MapleMBSE 2024.0 Application Guide

MapleMBSE 2024.0 Application Guide

Contents

Introduction

MapleMBSE Application Guide Overview

MapleMBSE™ gives an intuitive, spread-sheet based user interface for entering detailed system design definitions, which include structures, behaviors, requirements, and parametric constraints.

The Application directory of your MapleMBSE installation contains six applications. Each of the chapters in this guide corresponds to one of the applications:

Chapter	Application Name	Description
1	Working With Blocks in MapleMBSE	The first application uses the TWCSysML-Structure.mse file to demonstrate the use of blocks in MapleMBSE
2	Creating a Model in MapleMBSE (Fitness Tracker Model)	This model uses the **TWCSysML-Model.mse** and **TWCSysML-ModelActivity.mse** files to demonstrate how to create a model in MapleMBSE which can be exported to the No Magic server.
3	Working With State Machine Diagrams in MapleMBSE	The example in this chapter defines how to create states, define their transitions and the events that trigger these transitions using MapleMBSE.
4	Count Down Timer Model	This chapter contains a model of Countdown Timer that uses **TWCSysML-Timer.mse** to create a simulatable Timer model.
5	Turbofan Engine Model	This example model is used to identify design points of a turbofan engine. MapleMBSE and Cameo Systems Modeler™ were used to create a turbofan example model
6	UAV Model	This model uses Object Oriented System Engineering Methodology (OOSEM) to design a conceptual model of an Unmanned Aerial Vehicle (UAV).
7	FMEA Template	This model is used to perform FMEA analysis by accessing SysML model elements from the No Magic server.
8	Interface Definition Template	This template is used to show details on the interfaces between the systems
9	Cost Analysis	This example illustrates cost analysis applied to materials used in a turbofan engine.

10	Variant Management Template	This example illustrates how to identify the multiple variants in the product line and their dependencies, to manage complexity.
11	Default Value Generation	The model in this chapter is used to illustrate the use of the Default Value Generation feature.
12	Instance Table Template	This example illustrates how the InstanceTable template makes it easier to filter and review information on instances, gained from the MatrixTemplate worksheet.
13	Spacecraft Model	This example illustrates the use of MapleMBSE to explore this SysML-based model.
14	Telescope Model	This example provides a different view of the model and illustrates the use of Predicate Filtering.
15	Turbojet Model	This example illustrates the use of the Formula Evaluation feature in the context of an instance matrix.
16	Variant Management	Using the Model-Based Product Line Engineering profile and MapleMBSE to create a variant of a model.
17	Downloading sysML Diagrams	Configuring the MapleMBSE sysML Diagrams plugin to view sysML model diagrams in a MapleMBSE worksheet.
18	Relations Matrix	This example displays the Verify relation between Component Value property and Requirements.
19	Predicates	Predicates defined with stereotypes allow you to add new elements to the model.

Related Products

MapleMBSE 2024 requires the following products:

- Microsoft® Excel® 2010 Service Pack 2, Excel 2016 or Excel 2019.
- Oracle® Java® SE Runtime Environment 8.

Note: MapleMBSE looks for a Java Runtime Environment in the following order:

1) If you use the -vm option specified in **OSGiBridge.init** (not specified by default)

2) If your environment has a system JRE (meaning either: JREs specified by the environment variables JRE_HOME and JAVA_HOME in this order, or a JRE specified by the Windows Registry (created by JRE installer)), MapleMBSE will use it.

3) The JRE installed in the MapleMBSE installation directory.

If you are using IBM® Rational® Rhapsody® with MapleMBSE, the following versions are supported: Rational Rhapsody Version 8.15, 8.3 and 8.4

- No Magic server 19.0 SP4, 2021x and 2022.x
- Magic Collaboration Studio 2021.x and 2022x

If you are using Eclipse Capella™ with MapleMBSE, the following version is supported:

- 5.x

If you are using Eclipse™, the following version is supported:

- 2020-3

Note that the architecture of the supported non-server products (that is, 32-bit or 64-bit) must match the architecture of your MapleMBSE architecture.

Related Resources

Resource	Description
MapleMBSE Installation Guide	System requirements and installation instructions for MapleMBSE. The **MapleMBSE Installation Guide** is available in the **Install.html** file located in the folder where you installed MapleMBSE, or on the website. **https://www.maplesoft.com/documentation_center/**
MapleMBSE User Guide	Instructions for using MapleMBSE software. The **MapleMBSE User Guide** is available in the folder where you installed MapleMBSE.
MapleMBSE Configuration Guide	This guide provides detailed instructions on working with configuration files and the configuration file language.
Frequently Asked Questions	You can find MapleMBSE FAQs here: https://faq.maplesoft.com
Release Notes	The release notes contain information about new features, known issues and release history from previous versions. You can find the release notes in your MapleMBSE installation directory.

For additional resources, visit **http://www.maplesoft.com/site_resources**.

Getting Help

To request customer support or technical support, visit **http://www.maplesoft.com/support**.

Customer Feedback

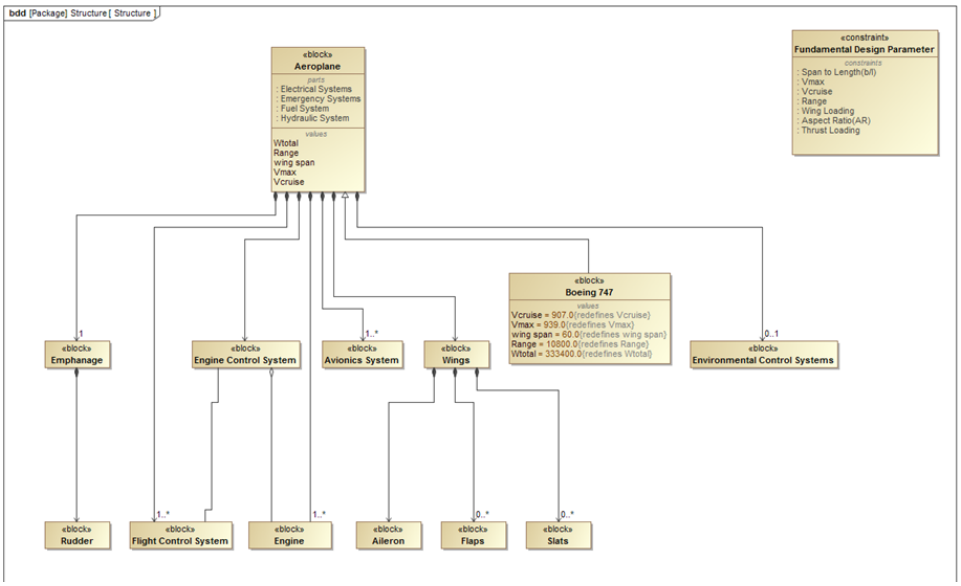
Maplesoft welcomes your feedback. For comments related to the MapleMBSE product documentation, contact doc@maplesoft.com.

Copyrights

1 Blocks in MapleMBSE

1.1 Blocks Table

The block diagram shown below is created using MapleMBSE and syncing it to the Teamwork Cloud. This chapter will explain how to work with blocks in MapleMBSE.



This example is created with the following package structure:

Model

+ Structure

The list of features available in MapleMBSE to define blocks are:

- Association
- Aggregation
- Composition
- Generalization
- OwnedEnd Multiplicty
- Constraint
- Property
  - Value

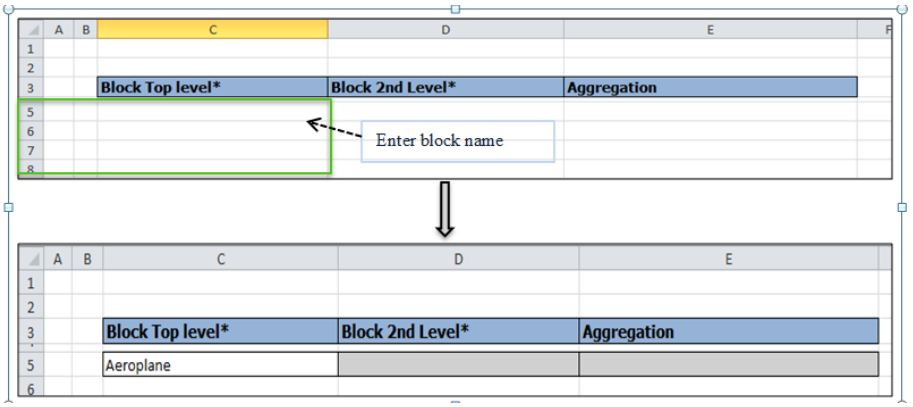
- Operations
- Redefine Value

The configuration file, **TWCSysML-Structure.mse** defines *seven* worksheet templates to work with blocks:

- The **BlocksTree** and **BlocksTreeDirect** worksheets are used to create blocks and their relationships.
- The **BlockProperties** worksheet is used to create generalizations, values and operations.
- The **Redefines** worksheet is used to specify values and redefine values to blocks.
- The **ConstraintTable** worksheet is used to create parameters, opaque expressions and define constraint blocks.
- **BlockConstraintTable** is used to create a direct association between Blocks and Constraint Blocks.
- **Parametric Table** is used to create a binding connector between the constraint parameters.

Creating a Block

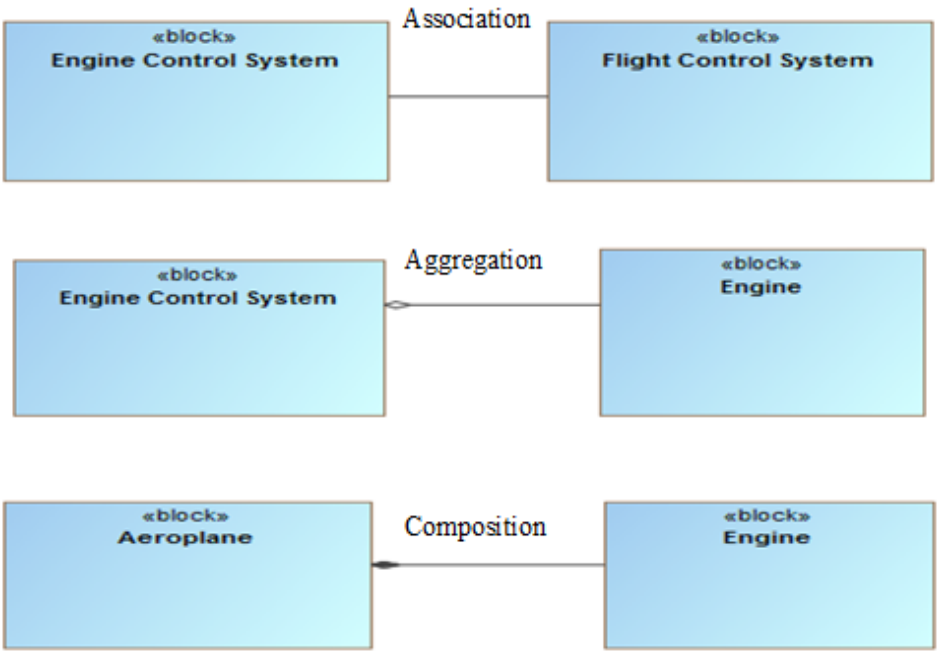
To create a block, enter a name for the block in the column C insertion area (the **Block Top Level** column) as shown below. A block called **Aeroplane** is created.



To create a relation between blocks, they must first be created in the **Block Top Level** column before they can be added in the second level.

