 !------------------------------------------------------------------------------
131 ! SPRUNG MASS
132 !------------------------------------------------------------------------------
133 ! The following parameters apply for the sprung mass without payloads, designated
134 ! SU (sprung mass unladen). If any payloads are attached, the combined inertia
135 ! properties (SU sprung mass + payloads) are also listed and designated SL (sprung
136 ! mass laden).
137
138 H_CG_SU            781 ; mm ! Height of CG of sprung mass, unladen (SU) [I]
139 LX_CG_SU          1330 ; mm ! X distance SU CG is behind sprung mass origin [I]
140 Y_CG_SU              0 ; mm ! Y coordinate of SU CG [I]
141 M_SU              2257 ; kg ! Mass of unladen sprung mass (SU) [I]
142 IXX_SU           846.6 ; kg-m2 ! Roll inertia for unladen sprung mass [I]
143 IYY_SU          3524.9 ; kg-m2 ! Pitch inertia for SU [I]
144 IZZ_SU          3524.9 ; kg-m2 ! Yaw inertia for SU [I]
145 IXY_SU               0 ; kg-m2 ! XY product of inertia for SU [I]
146 IXZ_SU               0 ; kg-m2 ! XZ product of inertia for SU [I]
147 IYZ_SU               0 ; kg-m2 ! YZ product of inertia for SU [I]
148
149 ! N_PAYLOADS         7 ! No. of payloads attached to this sprung mass (read only)
150 ! H_CG_SL 839.4451544 ; mm ! CALC -- Height of laden sprung mass CG (SL)
151 ! LX_CG_SL 1549.808307 ; mm ! CALC -- X distance SL CG is behind origin
152 ! Y_CG_SL            0 ; mm ! CALC -- Y coord. of laden sprung mass CG
153 ! M_SL            2817 ; kg ! CALC -- Mass of laden sprung mass (SL)
154 ! IXX_SL   1037.37175 ; kg-m2 ! CALC -- Roll inertia for SL
155 ! IYY_SL  4575.310446 ; kg-m2 ! CALC -- Pitch inertia for SL
156 ! IZZ_SL  4635.948696 ; kg-m2 ! CALC -- Yaw inertia for SL
157 ! IXY_SL            0 ; kg-m2 ! CALC -- XY product of inertia for SL
158 ! IXZ_SL  145.8555604 ; kg-m2 ! CALC -- XZ product of inertia for SL
159 ! IYZ_SL            0 ; kg-m2 ! CALC -- YZ product of inertia for SL
160
161 HT_SM             1677 ; mm ! Reference height of sprung mass (maybe for target)
162 LEN_SM            4000 ; mm ! [D] Reference length of sprung mass (maybe for target)
163 WID_SM            2384 ; mm ! Reference width of sprung mass (maybe for target)
164 LX_F_SM           1000 ; mm ! [D] Length from front to control pt (maybe for target)
165
166 !------------------------------------------------------------------------------
167 ! PAYLOADS
168 !------------------------------------------------------------------------------
169 ! NLOAD              7 ! Number of installed payloads (read only)
170 DEFINE_PAYLOADS      7 ! VS Command to add payloads
171
172 PAYLOAD_NAME(1)      1 ; Driver - Front Left Seat
173 LX_CG_PL(1)       1250 ; mm ! Distance payload mass center is behind origin (-X) [I]
174 Y_CG_PL(1)         500 ; mm ! Y coordinate of payload mass center [I]
175 Z_CG_PL(1)        1075 ; mm ! Z coordinate of payload mass center [I]
176 M_PL(1)             80 ; kg ! Mass of payload [I]
177 IXX_PL(1)         4.57 ; kg-m2 ! Roll moment of inertia of payload [I]
178 IYY_PL(1)         4.57 ; kg-m2 ! Pitch moment of inertia of payload [I]
179 IZZ_PL(1)         1.63 ; kg-m2 ! Yaw moment of inertia of payload [I]
180 IXY_PL(1)            0 ; kg-m2 ! XY product of inertia of payload [I]
181 IXZ_PL(1)            0 ; kg-m2 ! XZ product of inertia of payload [I]
182 IYZ_PL(1)            0 ; kg-m2 ! YZ product of inertia of payload [I]
183
184 PAYLOAD_NAME(2)      2 ; Passenger - Front Right
185 LX_CG_PL(2)       1250 ; mm ! Distance payload mass center is behind origin (-X) [I]
```

Figure 1. Echo file listing sprung mass and payload properties.

Alert `N_PAYLOADS` and `NLOAD` are calculated parameters. They are listed in the Echo file (lines 149 and 169 in the example) and can be used in VS Command expressions to assign values to other parameters. They cannot be set directly; trying to do so generates an error message and stops the simulation.

