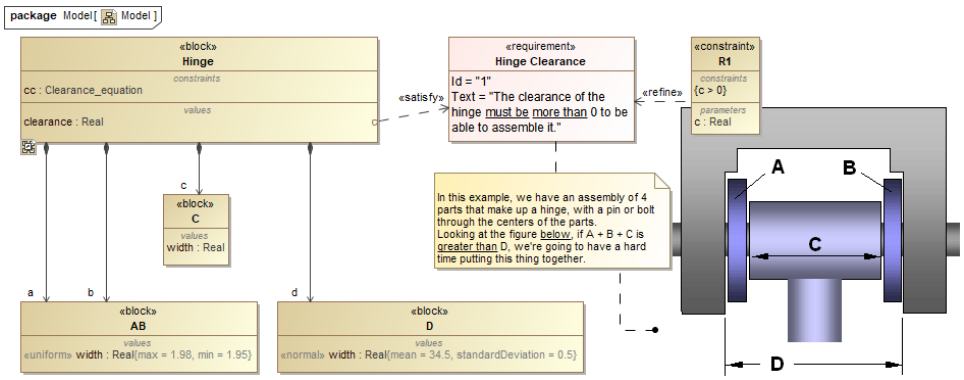
Monte Carlo simulation

On this page

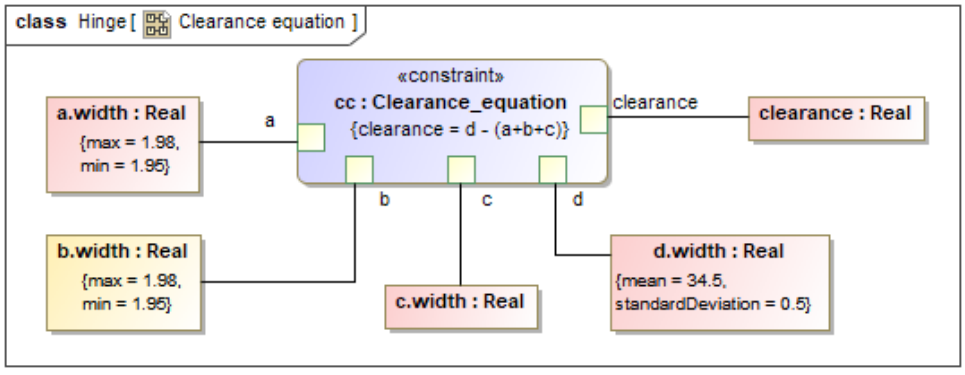
Cameo Simulation Toolkit introduces built-in support for Monte Carlo analysis, a technique that involves using random numbers and probability to solve problems. You can manage uncertainties and estimate how random parameters affect the overall performance of the system being modeled. Please refer to the HingeMonteCarloAnalysis sample model on the welcome screen as the feature demonstration with the following steps.

Creating a system model

1. Transform the stochastic model: *D > A+B+C* (random components) to the deterministic model: *D-(A+B+C) > 0*.
2. Create the system model and Parts with a Block Definition diagram with required value properties, e.g., Blocks *Hinge*, *AB*, *C*, and *D*.
3. Create constraint Blocks with parameters and constraint specification according to the requirement, e.g., *Clearance_equation*, *R1*, and *R2*.
4. Create a Requirement with a *satisfy* Relation to the value property to keep the result for the constraint, e.g., *Hinge Clearance* and *Unassemblable*.
5. Apply a «distribution» Type to get a set of random inputs of the value properties of the Parts based on Requirements, e.g., «uniform» with *max* and *min* and «normal» with *mean* and *standardDeviation*.