Blocks can be created in all worksheets except for the **ConstraintTable** worksheet.

1.2 Creating Association, Aggregation and Composition



To create relations without direction, use the **BlocksTree** worksheet. The blocks need to be created as shown below.

To create Association relations:

1. Enter the block name in the **Block Top Level** column.

Block Top level*	Block 2nd Level*	Aggregation
Aeroplane		
Engine		
Engine Control System		
Flight Control System		

2. The row is highlighted as a duplicate key to indicate the block already exists. Enter the related block name in the **Block 2nd Level** column, in the same row.

Block Top level*	Block 2nd Level*	Aggregation
Aeroplane		
Engine		
Engine Control System	Duplicated Key	
Flight Control System		
Engine Control System		

3. MapleMBSE checks if the entry is valid by comparing it with existing blocks and will add **none** in the **Aggregation** column by default.

Block Top level*	Block 2nd Level*	Aggregation
Aeroplane		
Engine		
Engine Control System		
Flight Control System		
Engine Control System	Flight Control System	none

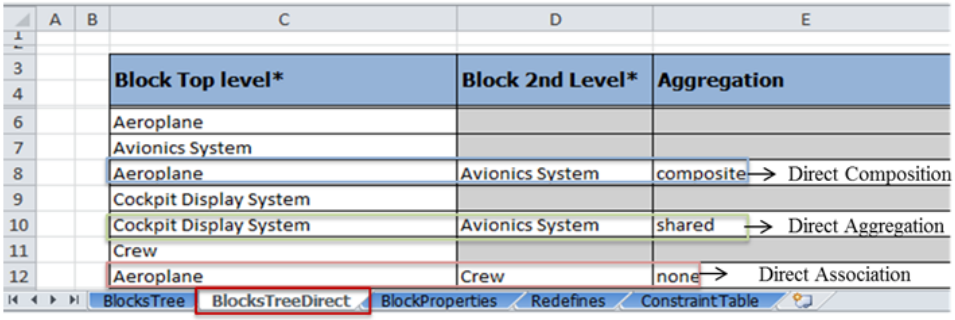
To create Aggregation and Composition relations, follow the previous steps by entering the owned end block (the class that has an association owned by another class) in column C, replace **none** with **composite** in the **Aggregation** column to create a composition relation and **shared** to create an aggregation relation.

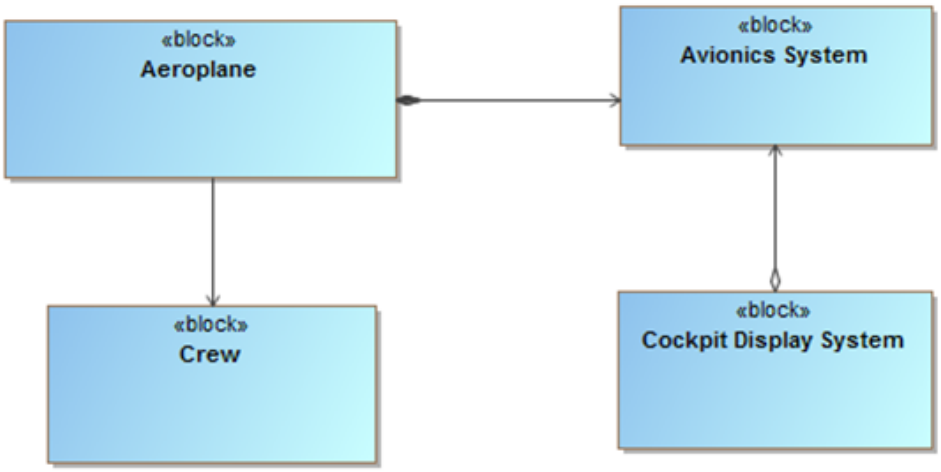
B	C	D	E	
	Block Top level*	Block 2nd Level*	Aggregation	
	Aeroplane			
	Engine			
	Engine Control System			
	Flight Control System			
	Aeroplane	Engine	composite	→ Composition
	Engine Control System	Engine	shared	→ Aggregation
	Flight Control System	Engine Control System	none	→ Association

BlocksTree | BlocksTreeDirect | BlockProperties | Redefines | ConstraintTable

1.3 Creating Direct Association, Aggregation and Composition

Use the **BlocksTreeDirect** worksheet to create relations with direction. Both tables are similar in defining relations, the type of relation differs based on the entry in the **Aggregation** column. Enter the class name in the **Block Top Level** column and enter the name of the **Attribute** class in the **Block 2nd Level** column and specify the aggregation type. The figure below shows relations between blocks with navigability.





The following table shows the necessary information needed to create a relation between blocks and their corresponding worksheet. The **Class** and **Attribute Class** columns imply that the class and its related class should be created first and then the respective aggregation type.

Worksheet	Type	Class	Attribute Class	Aggregation
BlocksTree	Association	x	x	None
	Aggregation	x	x	shared
	Composition	x	x	composite
BlocksTreeDirect	Direct Association	x	x	None
	Direct Aggregation	x	x	shared
	Direct Composition	x	x	composite

To represent multiplicity, at the Association level, enter a value for the respective blocks in the **Multiplicity** column as shown below.

Multiplicity
0
1
0..1
0..*
1..*

1.4 Block Generalization, Values and Operation

To generalize a block, enter the name of the generalizing block in the **Block Top Level** column of the **BlockProperties** worksheet and a corresponding value in the **Generalization Block** column.

	A	B	C	D	E	F
1						
2						
3			**Block Top Level**	**Generalization Block**	**Value**	**Operation**
5			Aeroplane			
6			Boeing 747			
7			Boeing 747	Aeroplane		

Use the same worksheet to add a value property to a block. Enter the block name in the **Block Top Level** column and then enter the value in the **Value** column.

	A	B	C	D	E	F
1						
2						
3			**Block Top Level**	**Generalization Block**	**Value**	**Operation**
5			Aeroplane			
6			Aeroplane		Wtotal	
7			Aeroplane		wing span	
8			Aeroplane		Vmax	
9			Aeroplane		Vcruise	
10			Aeroplane		Range	

Similarly, to add operations to the blocks, enter the block name in the **Block Top Level** column and the operation name in the **Operation** column.

	Block Top Level	Generalization Block	Value	Operation
5	Engine Control System			
6	Engine Control System			monitor engine temperature
7	Engine Control System			monitor engine pressure
8	Engine Control System			control fuel flow

In the **Redefines** worksheet, to enter a numerical value for Value Property use the **Value** column, as shown below.

	Block	Value Property	Value	Redefine	
				Block	Property
5	Aeroplane				
6	Aeroplane	Range			
7	Aeroplane	Vcruise			
8	Aeroplane	Vmax			
9	Aeroplane	wing span			
10	Aeroplane	Wtotal			
11	Boeing 747				
12	Boeing 747	Range	10800	Aeroplane	Range
13	Boeing 747	Vcruise	907	Aeroplane	Vcruise
14	Boeing 747	Vmax	939	Aeroplane	Vmax
15	Boeing 747	wing span	60	Aeroplane	wing span
16	Boeing 747	Wtotal	333400	Aeroplane	Wtotal

To redefine a property of an existing block, type a new value in the **Value** column along with information about the block from which the value is redefined. For example, **Aeroplane** has value properties: **Range**, **Vcruise**, **Vmax**, **wing span** and **Wtotal.** These properties are not defined with numerical values, as shown above (these fields can hold numerical values). The **Boeing 747** block is generalized to **Aeroplane**. To redefine the values from **Aeroplane** to **Boeing 747**, enter the same value for **Boeing 747** properties as that of **Aeroplane**. In the **Value** column, enter the desired values. Now to redefine, enter the block from which the value is redefined and the name of the value being redefined as shown below.

	Block	Value Property	Value	Redefine	
				Block	Property
5	Aeroplane				
6	Aeroplane	Range	Values to be		
7	Aeroplane	Vcruise	redefined from		
8	Aeroplane	Vmax	Aeroplane	Redefined Value	and
9	Aeroplane	wing span	Values redefined to	Block name	
10	Aeroplane	Wtotal	Boeing 747		
11	Boeing 747				
12	Boeing 747	Range	10800	Aeroplane	Range
13	Boeing 747	Vcruise	907	Aeroplane	Vcruise
14	Boeing 747	Vmax	939	Aeroplane	Vmax
15	Boeing 747	wing span	60	Aeroplane	wing span
16	Boeing 747	Wtotal	333400	Aeroplane	Wtotal

1.5 Constraint Blocks

The process for creating constraint blocks, relations and parameters is similar to that of working with blocks in the previous section.

Constraint Block Top Level	Constraint Block 2nd Level*	Constraint Parameters	Constraint Name	Constraint Block	Specification Name	OpaqueExpression
Aspect Ratio						
Aspect Ratio		AR				
Aspect Ratio			ratio	Aspect Ratio		
Aspect Ratio			ratio	Aspect Ratio	eq	b^2/s
Fundamental Design Parameter						
Fundamental Design Parameter	Aspect Ratio					

In the **Constraint Block Top Level** column, enter a constraint block and its breakdown in the **Constraint Block 2nd Level** column. This creates a direct composition relation between the blocks. In order to create different relations between the constraint blocks the configuration file has to be edited. To create parameters, enter the respective block in the **Constraint Block Top Level** column and the parameter name in the **Constraint Parameters** column. To add an equation to a constraint block, enter the block name followed by the name of the constraint in the **Constraint Name** column, as shown above. Enter the constraint block name in the **Constraint Block Top Level** column and a name for the specification equation in the **Specification** column. MapleMBSE accepts the entry. The corresponding field in the **Opaque Expression** column is empty. Enter an expression, as shown in the figure.

To create a direct association between the blocks and *Constraint Blocks* select the Block-ConstraintTable worksheet. Next, enter the block name in the **Block Name** column and *Constraint Block* in the **Constraint Block Name** column, as shown below.

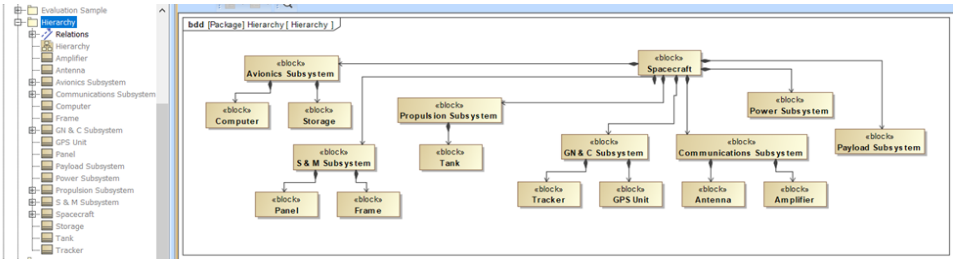
Block Name	Constraint Block Name
Analysis Context	
Fundamental Design Parameter	
Analysis Context	Fundamental Design Parameter

To create a binding connector between the parameters of the Constraint Blocks, you must first open the ParametricTable worksheet. Enter the *Constraint Block* and the parameter of the constraint that has to be connected in the **Constraint Parameter Column**, followed by the *Constraint Block* name and the target parameter in the respective column. MapleMBSE will automatically create a binding connector between the two parameters of the constraint blocks specified.