Payload Library Screens

The easiest way to add payloads to a vehicle model is by using datasets from one of two libraries:

1. **Payload: Box Shape** — the mass center height and moments of inertia are calculated by the VS Browser for a payload made of a material with uniform density, in the shape of a box whose dimensions are specified.
2. **Payload: Custom** — the inertial parameters for the payload are specified directly on the screen.

The screens can be used more than one time to represent multiple payloads. Each time a payload dataset is read, the command `DEFINE_PAYLOADS` adds a payload to the math model. If the vehicle has trailers, the payload is added to the current vehicle unit.

All VS Math Model parameters that are set on a payload screen are indexed to the payload number as indicated by the current value of the system parameter `ILOAD`, set automatically to the last payload that has been defined (`ILOAD` = `NLOAD`). For models with trailers, they are also indexed to the vehicle unit as indicated by the current value of the system parameter `IUNIT` by setting `OPT_PL_BODY_ID` to `IUNIT`.

Payload: Box Shape

Figure 2 shows the **Payload: Box Shape** screen. The payload has an assumed rectangular shape to simplify the description and animation.

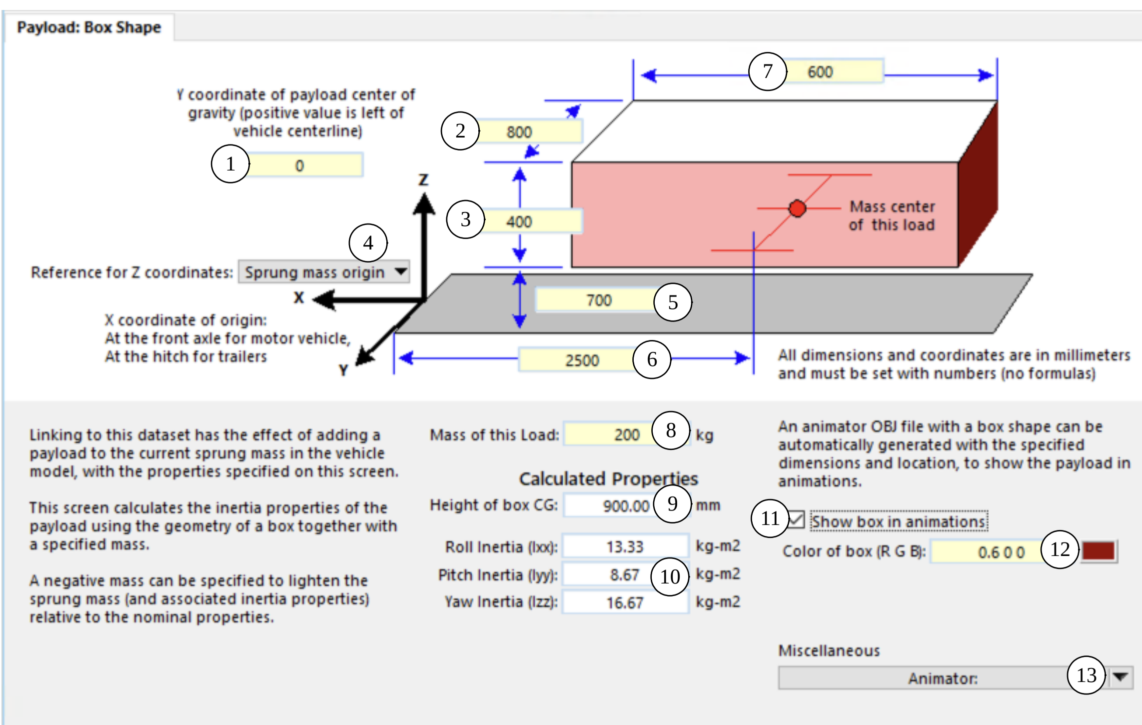

Figure 2: Payload: Box Shape screen.

Calculated properties shown in white fields are passed directly to the math models. Some of the values shown in yellow data fields are used only to calculate values for the white fields and are not used directly by the VS Math Models. For example, the dimensions of the box are used to calculate the CG location of the box and the moments of inertia.

1 Y coordinate of payload mass center (keyword = `Y_CG_PL`). Normally zero, this can be set to simulate off-center loads.

2 Width of box. This value is not used directly by the VS Math Models but is used to calculate the roll (I_{xx}) and yaw (I_{zz}) moments of inertia of the payload 9.

3 Height of box. This value is not used directly by the VS Math Models but is used to calculate the height of the mass center of the payload 9, and the roll (I_{xx}) and pitch (I_{yy}) moments of inertia of the payload 10.