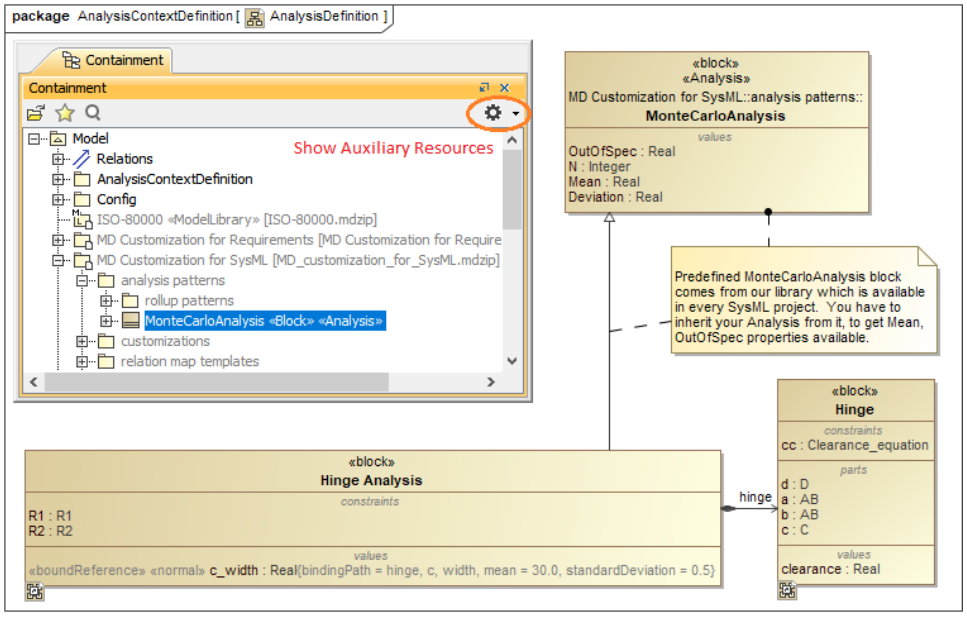


6. Create a parametric diagram in the system to bind the value properties to the parameters of the constraint Block, e.g., *Clearance equation*.



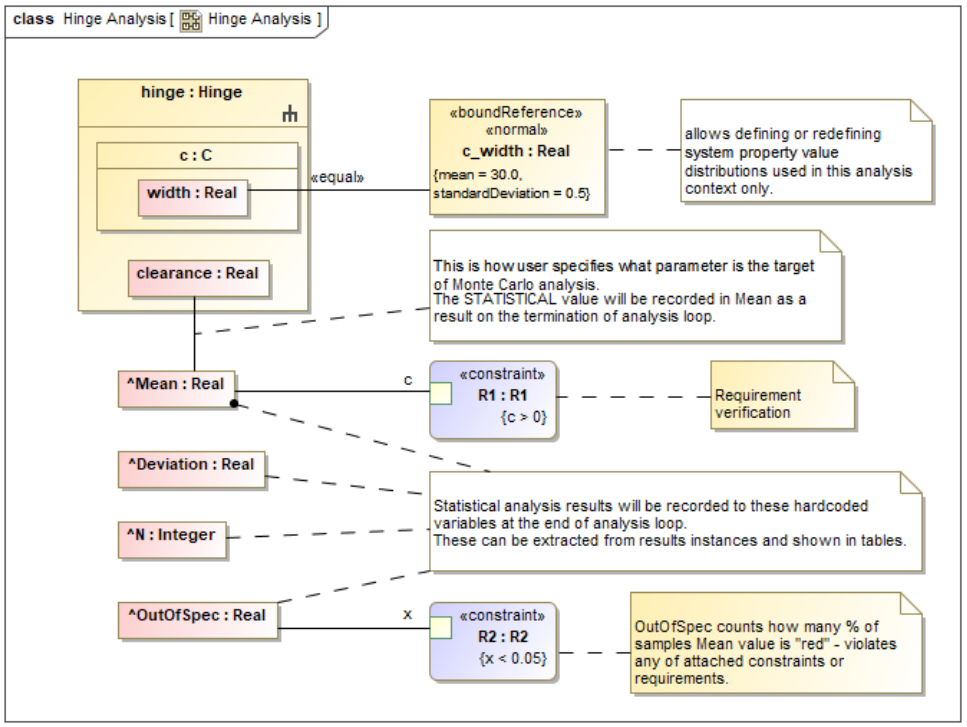
Inheriting the Hinge Analysis Block from the MonteCarloAnalysis Block

1. Create another Block Definition diagram and include an analysis context definition by dragging the *MonteCarloAnalysis* Block from *MD Customization for SysML::analysis patterns* into the newly created Block Definition diagram, e.g., *AnalysisDefinition*.
2. Create and inherit a new Block from the Block Definition diagram created in Step 1 as an analysis Block, e.g., *Hinge Analysis*, to get *OutOfSpec*, *N Mean*, and *Deviation* properties. The inheritance can be done by creating a generalization Relation from the *MonteCarloAnalysis* Block to the system model Block (from the Creating a system model section).
3. Create an association Relation, e.g., *hinge*, to make the *Hinge* system model block part of the analysis Block, e.g., *Hinge Analysis*.



Creating a parametric diagram and binding values

1. To specify a parameter as the target of Monte Carlo analysis, create a parametric diagram in the analysis block to bind properties and constraints. The statistical value will be recorded in *Mean* as a result of the termination of the analysis loop, e.g., *clearance*.
2. Connect constraints from Requirements to *Mean* for the Requirement verification and to *OutOfSpec* for the percentage of the samples whose *Mean* value violates any of the attached constraints or Requirements, e.g., *R1* and *R2*.