		Binding Connector	
Constraint Block	**Constraint Parameter**	**Constraint Block**	**Constraint Parameter**
Aspect Ratio			
Aspect Ratio	AR		
Fundamental Design Parameter			
Fundamental Design Parameter	AR		
Aspect Ratio	AR	Fundamental Design Parameter	AR
Fundamental Design Parameter	AR	Aspect Ratio	AR

1.6 Blocks Hierarchy

This template is used to create hierarchies with a direct composition relationship. In previous sections, the sub-blocks(subcomponents) should be created first before you add a relation between the blocks. This specific worksheet will allow you to create a new component and relations without the need to create the subblocks(subcomponents) first. To create a new component in the hierarchy enter the top-level component in the **Components** column and add the subcomponent name in the **Sub-Components L1** column. The top-level block and the sub-blocks will be added to the same package in the model.

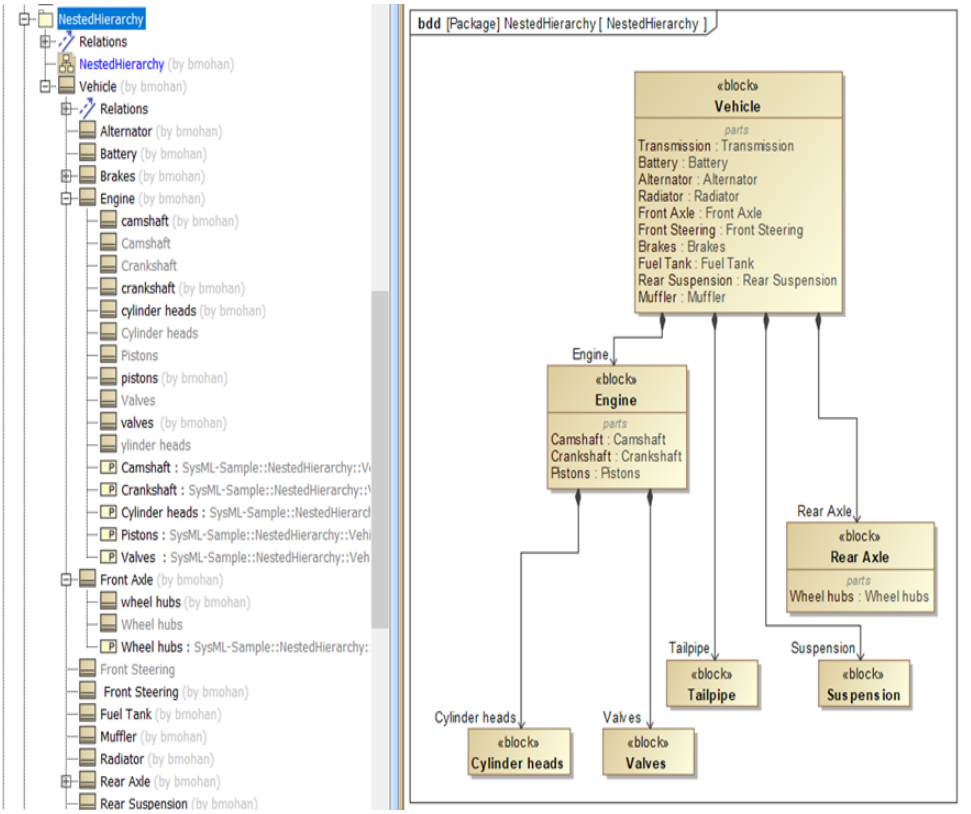


Components	Sub-Components L1	Sub-Components L2	Sub-Components L3
Amplifier			
Antenna			
Avionics Subsystem			
Avionics Subsystem	Computer		
Avionics Subsystem	Storage		
Communications Subsystem			
Communications Subsystem	Amplifier		
Communications Subsystem	Antenna		
Computer			
Frame			
GN & C Subsystem			
GN & C Subsystem	GPS Unit		
GN & C Subsystem	Tracker		
GPS Unit			
Panel			
Payload Subsystem			
Power Subsystem			
Propulsion Subsystem			
Propulsion Subsystem	Tank		
S & M Subsystem			
S & M Subsystem	Frame		
S & M Subsystem	Panel		
Spacecraft			
Spacecraft	Avionics Subsystem		
Spacecraft	Avionics Subsystem	Computer	
Spacecraft	Avionics Subsystem	Storage	
Spacecraft	Communications Subsystem		
Spacecraft	Communications Subsystem	Amplifier	
Spacecraft	Communications Subsystem	Antenna	
Spacecraft	GN & C Subsystem		
Spacecraft	GN & C Subsystem	GPS Unit	
Spacecraft	GN & C Subsystem	Tracker	

1.7 Nested Hierarchy

This template will also create the hierarchy with the direct composition relationship but it differs from the previous template by adding the new blocks with a nested structure in the model. As shown in the image below.

Components	Sub-Components L1	Sub-Components L2	Sub-Components L3
Vehicle			
Vehicle	Alternator		
Vehicle	Battery		
Vehicle	Brakes		
Vehicle	Brakes	Brake pads	
Vehicle	Brakes	Calipers	
Vehicle	Engine		
Vehicle	Engine	Camshaft	
Vehicle	Engine	Crankshaft	
Vehicle	Engine	Cylinder heads	
Vehicle	Engine	Pistons	
Vehicle	Engine	Valves	
Vehicle	Front Axle		
Vehicle	Front Axle	Wheel hubs	
Vehicle	Front Steering		
Vehicle	Fuel Tank		
Vehicle	Muffler		
Vehicle	Radiator		
Vehicle	Rear Axle		
Vehicle	Rear Axle	Wheel hubs	
Vehicle	Rear Suspension		
Vehicle	Suspension		
Vehicle	Tailpipe		
Vehicle	Transmission		


NestedHierarchy
Relations
NestedHierarchy (by bmohan)
Vehicle (by bmohan)
Relations
Alternator (by bmohan)
Battery (by bmohan)
Brakes (by bmohan)
Engine (by bmohan)
camshaft (by bmohan)
Camshaft
Crankshaft
crankshaft (by bmohan)
cylinder heads (by bmohan)
Cylinder heads
Pistons
pistons (by bmohan)
Valves
valves (by bmohan)
ylinder heads
Camshaft : SysML-Sample::NestedHierarchy::V
Crankshaft : SysML-Sample::NestedHierarchy::
Cylinder heads : SysML-Sample::NestedHierarcl
Pistons : SysML-Sample::NestedHierarchy::Vehi
Valves : SysML-Sample::NestedHierarchy::Veh
Front Axle (by bmohan)
wheel hubs (by bmohan)
Wheel hubs
Wheel hubs : SysML-Sample::NestedHierarchy:
Front Steering
Front Steering (by bmohan)
Fuel Tank (by bmohan)
Muffler (by bmohan)
Radiator (by bmohan)
Rear Axle (by bmohan)
Rear Suspension (by bmohan)
bdd [Package] NestedHierarchy [NestedHierarchy]
«block»
Vehicle
parts
Transmission : Transmission
Battery : Battery
Alternator : Alternator
Radiator : Radiator
Front Axle : Front Axle
Front Steering : Front Steering
Brakes : Brakes
Fuel Tank : Fuel Tank
Rear Suspension : Rear Suspension
Muffler : Muffler
Engine
«block»
Engine
parts
Camshaft : Camshaft
Crankshaft : Crankshaft
Pistons : Pistons
Rear Axle
«block»
Rear Axle
parts
Wheel hubs : Wheel hubs
Tailpipe
«block»
Tailpipe
Suspension
«block»
Suspension
Cylinder heads
«block»
Cylinder heads
Valves
«block»
Valves

2 The Fitness Tracker Model

The Excel Workbook template, **TWCSysML-Model.xlsx**, arranges the display of the elements in worksheets as defined in the configuration files.

The Package structure of the model is displayed in the **Packages** worksheet.

The Requirements packages are defined hierarchically; defining a top-level requirement, decomposing the requirements into groups and finally stating the requirements.

Once the requirements are defined, actors and their interactions with the system are created in the **Actors** and **UseCases** worksheets.

The **BlockTree** and **BlockProperties** worksheets are used to display information about the system context, specifications and relations.

The **BlockConnectorTable** and **BlockPropertyTable** worksheets create connections between block properties.

Once the structural aspects are defined, the system's behavior are defined by using the **TWCSysML-ModelActivity.mse** configuration file.

This example was created with the following package structure:

Model

- Requirements

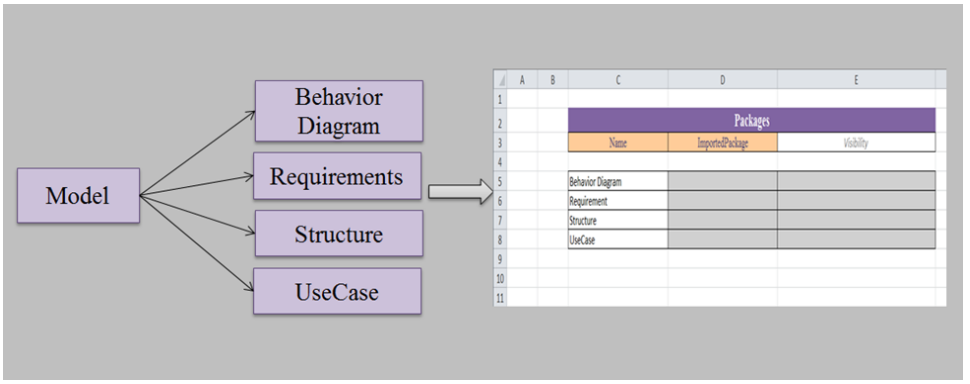
- Use Case

- Structure

- Behavior

2.1 Packages

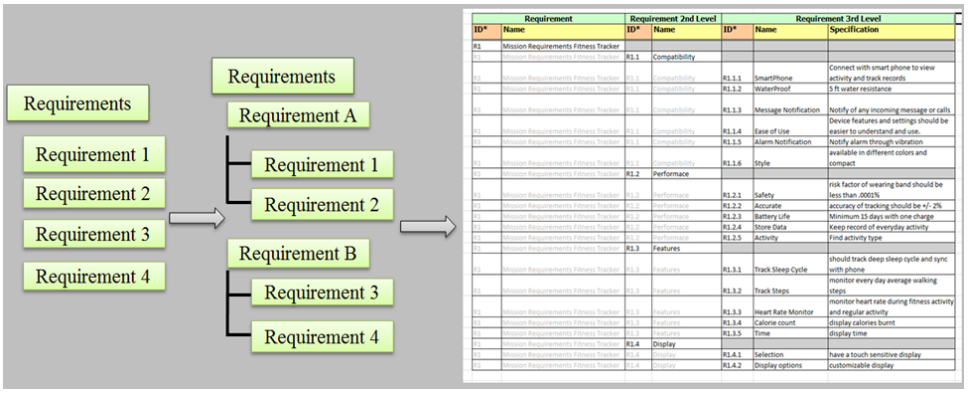
The **Packages** worksheet is used to organize the model elements into respective *Packages*. The user can create packages by specifying a name for the package under the **Name** column in the **Packages** worksheet. *Packages* are created as shown in the figure below. The configuration (.mse) file is configured in such as way so that when a user begins working directly in a worksheet, without creating any packages beforehand, the packages are automatically created and elements are displayed under the packages corresponding to the worksheet.



2.2 Requirements Table

The requirements defined for a system are used to identify the behavior, constraints, system specifications, etc. for which the system is modeled. Requirements can be categorized or grouped based on their definition of the system such as: performance, functional, constraints, etc.