4 Drop-down control to specify a reference for Z coordinates on the screen. The control has two options (Figure 3). In both cases, the height of the box center of gravity (CG) relative to the origin of the sprung mass coordinate system is calculated from other dimensions on the screen.

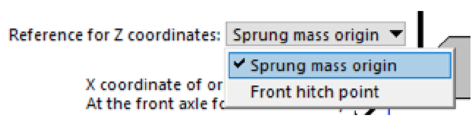

Figure 3. Two options for specifying a reference for Z coordinates on the screen.

- If the sprung mass origin is selected, the height of the payload CG (`Z_CG_PL`) is calculated as the height to the box bottom (`H_BOX_BOTTOM` 5) plus half the height of the box (`*Z_LENGTH` 3). Of these three dimensions, only the calculated parameter `Z_CG_PL` exists in the VS Math Model and therefore appears in the Echo file.
- If the front hitch point is selected, then the calculated value of `Z_CG_PL` is increased by the height of the front hitch point (specified by the parameter `H_H_FRONT`).

The option selected by this drop-down control does not get used directly by the VS Math Model. It is used locally by the VS Browser to calculate `Z_CG_PL`, which is always defined in the VS Math Model as the Z coordinate in the sprung mass coordinate system.

5 Height of box bottom above the reference point specified with the drop-down control 4. This value is not used directly by the VS Math Models; it is used locally to calculate the height of the mass center of the payload 9.

6 Longitudinal distance that the mass center of the box lies behind the origin of the sprung-mass coordinate system (keyword = `LX_CG_PL`). For a lead unit, the vehicle is usually defined such that the front axle longitudinal position is at the origin of the sprung mass coordinate system. For a trailing unit, the origin is below the front hitch point.

7 Length of box. This value is not used directly by the VS Math Models; it is used locally to calculate the pitch (I_{yy}) and yaw (I_{zz}) moments of inertia of the payload 10.

8 Mass of box (keyword = `M_PL`). This value is sent directly to the VS Math Models (this mass is added to the vehicle sprung mass) and is used to calculate the three moments of inertia 10.

9 Height of mass center (keyword = `H_CG_PL`). This height is calculated automatically by taking the height of the bottom of the box 5 above the reference point specified with the drop-down control 4 and adding half the box height 5. If the drop-down control 4 specifies that the reference height is the front hitch point, then `_CG_PL` is increased by the height of the front hitch point (`H_H_FRONT`).

10 Moments of inertia (keywords = `IXX_PL, IYY_PL, IZZ_PL`) needed by the VS Math Model. These cannot be set directly on this screen; they are calculated from the mass of the box and its dimensions.

11 Check this to cause a box shape file to be generated automatically and shown in the animations associated with vehicles that link to this dataset.

12 Color of box (keyword = `SET_COLOR`). The dimensions and location of the box are used to create an animator shape file. The color can be specified with RGB numbers separated by spaces or with the adjacent color control that displays the current color.

13 Miscellaneous blue link, available for advanced users to provide more animation data.

Payload: Custom

Figure 4 shows the **Payload: Custom** screen used to define the mass and dimensions of an arbitrary object or mass that is rigidly attached to a vehicle sprung mass.