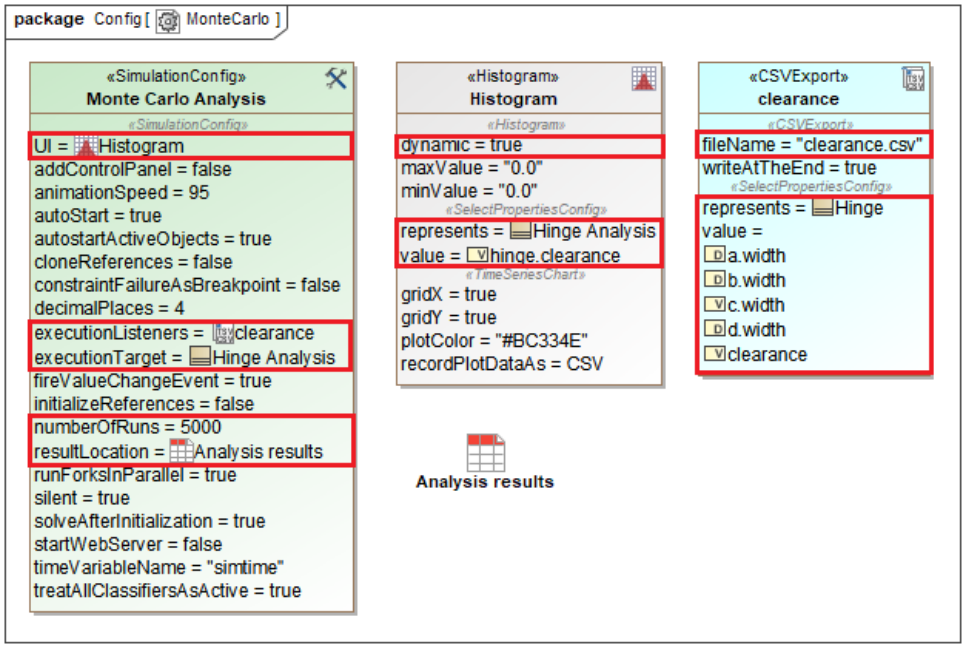
Creating a Simulation Configuration diagram and configuring other settings

1. Create a Simulation Configuration diagram, add a SimulationConfig to the newly created diagram, and set the following tags:
   - *executionTarget*: the analysis block, e.g., *Hinge Analysis Block*.
   - *numberOfRuns*: the number of runs, e.g., *5000*.
   - *resultLocation*: an Instance table, e.g., *Analysis results*.

- *silent*: **true** for the optimum performance of the simulation.
- *name* (optional): e.g., *Monte Carlo Analysis*.

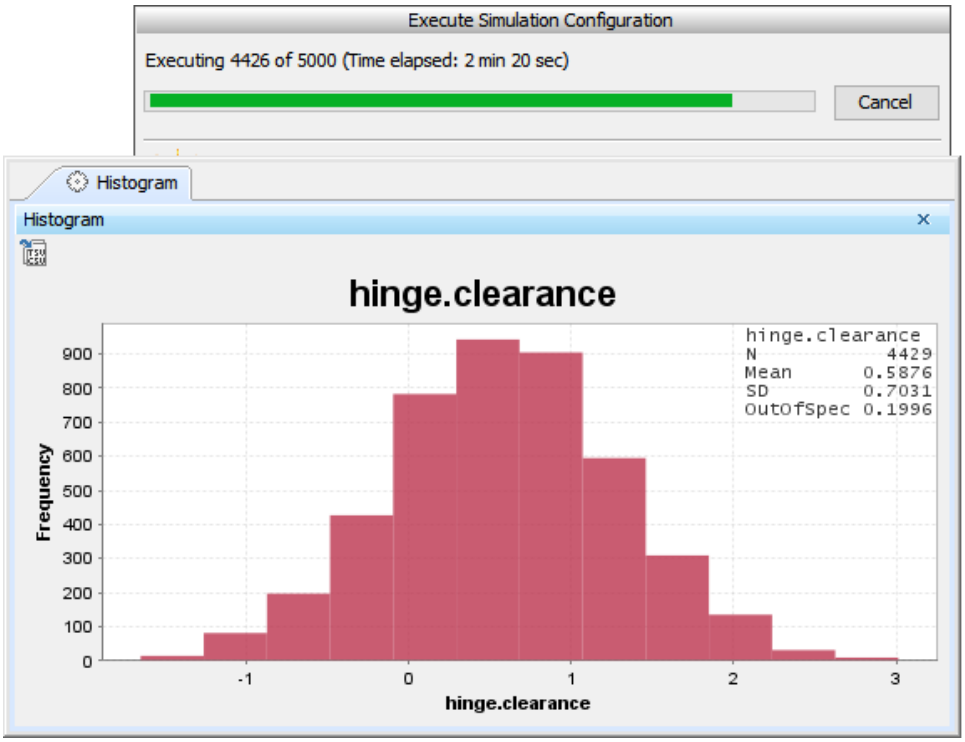
> **Note**
> - For a model that has Behaviors (Classifier Behavior and/or Part Property with Behaviors), see the *autoStart* tag in Simulation Config.
> - If *numberOfRuns* of any table (*executionTarget*) is more than 1, it will be ignored in the Monte Carlo simulation. The table, however, will be calculated only once.
> - If *silent* is set to false, the simulation will run with animation and idle time for each iteration, which is not practical for the Monte Carlo simulation.