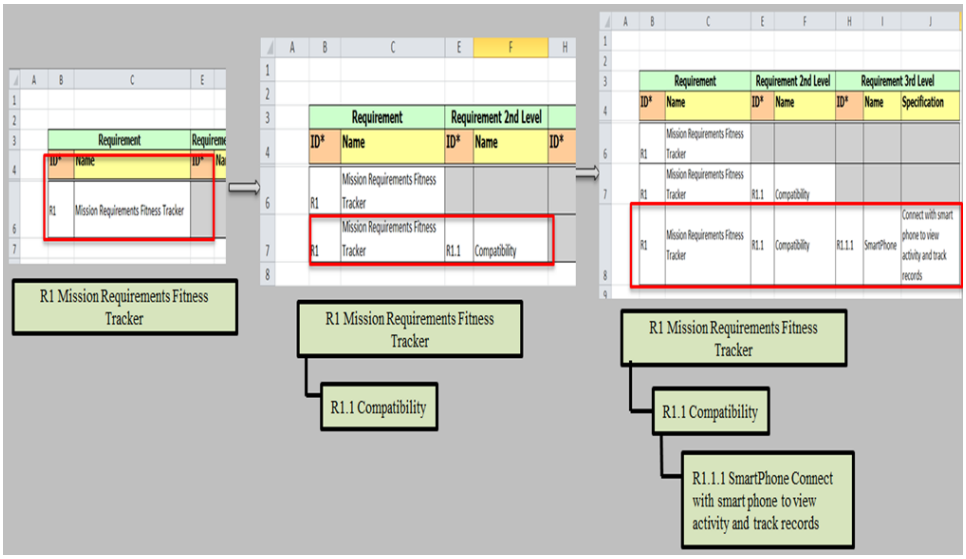
This example was created with requirements in three levels, as shown in the Excel file below. The number of levels and appearance of the **Requirements** worksheet is controlled by the configuration (.mse) file and can be changed by editing the configuration file.



Requirement		Requirement 2nd Level		Requirement 3rd Level		
ID*	Name	ID*	Name	ID*	Name	Specification
R1	Mission Requirements Fitness Tracker					
R1	Mission Requirements Fitness Tracker	R1.1	Compatibility			
R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.1	SmartPhone	Connect with smart phone to view activity and track records
R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.2	WaterProof	5 ft water resistance
R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.3	Message Notification	Notify of any incoming message or calls
R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.4	Ease of Use	Device features and settings should be easier to understand and use.
R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.5	Alarm Notification	Notify alarm through vibration
R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.6	Style	available in different colors and compact
R1	Mission Requirements Fitness Tracker	R1.2	Performace			
R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.1	Safety	risk factor of wearing band should be less than .0001%
R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.2	Accurate	accuracy of tracking should be +/- 2%
R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.3	Battery Life	Minimum 15 days with one charge
R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.4	Store Data	Keep record of everyday activity
R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.5	Activity	Find activity type
R1	Mission Requirements Fitness Tracker	R1.3	Features			
R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.1	Track Sleep Cycle	should track deep sleep cycle and sync with phone
R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.2	Track Steps	monitor every day average walking steps
R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.3	Heart Rate Monitor	monitor heart rate during fitness activity and regular activity
R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.4	Calorie count	display calories burnt
R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.5	Time	display time
R1	Mission Requirements Fitness Tracker	R1.4	Display			
R1	Mission Requirements Fitness Tracker	R1.4	Display	R1.4.1	Selection	have a touch sensitive display
R1	Mission Requirements Fitness Tracker	R1.4	Display	R1.4.2	Display options	customizable display

Creating Requirements

Requirements contain a unique **ID**, **Name** and **Specification** field to identify and name each requirement with a brief description.



To enter a new requirement:

1. Enter an ID for a top level requirement in the **ID** column, as shown above. MapleMBSE checks for duplicate entries and adds a row for the corresponding ID, enabling the user to enter a name and specification for the requirement.
2. To create a second level requirement, use the same ID and name as for the top-level requirement. MapleMBSE will detect it as a duplicate entry and highlight it as a duplicate key. Type an ID for the requirement in the **ID** column, of the **Requirement 2nd Level** section (column E), as shown above. MapleMBSE considers this to be a unique entry and enables the corresponding row to accept a name and description for the requirement.
3. To create a third-level Requirement, follow step 2, then enter a new ID in column H.

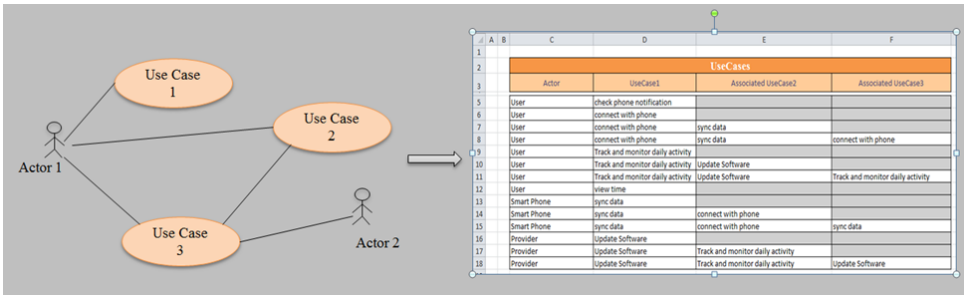
Follow the above steps to create any number of requirements. Excel identifies the **ID** columns as text format fields. The figure below shows the requirements created for the Fitness Tracker model, using the steps above.

	Requirement		Requirement 2nd Level		Requirement 2nd Level		
	ID*	Name	ID*	Name	ID*	Name	Specification
	R1	Mission Requirements Fitness Tracker					
	R1	Mission Requirements Fitness Tracker	R1.1	Compatibility			
	R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.1	SmartPhone	Connect with smart phone to view activity and track records
	R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.2	WaterProof	5 ft water resistance
	R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.3	Message Notification	Notify of any incoming message or calls
	R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.4	Ease of Use	Device features and settings should be easier to understand and use.
	R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.5	Alarm Notification	Notify alarm through vibration
	R1	Mission Requirements Fitness Tracker	R1.1	Compatibility	R1.1.6	Style	available in different colors and compact
	R1	Mission Requirements Fitness Tracker	R1.2	Performace			
	R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.1	Safety	risk factor of wearing band should be less than .0001%
	R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.2	Accurate	accuracy of tracking should be +/- 2%
	R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.3	Battery Life	Minimum 15 days with one charge
	R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.4	Store Data	Keep record of everyday activity
	R1	Mission Requirements Fitness Tracker	R1.2	Performace	R1.2.5	Activity	Find activity type
	R1	Mission Requirements Fitness Tracker	R1.3	Features			
	R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.1	Track Sleep Cycle	should track deep sleep cycle and sync with phone
	R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.2	Track Steps	monitor every day average walking steps
	R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.3	Heart Rate Monitor	monitor heart rate during fitness activity and regular activity
	R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.4	Calorie count	display calories burnt
	R1	Mission Requirements Fitness Tracker	R1.3	Features	R1.3.5	Time	display time
	R1	Mission Requirements Fitness Tracker	R1.4	Display			
	R1	Mission Requirements Fitness Tracker	R1.4	Display	R1.4.1	Selection	have a touch sensitive display
	R1	Mission Requirements Fitness Tracker	R1.4	Display	R1.4.2	Display options	customizable display

2.3 Use Case Table

The **Use Case** table describes the goals and interactions of the system model with external users (stakeholders).

To create a use case table, the actors of the system are identified, then the goals of the system and other functionality expected by the user.

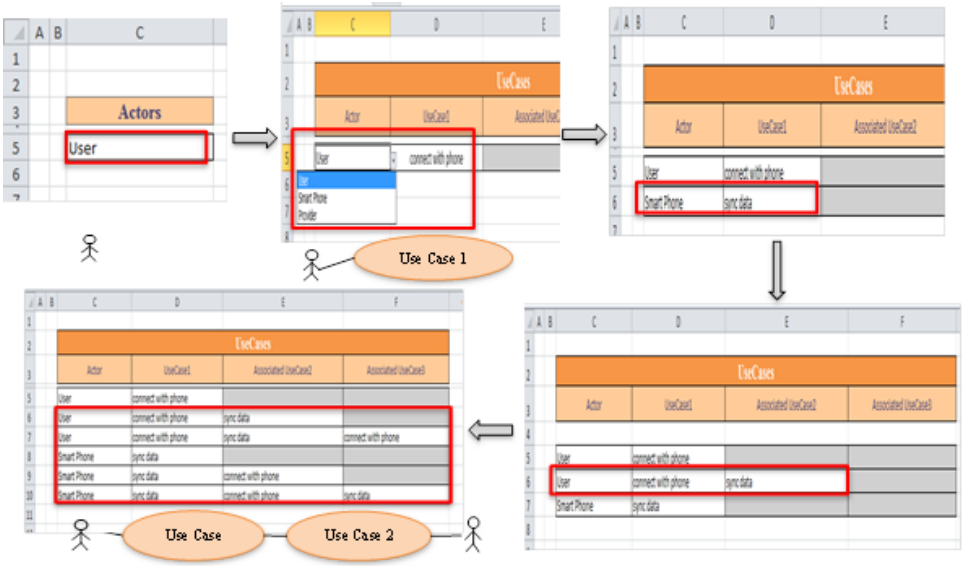


Creating a Use Case Table

Use cases and actors are identified by unique names. The configuration file is created in such a way that two different tables are needed to create the use case table. The **Actors** worksheet is used to list the identified actors of the system. The **UseCases** worksheet is then used to create the interaction between actors and use cases.

To create a Use Case table:

1. Create actors in the **Actors** worksheet as shown below.



2. In the **UseCases** worksheet, type the name of the actor to create a use case or select a name from the list. Type the use case in the **UseCase1** column as shown above.
3. To relate use cases, enter the actor name and corresponding use case in columns C and D respectively. MapleMBSE will highlight this as a duplicate key. Enter the other use case in the **Associated UseCase2** column (column E). This entry is considered valid and rows are automatically created to show that the association is bidirectional.

The **Use Case** table created for the Fitness Tracker is shown below. The **Associated UseCase3** column is automatically generated by MapleMBSE based on the input in the other columns. To associate use cases, they must already exist in the **UseCase1** column.

	C	D	E	F
2	UseCases			
3	Actor	UseCase1	Associated UseCase2	Associated UseCase3
5	User	check phone notification		
6	User	connect with phone		
7	User	connect with phone	sync data	
8	User	connect with phone	sync data	connect with phone
9	User	Track and monitor daily activity		
10	User	Track and monitor daily activity	Update Software	
11	User	Track and monitor daily activity	Update Software	Track and monitor daily activity
12	User	view time		
13	Smart Phone	sync data		
14	Smart Phone	sync data	connect with phone	
15	Smart Phone	sync data	connect with phone	sync data
16	Provider	Update Software		
17	Provider	Update Software	Track and monitor daily activity	
18	Provider	Update Software	Track and monitor daily activity	Update Software

2.4 Blocks Table

Blocks are created in a predefined package named **Structure**. From the configuration file, three worksheets are created:

- **BlockTree** to create blocks and parts,
- **BlockProperties** to create operations, generalizations and to create values for the blocks, and
- **BlockSatisfiesMatrix** to validate the model against the requirements to identify if all requirements have been met.

To make the example model simpler, only direct composition and generalization relations between blocks are used.