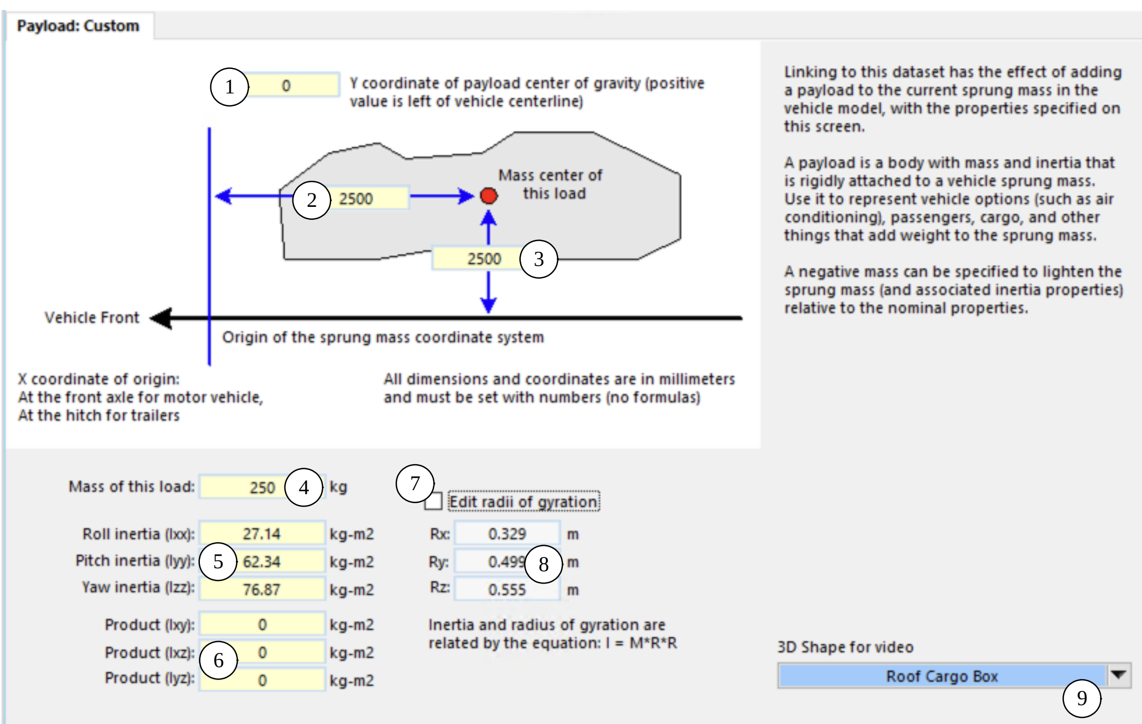

Figure 4: Payload: Custom screen.

1 Y coordinate of mass center (keyword = `Y_CG_PL`). Use a non-zero value to apply an off-center load. Positive values mean the payload mass is located to the left of the vehicle longitudinal centerline.

(2) Longitudinal distance that the mass center of the payload lies behind the origin of the sprung-mass coordinate system (keyword = `LX_CG_PL`). For a lead unit, the vehicle is usually defined such that the front axle longitudinal position is at the origin of the sprung mass coordinate system. For a trailing unit, the origin is below the front hitch point.

(3) Height of the mass center of the payload above the origin of the sprung-mass coordinate system (keyword = `H_CG_PL`).

(4) Mass of the payload (keyword = `M_PL`). This value is sent directly to the math models (this mass is added to the vehicle sprung mass). It is also used to calculate the three moments of inertia (5) if they are calculated using radii of gyration.

(5) Moments of inertia of the payload (keywords = `IXX_PL, IYY_PL, IZZ_PL`). These moments are all taken about the mass center of the payload and are based on a vehicle axis system in which the X axis (longitudinal) and Y axis (lateral) are parallel with the ground when the sprung mass has zero pitch and roll.

The moments of inertia can be entered directly in these fields, or they can be calculated using radii of gyration (8).

(6) Products of inertia of the payload (keywords = `IXY_PL, IXZ_PL, IYZ_PL`). The products are all taken about the mass center of the payload and are based on a vehicle axis system in which the X axis (longitudinal) and Y axis (lateral) are parallel with the ground when the sprung mass has zero pitch and roll. The products are defined as the negative of the volume integral. For example, the X-Z product is defined as:

$$I_{XZ} = -\int^{V} \rho \, x \, z \, dv$$

The product is positive when the principal X axis of the sprung mass tilts down (looking forward). The three products of inertia must be entered directly—there are no built-in tools to calculate them.

(7) **(Optional) Radii of Gyration** checkbox. Check to enable editing of three data fields with X, Y, and Z radii of gyration (8); in this case, the fields for moments of inertia (5) are calculated automatically and displayed but cannot be edited directly. Uncheck to enable editing of the inertia data fields, in which case the radii of gyration are calculated automatically but cannot be edited.

(8) Radius of gyration. Sometimes measured values for I_{XX}, I_{YY}, and I_{ZZ} are not available but R_X, R_Y, and R_Z can be estimated. When the box (7) is checked, the corresponding moment of inertia is calculated with the equation:

$$I = M \bullet R^2$$

where M is the payload mass (4) and R is the specified radius of gyration.

Conversely, when the box (7) is unchecked and you edit a moment of inertia value, the corresponding radius of gyration is updated with the same equations.

Use any of these three radii if the corresponding moment of inertia is not available but the corresponding radius can be estimated. For solid objects, a typical radius of gyration in a direction is about 1/3 of the dimension in that direction.

The radii of gyration are used only to calculate the moments of inertia; they not used directly by the VS Math Models.

9 Link to animator data that will be used to show the payload animations of the loaded vehicle. The specified animation shape will be added to the animator reference frame for the sprung mass associated with the payload. The 3D shape data should be adjusted relative to the origin of the sprung-mass coordinate system.