2. Drag a *Histogram* control from the **Simulation** toolbar to the Simulation Configuration diagram. You can use the histogram as a local user interface by setting the following tags:
   - *represents*: the analysis Block, e.g., *Hinge Analysis*.
   - *value*: the monitored value property, e.g., *clearance*.
   - *dynamic*: **true** for viewing dynamically updated statistical values (**false** will open the histogram at the end of execution).
   - *name* (optional): e.g., *Histogram*.
3. Record generated value properties of every iteration using the *CSV Export* control by setting the following tags:
   - *represents*: the system model Block, e.g., *Hinge*.
   - *value*: related value properties, e.g., *a.width, b.width,* or *clearance*.
   - *fileName*: the exported file name, e.g., *clearance.csv*.
   - *name* (optional): e.g., *clearance*.
4. Drag the *Histogram* and *CSV Export* controls to the «SimulationConfig». *UI* and *executionListeners* tags will be updated with the names of the *Hist ogram* and *CSV Export* controls accordingly, e.g., *Histogram* and *clearance*.

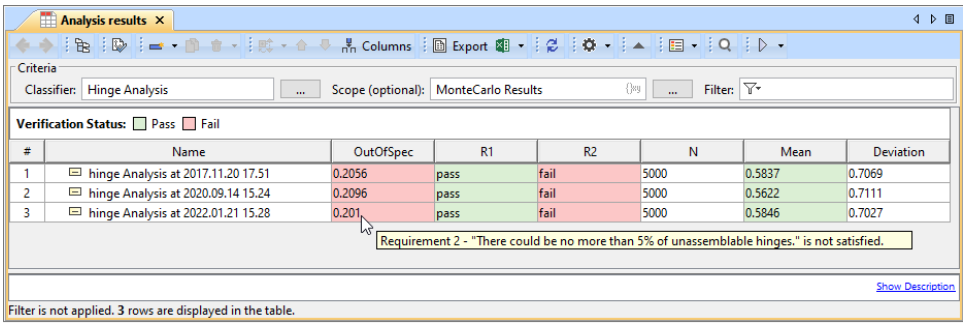


Running SimulationConfig and reviewing results

1. Run the SimulationConfig from the previous section, e.g., *Monte Carlo Analysis*.
2. During the simulation, the histogram will dynamically show the estimated distribution of the values of the analysis context definition at the top right, e.g., *hinge.clearance, N, Mean, SD,* and *OutOfSpec*.
3. The simulation progress bar will be shown with the number of iterations and time elapsed. You can click **Cancel** to terminate the simulation, and the analysis result will be saved at the terminated iteration.



4. The summary result is recorded in the Instance table along with «VerificationStatus» between value property and constraint, e.g., *Mean-R1* and *OutOfSpec-R2*. You can also see the details of both failed and passed constraints in the tooltip when hovering the mouse over any highlighted values.



5. Sampling results of value properties from applied distributions stereotypes are exported to the CSV file in the same location as the project. The file can be accessed through the link, e.g., *clearance.csv*, in the **Console** pane.

	A	B	C	D	E	F
1	time(ms)	a.width	b.width	c.width	d.width	clearance
2	0	1.9699	1.9527	29.7489	34.1094	0.438
3	0	1.9719	1.9589	30.1333	34.3102	0.2462
4	0	1.9793	1.9689	29.5465	34.9699	1.4751
5	0	1.9607	1.9623	31.0178	35.0214	0.0807
6	0	1.9783	1.9779	30.2774	35.2926	1.0591
7	0	1.953	1.9504	28.786	34.5033	1.8138
8	0	1.9794	1.9584	29.6696	34.3921	0.7848
9	0	1.966	1.9579	30.4552	34.4694	0.0903
10	0	1.9517	1.965	30.2331	34.6525	0.5027
11	0	1.9654	1.9678	30.4735	34.7705	0.3638
12	0	1.9719	1.9655	29.8754	34.7032	0.8903
13	0	1.9782	1.9779	29.3136	35.0491	1.7795
14	0	1.971	1.965	29.5043	34.9351	1.4948
15	0	1.9561	1.9783	29.3873	34.0719	0.7502
16	0	1.9538	1.9629	29.9016	34.4221	0.6039
17	0	1.9795	1.956	30.1975	34.5067	0.3736
18	0	1.9608	1.9632	29.7818	34.5114	0.8055
19	0	1.961	1.9762	29.4141	34.683	1.3316
20	0	1.9797	1.9608	30.5296	35.7698	1.2997