Blocks Tree

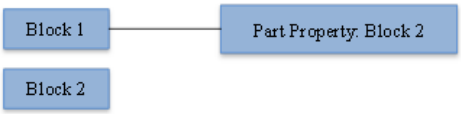
Blocks are identified uniquely by their names and can be accessed between worksheets. To identify the scope and working environment of the system, the mission context table is created using the **BlockTree** and **BlockProperties** worksheets.

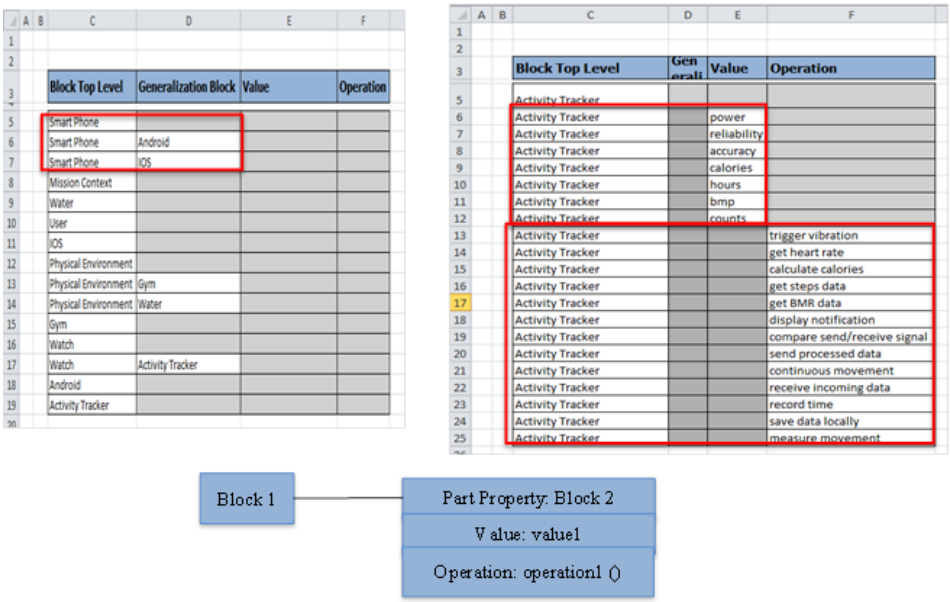
Once the system scope is defined, a black-box specification for the system of interest is created in terms of values and operations. These operations defined for the system are used to work with the behavior of the system defined in a different configuration file.

On defining activities of the system using the behavior configuration file, logical blocks are defined in the same table using **BlocksTree**. Finally, parts of the system are defined at

a physical level to meet the requirements specifications and also to satisfy the behavioral aspect of the system modeled.

1. To create a block, enter a name for the block in the **Block Top Level** column (column C), as shown below. Every unique entry in this column creates a block. Text entered is case sensitive so to create properties for a block in the second level, the block name should be accessed with the same case.





2. To create a direct compostion between blocks or to assign a block as part of another block type, enter the name of the block for which a part has to be created in the **Block Top Level** column followed by the part name in **Block 2nd Level**, as shown above. Now a direct association is created between **Mission Context** and **Activity Tracker**.

3. Blocks can be created at a third level in two ways: similar to adding blocks at the second level, specify the top level block, then the second level block, and finally the third level

block name. The figure below illustrates this way of adding a third level block. Since **Screen** is already a part property of **Activity Tracker**, physically adding a part to **Screen**, as shown in row 9, will automatically create row 6 and vice versa.

	Block Top level*	Block 2nd Level*	Block 3rd Level*
5	Activity Tracker - Physical	Screen	
6	Activity Tracker - Physical	Screen	Capacitive touch Screen
7	Capacitive touch Screen		
8	Screen		
9	Screen	Capacitive touch Screen	

To create generalizations, the **BlockProperties** worksheet is used. Similar to the above step, once blocks are created in the top level column, enter the block name in **Block Top Level** and the generalizing block in the **Generalization Block** column (cell D6). In the table, **Android** and **IOS** are generalized to **Smartphone**.

	Block Top Level	Generalization Block	Value	Operation
5	Smart Phone			
6	Smart Phone	Android		
7	Smart Phone	IOS		
8	Mission Context			
9	Water			
10	User			
11	IOS			
12	Physical Environment			
13	Physical Environment	Gym		
14	Physical Environment	Water		
15	Gym			
16	Watch			
17	Watch	Activity Tracker		
18	Android			
19	Activity Tracker			

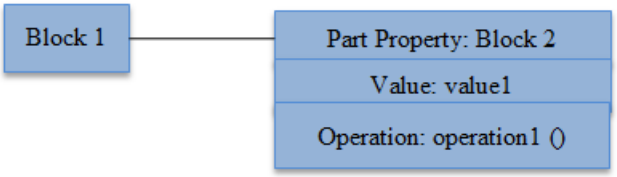
To create the value and operation property of a block, in the **BlockProperties** worksheet enter the name of the block that you want to assign a value. Since the block already exists, the row is highlighted as a duplicate key. Type the value in the **Value** column (column E),

as shown below, to add a value to the block, **Activity Tracker** for this example. Notice cells E6 to E12 have values assigned to **Activity Tracker**.

	A	B	C	D	E	F
1						
2						
3			**Block Top Level**	**Gen erali**	**Value**	**Operation**
5			Activity Tracker			
6			Activity Tracker		power	
7			Activity Tracker		reliability	
8			Activity Tracker		accuracy	
9			Activity Tracker		calories	
10			Activity Tracker		hours	
11			Activity Tracker		bmp	
12			Activity Tracker		counts	
13			Activity Tracker			trigger vibration
14			Activity Tracker			get heart rate
15			Activity Tracker			calculate calories
16			Activity Tracker			get steps data
17			Activity Tracker			get BMR data
18			Activity Tracker			display notification
19			Activity Tracker			compare send/receive signal
20			Activity Tracker			send processed data
21			Activity Tracker			continuous movement
22			Activity Tracker			receive incoming data
23			Activity Tracker			record time
24			Activity Tracker			save data locally
25			Activity Tracker			measure movement

In a single row for the block, either value or operation can be assigned to it. To assign operation to a block, a similar procedure is followed. Enter the block to which an operation has to be created in the **Block Top Level** column and enter the operation name in the **Operation** column (column F), as shown below.

	A	B	C	D	E	F
1						
2						
3			**Block Top Level**	**Gen erali**	**Value**	**Operation**
5			Activity Tracker			
6			Activity Tracker		power	
7			Activity Tracker		reliability	
8			Activity Tracker		accuracy	
9			Activity Tracker		calories	
10			Activity Tracker		hours	
11			Activity Tracker		bmp	
12			Activity Tracker		counts	
13			Activity Tracker			trigger vibration
14			Activity Tracker			get heart rate
15			Activity Tracker			calculate calories
16			Activity Tracker			get steps data
17			Activity Tracker			get BMR data
18			Activity Tracker			display notification
19			Activity Tracker			compare send/receive signal
20			Activity Tracker			send processed data
21			Activity Tracker			continuous movement
22			Activity Tracker			receive incoming data
23			Activity Tracker			record time
24			Activity Tracker			save data locally
25			Activity Tracker			measure movement

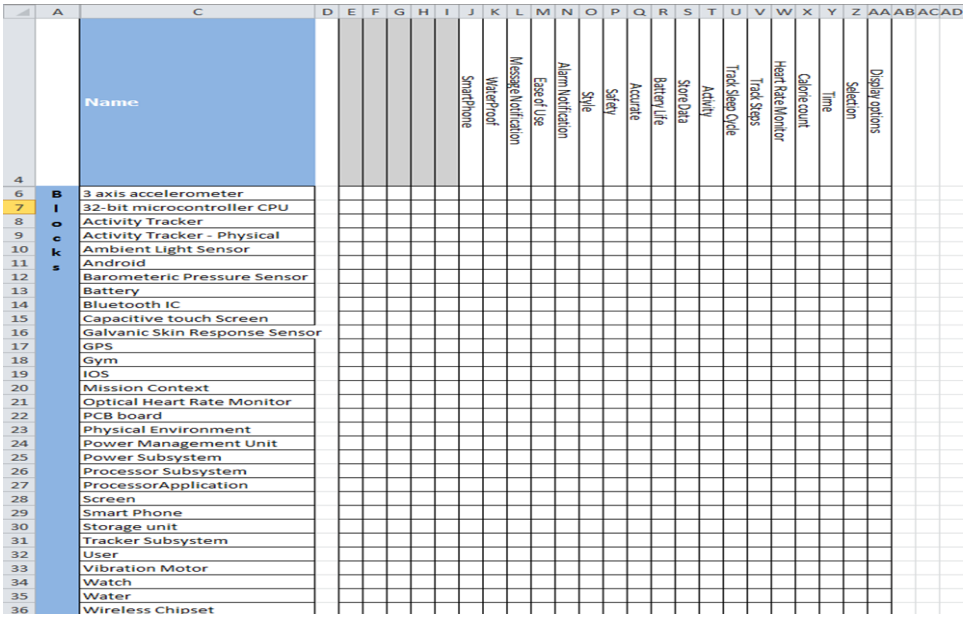


Using the steps mentioned above, the **Activity Tracker** is created and the block table at the physical level is shown while the rest of the inputs are filtered.

Block Top level*	Block 2nd Level*	Block 3rd Level*
3 axis accelerometer		
32-bit microcontroller CPU		
Activity Tracker - Physical		
Activity Tracker - Physical	Power Subsystem	
Activity Tracker - Physical	Power Subsystem	Battery
Activity Tracker - Physical	Power Subsystem	Power Management Unit
Activity Tracker - Physical	Processor Subsystem	
Activity Tracker - Physical	Processor Subsystem	32-bit microcontroller CPU
Activity Tracker - Physical	Processor Subsystem	Bluetooth IC
Activity Tracker - Physical	Processor Subsystem	PCB board
Activity Tracker - Physical	Processor Subsystem	ProcessorApplication
Activity Tracker - Physical	Processor Subsystem	Vibration Motor
Activity Tracker - Physical	Processor Subsystem	Wireless Chipset
Activity Tracker - Physical	Screen	
Activity Tracker - Physical	Screen	Capacitive touch Screen
Activity Tracker - Physical	Tracker Subsystem	
Activity Tracker - Physical	Tracker Subsystem	3 axis accelerometer
Activity Tracker - Physical	Tracker Subsystem	Ambient Light Sensor
Activity Tracker - Physical	Tracker Subsystem	Barometeric Pressure Sensor
Activity Tracker - Physical	Tracker Subsystem	Galvanic Skin Response Sensor
Activity Tracker - Physical	Tracker Subsystem	Optical Heart Rate Monitor
Ambient Light Sensor		
Barometeric Pressure Sensor		
Battery		
Bluetooth IC		
Capacitive touch Screen		
Galvanic Skin Response Sensor		
Optical Heart Rate Monitor		
PCB board		
PCB board	Storage unit	
Power Management Unit		
Power Subsystem		
Power Subsystem	Battery	
Power Subsystem	Power Management Unit	
Processor Subsystem		
Processor Subsystem	32-bit microcontroller CPU	
Processor Subsystem	Bluetooth IC	
Processor Subsystem	PCB board	
Processor Subsystem	PCB board	Storage unit
Processor Subsystem	ProcessorApplication	
Processor Subsystem	ProcessorApplication	32-bit microcontroller CPU
Processor Subsystem	Vibration Motor	
Processor Subsystem	Wireless Chipset	
ProcessorApplication		
ProcessorApplication	32-bit microcontroller CPU	
Screen		
Screen	Capacitive touch Screen	
Storage unit		
Tracker Subsystem		
Tracker Subsystem	3 axis accelerometer	
Tracker Subsystem	Ambient Light Sensor	
Tracker Subsystem	Barometeric Pressure Sensor	
Tracker Subsystem	Galvanic Skin Response Sensor	
Tracker Subsystem	Optical Heart Rate Monitor	
Vibration Motor		
Wireless Chipset		

Block Satisfaction Matrix

The **Block Satisfaction Matrix** is used to verify whether the blocks created satisfy the requirements. The matrix template is created automatically using the information from the **Blocks** and **Requirements** worksheets.



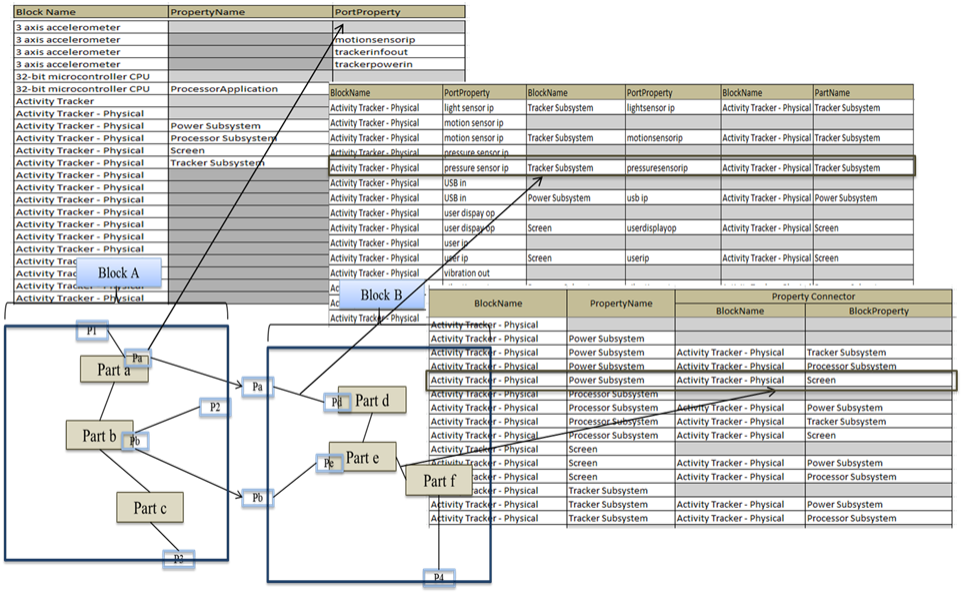
		Name	SmartPhone	WaterProof	Message Notification	Ease of Use	Alarm Notification	Style	Safety	Accurate	Battery Life	Store Data	Activity	Track Sleep Cycle	Track Steps	Heart Rate Monitor	Calorie count	Time	Selection	Display options
6	Blocks	3 axis accelerometer																		
7		32-bit microcontroller CPU																		
8		Activity Tracker																		
9		Activity Tracker - Physical																		
10		Ambient Light Sensor																		
11		Android																		
12		Barometeric Pressure Sensor																		
13		Battery																		
14		Bluetooth IC																		
15		Capacitive touch Screen																		
16		Galvanic Skin Response Sensor																		
17		GPS																		
18		Gym																		
19		IOS																		
20		Mission Context																		
21		Optical Heart Rate Monitor																		
22		PCB board																		
23		Physical Environment																		
24		Power Management Unit																		
25		Power Subsystem																		
26		Processor Subsystem																		
27		ProcessorApplication																		
28		Screen																		
29		Smart Phone																		
30		Storage unit																		
31		Tracker Subsystem																		
32		User																		
33		Vibration Motor																		
34		Watch																		
35		Water																		
36		Wireless Chipset																		

To create a satisfy relation between the blocks and requirements, identify the block that satisfies a requirement and in their intersection of row and column, enter 'x' to indicate that the corresponding requirement has been met. This creates a satisfy relation between block and requirement.

2.5 Internal Blocks Table

In the previous sections the system of interest has been defined with operations, values, and by different parts of the system. In this section, we will define how these parts of the system and its properties, will interact with each other.

To define ports through which the system interacts with other parts and subsystems, we create ports to blocks and then represent how these ports are connected. As shown in the diagram below, we can represent the interaction of block properties using ports and connectors.



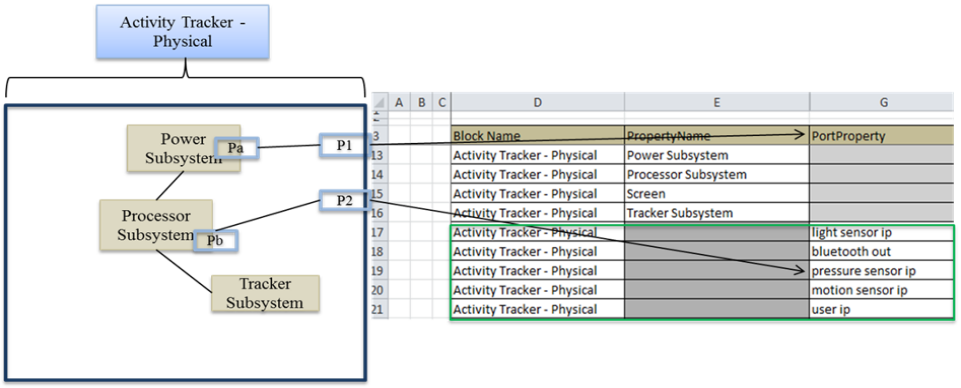
Block Property Table

This worksheet displays the blocks and their part properties based on how they are defined in previous worksheets. In addition to the part properties, you can create ports by using the **PortProperty** column.

Creating an entry is similar to entries discussed in other sections:

1. Specify the block to which a port has to be created
2. In the **PortProperty** column, enter a name for the port.

In the example below for the **Activity Tracker- Physical** block, the **PropertyName** column displays the existing part properties from previous worksheets. To create ports, enter the block name in the **Block Name** column (column D) and the port name in the **PortProperty** column (column G).



	A	B	C	D	E	G
3				Block Name	PropertyName	PortProperty
13				Activity Tracker - Physical	Power Subsystem	
14				Activity Tracker - Physical	Processor Subsystem	
15				Activity Tracker - Physical	Screen	
16				Activity Tracker - Physical	Tracker Subsystem	
17				Activity Tracker - Physical		light sensor ip
18				Activity Tracker - Physical		bluetooth out
19				Activity Tracker - Physical		pressure sensor ip
20				Activity Tracker - Physical		motion sensor ip
21				Activity Tracker - Physical		user ip

Property Connector Table

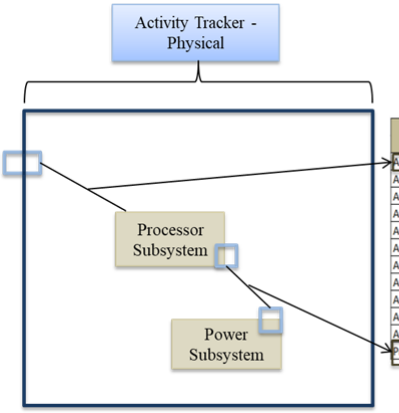
The Property Connector Table is used to connect part properties within the block, as shown below.

To create a connector between the ports of the different system example between Activity Tracker – Physical's port Bluetooth out to the Process Subsystem bluetoothout port, in the Block Name column enter the name of the block in this case it is the Activity Tracker – Physical and the port details in the Port Name column this entry will be highlighted as duplicate by MapleMBSE cause this relation already exist in the model now in the Property Connector columns enter the Block and port to which the connector has to be created.

BlockName	Port Name	Property Connector	
		BlockName	Block Port
Activity Tracker - Physical	galvanic sensor ip	Tracker Subsystem	galvanic sensor ip
Activity Tracker - Physical	heart sensor ip	Tracker Subsystem	heartsensorip
Activity Tracker - Physical	light sensor ip	Tracker Subsystem	lightsensor ip

BlockName	Port Name	Property Connector	
		BlockName	Block Port
Activity Tracker - Physical	galvanic sensor ip	Tracker Subsystem	galvanic sensor ip
Activity Tracker - Physical	heart sensor ip	Tracker Subsystem	heartsensorip
Activity Tracker - Physical	light sensor ip	Tracker Subsystem	lightsensor ip
Activity Tracker - Physical	bluetooth out		

BlockName	Port Name	Property Connector	
		BlockName	Block Port
Activity Tracker - Physical	galvanic sensor ip	Tracker Subsystem	galvanic sensor ip
Activity Tracker - Physical	heart sensor ip	Tracker Subsystem	heartsensorip
Activity Tracker - Physical	light sensor ip	Tracker Subsystem	lightsensor ip
Activity Tracker - Physical	bluetooth out	Processor Subsystem	bluetoothout



BlockName	Port Name	Property Connector	
		BlockName	Block Port
Activity Tracker - Physical	bluetooth out	Processor Subsystem	bluetoothout
Activity Tracker - Physical	galvanic sensor ip	Tracker Subsystem	galvanic sensor ip
Activity Tracker - Physical	heart sensor ip	Tracker Subsystem	heartsensorip
Activity Tracker - Physical	light sensor ip	Tracker Subsystem	lightsensor ip
Activity Tracker - Physical	motion sensor ip	Tracker Subsystem	motionsensorip
Activity Tracker - Physical	pressure sensor ip	Tracker Subsystem	pressuresensorip
Activity Tracker - Physical	USB in	Power Subsystem	usb ip
Activity Tracker - Physical	user dispay op	Screen	userdisplayop
Activity Tracker - Physical	user ip	Screen	userip
Activity Tracker - Physical	vibration out	Processor Subsystem	vibrationout
Activity Tracker - Physical	wireless connect	Processor Subsystem	wirelessconnect
Processor Subsystem	displayop	ProcessorApplication	displayop

2.6 Activity Diagram

An Activity Diagram is used to define system behavior. The top level system functionality is initially defined and these defined actions are further decomposed to show the logical behavior of the system.

Only call behavior actions with pins are used in this model.

Creating Actions for an Activity

Using the **Use Case** diagram, we have identified that the basic use case for the model is to track daily activity.

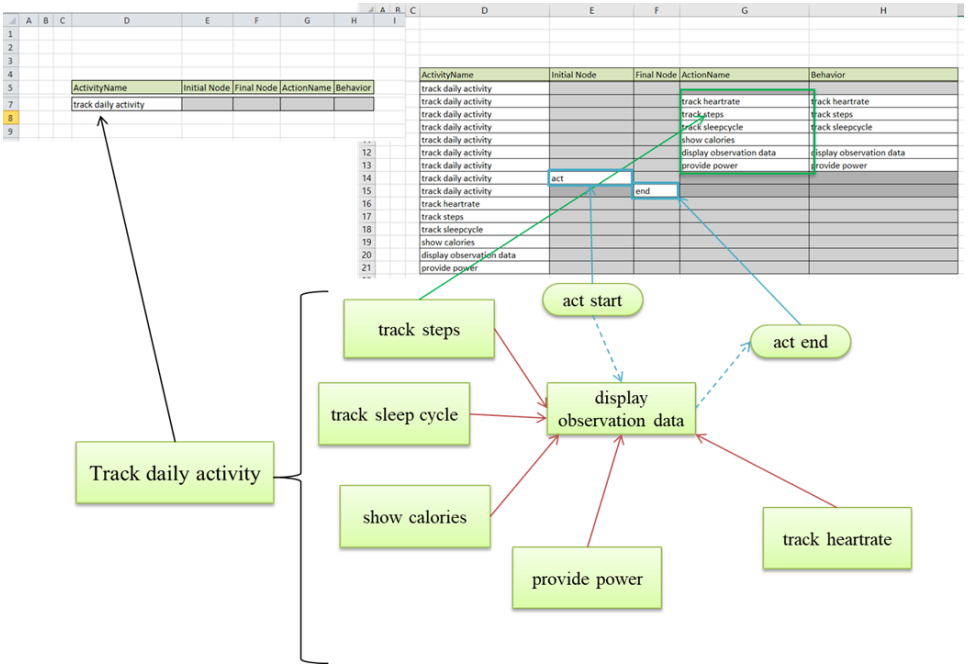
The **ActivityTable** worksheet is used to create activities, action, control flow and object flows. To create an activity diagram named **track daily activity**, enter the name in the **ActivityName** column, as shown below. Once we create the actions for the activity, we need to now create flow between the actions. In this model, control flows are used only to represent the start and end of an activity.

To create control flows to denote the start and end of the activity, use the **ControlFlowName** column. Following the creation of the control flows, object flows can be created in the same worksheet.

Enter a name for the object flow in the **ObjectFlowName** column. As shown in the diagram below, control flows and object flows are created for the activity diagram, **track daily activity**. Linking these flows with actions is discussed in the following section.

Creating Actions for an Activity

Using the Use Case diagram we have identified the basic use case for our model is to track daily activity. The **ActivityTable** worksheet is used to create activities, action, control flow and object



To create an Activity Diagram, first create an activity and its elements in **ActivityTable**. Enter the name of the activity in column D (**ActivityName**) as shown above. Once an activity is created we can create its initial node, final node and its actions in the respective column as shown. Use column H (**Behavior**) to allocate a behavior to the actions we created. In order to allocate a behavior, it should exist as an activity in the ActivityName Column.

Adding New Duration Constraints

The **DurationConstraint** worksheet is used to define the constraints in terms of durations for the activities. The **Activities** column displays the list of all the activities defined for the model.

To add a new duration constraint, enter the activity in the first column followed by the name of the duration in the **Duration** column. This will create a duration for the activity but does

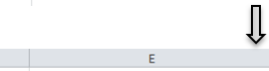
not add the duration specification. Use the **Specification** column to add the duration specification in the format *min..max* where *min* is the minimum constraint value and *max* is the maximum constraint value. The min and max value are joined by the double period (..).

Activities	Duration	Specification
track daily activity		
display notification		
connect smartphone		
connect smartphone	durationConnect	5 .. 10
provide power		
display observation data		
track sleepcycle		
track heartrate		
track heartrate	durationHRt	45 .. 60
display time		
display time	responseTime	0.1 .. 1
track steps		

Creating Flows

Using the ObjectFlow and ControlFlow Table we can now complete the activity diagram. To create an object flow between two actions in the ObjectFlow Table, Enter the activity under which the action was created in ActivityTable under Column D and the action name in Column E(Action Name Column) and the other action to be link with in Column G and its activity in Column F. Now MapleMBSE will create the input and output pins for the respective actions. In the case of Behavior being allocated to the action being links, MapleMBSE will automatically create parameters.

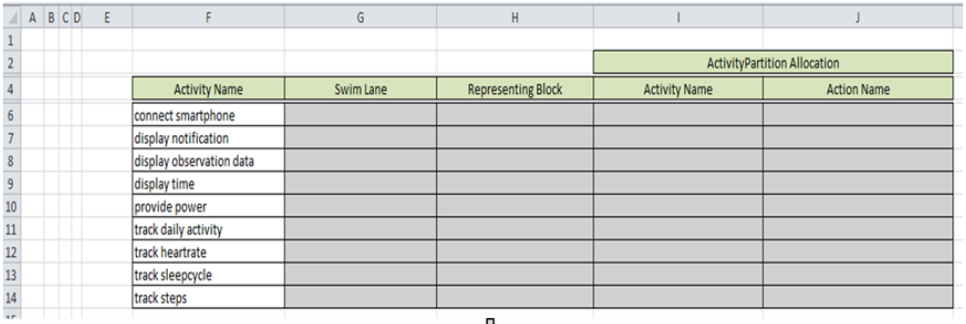
		Object Flow	
Activity Name	Action Name	Activity Name	Action Name
track daily activity			
track daily activity	track heartrate		
track daily activity	track steps		
track daily activity	track sleepcycle		
track daily activity	show calories		
track daily activity	display observation data		
track daily activity	act		
track daily activity	end		
track daily activity	provide power		



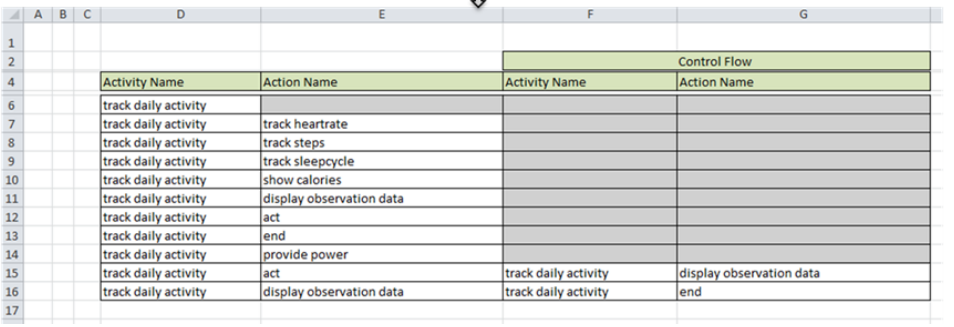
		Object Flow	
Activity Name	Action Name	Activity Name	Action Name
track daily activity			
track daily activity	track heartrate		
track daily activity	track steps		
track daily activity	track sleepcycle		
track daily activity	show calories		
track daily activity	display observation data		
track daily activity	act		
track daily activity	end		
track daily activity	provide power		
track daily activity	track heartrate	track daily activity	display observation data

		Object Flow	
Activity Name	Action Name	Activity Name	Action Name
track daily activity			
track daily activity	track heartrate		
track daily activity	track steps		
track daily activity	track sleepcycle		
track daily activity	show calories		
track daily activity	display observation data		
track daily activity	act		
track daily activity	end		
track daily activity	provide power		
track daily activity	track heartrate	track daily activity	display observation data
track daily activity	track steps	track daily activity	display observation data
track daily activity	track sleepcycle	track daily activity	display observation data
track daily activity	show calories	track daily activity	display observation data
track daily activity	provide power	track daily activity	display observation data

To create control flow between nodes we follow the same steps we used for creating object flow, In ControlFlow Table, enter the activity name in Column C(ActivityName) and the node in Column D(Activity Node) and the action node to be linked with in Column F and its activity in Column E. Similarly we can link nodes and actions with Control or object flows.



Activity Name	Swim Lane	Representing Block	ActivityPartition Allocation: Activity Name	ActivityPartition Allocation: Action Name
connect smartphone				
display notification				
display observation data				
display time				
provide power				
track daily activity				
track heartrate				
track sleepcycle				
track steps				



Activity Name	Action Name	Control Flow: Activity Name	Control Flow: Action Name
track daily activity			
track daily activity	track heartrate		
track daily activity	track steps		
track daily activity	track sleepcycle		
track daily activity	show calories		
track daily activity	display observation data		
track daily activity	act		
track daily activity	end		
track daily activity	provide power		
track daily activity	act	track daily activity	display observation data
track daily activity	display observation data	track daily activity	end

To create an object flow between parameter and an action we use the same method we used for creating object flow between actions, MapleMBSE will automatically identify the element type and create the corresponding links.

Allocate Actions to Swim Lanes

			ActivityPartition Allocation	
Activity Name	Swim Lane	Representing Block	Activity Name	Action Name
connect smartphone				
display notification				
display observation data				
display time				
provide power				
track daily activity				
track heartrate				
track sleepcycle				
track steps				
display observation data	PA	ProcessorApplication		

			ActivityPartition Allocation	
Activity Name	Swim Lane	Representing Block	Activity Name	Action Name
connect smartphone				
display notification				
display observation data				
display time				
provide power				
track daily activity				
track heartrate				
track sleepcycle				
track steps				
display observation data	PA	ProcessorApplication		
display observation data	PA	ProcessorApplication	display observation data	get sleep rate

Before we can allocate actions to a swim lane. We first create swim lanes and assign a block to the swim lane. BlocksTable tab displays the list of available blocks that can be assigned to a swim lane. In SwimLanesTable tab ActivityName column displays the activities created using previous tables. To create a swim lane enter a name in Column G (Swim Lane) and the block it represents in Column H(Representing Block). Now we have created the swim lanes with the respective blocks it represents. To allocate an action enter the name of the activity in column F(Activity Name) and the swim lane name in column G. MapleMBSE will highlight this record as duplicate field, enter the action to be allocated in column J and the activity in column I to complete the allocation. MapleMBSE will now accept this as a valid record and remove the error. Similar we can access different activities we created and allocate the actions to swim lanes.

3 State Machine Diagram

This section defines how to create states, define their transitions and the events that trigger these transitions using MapleMBSE. The configuration file, **TWCSysML-StateMachines.MSE** defines four worksheets that can be used to create states and define their transitions. The **TWCSysML-StateMachines.MSE** file is located in the **Application** subdirectory of your MapleMBSE installation directory. This example only covers the case where a transition is triggered by a signal event. The following package structure is followed:

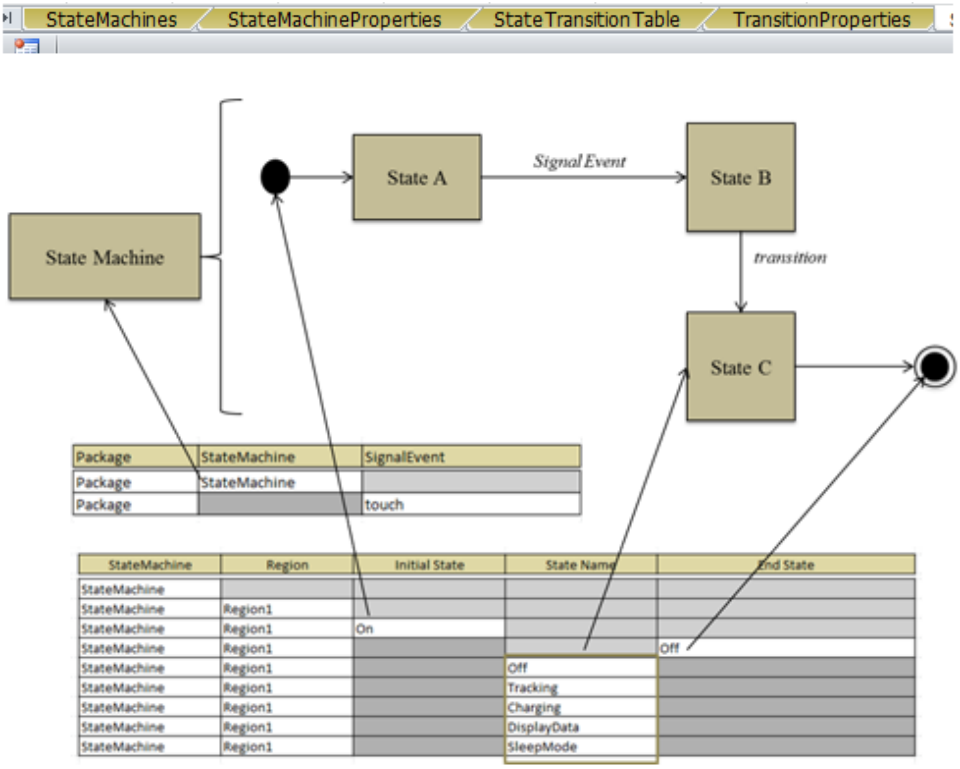
- Model

-Package

+StateMachine

+Region

+SignalEvent



3.1 How to Create a State Machine Diagram

In the **StateMachines** worksheet enter **Package** name as **Package**, and **StateMachine** name as **StateMachine**. These naming conventions can be changed by modifying the configuration file.

Package	StateMachine	SignalEvent
Package	StateMachine	
Package		touch

Once the state machine is created, we have to define a region in which states will be created. To create a region, use the **Pseudo State Properties** worksheet. Enter a name for the region, as shown in the table below (**Region1** is used as default as defined in configuration file). This table is also used to create the pseudo state (**PseudoState** column) and final state (**FinalState** column) that defines the start and end of the state machine. Enter a name for the states, as shown below. We define the transition from the pseudo state in this worksheet, once we have created other states, and its transition in the **Transition Matrix Table** worksheet.

StateMachine	Region	Pseudo State	Final State	Source State	Transition	Target State
StateMachine						
StateMachine	Region1					

StateMachine	Region	Pseudo State	Final State	Source State	Transition	Target State
StateMachine						
StateMachine	Region1					
StateMachine	Region1		Off			
StateMachine	Region1	On				

3.2 How to Create States and Transitions

To create a transition between states in the **State Transition Table**, enter the source state in the **SourceState** column and the target in the **TargetState** column, as shown below. Once we create these transitions between the states, we can edit the properties of these transitions in **TransitionProperties** worksheet.

SourceState	TargetState
Charging	
DisplayData	
Off	
On	
SleepMode	
Tracking	

SourceState	TargetState
Charging	
DisplayData	
Off	
On	
SleepMode	
Tracking	
On	Tracking
Tracking	DisplayData
Tracking	Charging
Charging	SleepMode
Tracking	Off

3.3 How to Create Triggers with Signal Events

Initially, the **Transition Name** column will be displayed as a blank column since we haven't named the transitions. Enter a name for the transitions so they can be identified to create a trigger and assign a signal event. Enter the Transition name in the **Transition Name** column followed by the **Signal Event** name we created in **StateMachine Table**. MapleMBSE will accept this as a valid input and automatically populate the other fields.

Transition Name	Source State	Target State	Signal Event
	Tracking	Off	
	On	Tracking	
	Tracking	DisplayData	
	Tracking	Charging	
	Charging	SleepMode	

Transition Name	Source State	Target State	Signal Event
usercommand/power	Tracking	Off	
powerOn	On	Tracking	
touch	Tracking	DisplayData	
usb connect	Tracking	Charging	
Charge/Non-Tracking	Charging	SleepMode	

Transition Name	Source State	Target State	Signal Event
usercommand/power	Tracking	Off	
powerOn	On	Tracking	
touch	Tracking	DisplayData	
usb connect	Tracking	Charging	
Charge/Non-Tracking	Charging	SleepMode	
touch	Tracking	DisplayData	touch
usb connect	Tracking	Charging	usb connect

4 Countdown Timer Model

The example is create with the following package structure

Model

-Requirements

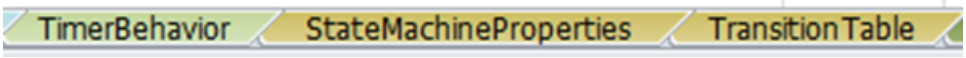
-Use Case

-Timer

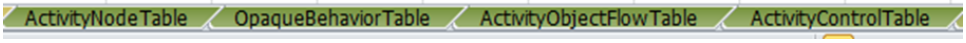
To create a Timer model we define the simplest requirements that is expected of the Timer. The model is required to have functions that enable the user to start, reset, pause, and stop the timer. When Timer reaches zero, the user must be notified and the timer should continue counting down. Keeping these as the only requirements, a Requirements table is initially created. From these requirements we identify the actors and use cases. We create a Timer block to define its behavior based on these identified Use Cases.

To define the Timer properties, we create operations and properties to the Timer block. To enable the user to reset, stop, pause, etc., we create these as signals so the user can command the system when it is being executed. **State Machine** and **Activities** are used to define the system behavior and its different states of operation.

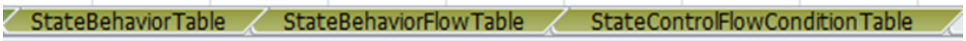
The **RequirementsTree** and **UseCases** worksheets are used to define the requirements that should be met by the model and its use cases. The **CountDownTimer**, **SignalTable**, and **TimeEventTable** worksheets are used to create blocks and events that will trigger the system to transition to a different state.



The **TimerBehavior** worksheet is used to create a *StateMachine* that will define the states at which the system will exist and its behavior at different states. It is also used to create operations and activities that will define system behavior. The **StateMachineProperties** worksheet is used to create the states and the **TransitionTable** worksheet is used to define their transition and events that triggered them.



ActivityNode Table and OpaqueBehavior Table are used to create activity nodes and behaviors. ActivityObjectFlow table and ActivityControlTable are used to create flows between the actions and nodes created in previous tables.



The **StateBehaviorTable**, **StateBehaviorFlowTable** and **StateControlFlowCondtionTable** worksheets are similar to that of previously mentioned worksheets. The only difference being that they are used to create activity flows that define states entry behavior.

4.1 Requirements Table

The **Requirements Table** worksheet is used to create *Requirements*. The configuration file is defined in a way that this table can be use to create two levels of requirements. As shown below, requirements for the system are created.

RequirementsSatisfy Table worksheet is used to create a *Satisfy* relation between the *Requirements*, *Blocks* and its properties. This table will be used to verify if the requirements are met once the system has been created.

Requirements Table

Requirement		Requirement 2nd Level		
ID*	**Name**	**ID***	**Name**	**Specification**
1	Timer			
1	Timer	1.1	Accurate	The timer should count down every 1 second.
1	Timer	1.2	Functions	The timer must have functions to start, reset, pause and notify user.
1	Timer	1.3	Working	The timer should continue counting even after 0, until user signals to stop.
1	Timer	1.4	Notify	The timer should notify the user at 0.

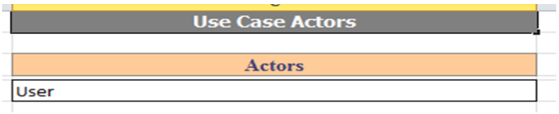
4.2 UseCase Table

The **Actors** tab is used to identify the actors, while the **UseCases** tab is used to associate these Actors with UseCases.

To create an association between Actor and UseCase, enter the Actor Name in the **Actor** column, followed by the UseCase in **UseCase1** column.

To create an association between UseCases, Enter the **Actor** name in **Actor** column followed by the UseCase name in the **UseCase1** column and associating UseCase in the **Associated-UseCase2** column.

The **UseCases** table is created as shown below:



Use Case Actors
Actors
User

UseCases			
Actor	UseCase1	Associated UseCase2	Associated UseCase3
User	count down		
User	count down	notified	
User	count down	notified	count down
User	count down	pause	
User	count down	pause	count down
User	count down	reset	
User	count down	reset	count down
User	notified		
User	notified	count down	
User	notified	count down	notified
User	notified	count down	pause
User	notified	count down	reset
User	pause		
User	pause	count down	
User	pause	count down	notified
User	pause	count down	pause
User	pause	count down	reset
User	reset		
User	reset	count down	
User	reset	count down	notified
User	reset	count down	pause
User	reset	count down	reset

4.3 CountDownTimer Table

This table is used to create the Timer block, signals, and events that will be used later in creating the model.

To create a block, enter the name in the **Block Name** column.

To create signals, enter a name for the signal in the **Signals** column, and its package name in the **PackageName** column.

Note: Two kinds of events can be created in this worksheet, Signal events and Time events. These events are created based on the signals that are being used.

Timer Events & Signals					
Package Name	**Block Name**	**Signals**	**Signal Events**	**Timed Event**	**Instances**
CountDownTimer					
CountDownTimer	Timer				
CountDownTimer					instance
CountDownTimer		reset			
CountDownTimer		notified			
CountDownTimer		timeup			
CountDownTimer		start			
CountDownTimer		pause			
CountDownTimer		stop			
CountDownTimer		resume			
CountDownTimer			startEvent		
CountDownTimer			stopEventA		
CountDownTimer			pauseEvent		
CountDownTimer			resumeEvent		
CountDownTimer			stopEventB		
CountDownTimer			stopEvent		
CountDownTimer			resetEvent		
CountDownTimer			notifyEvent		
CountDownTimer			timeupEvent		
CountDownTimer				TimeEvent	

Signal Table

The **Signal** table is an extension of the previous section. Here, we relate the signals that were created with the SignalEvent. Later in the model, we will use these signal events as triggers to define transition between states.

To assign a signal to *SignalEvent*, enter the *SignalEvent* name from the previous table and its corresponding signal in the **Signals** column.

Signal Event	
SignalEvent	**Signals**
notifyEvent	
pauseEvent	
resetEvent	
resumeEvent	
startEvent	
stopEvent	
stopEventA	
stopEventB	
timeupEvent	

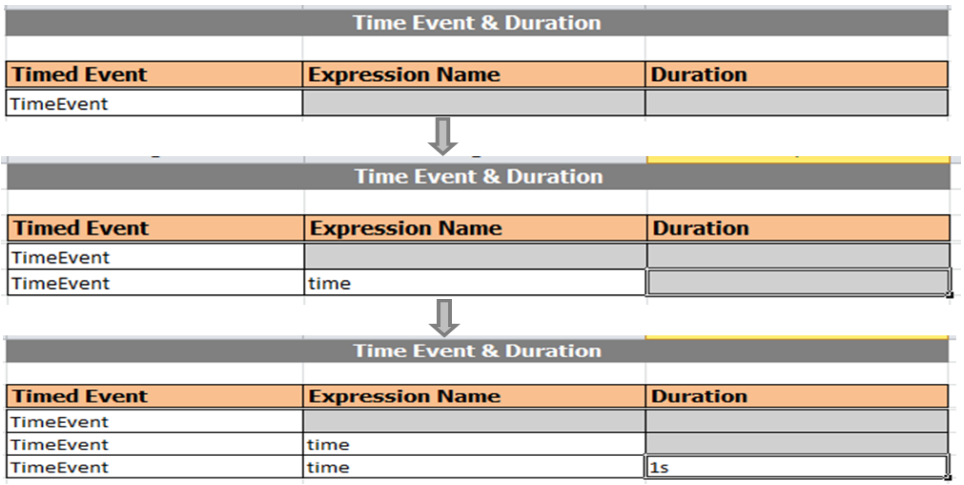
Signal Event	
SignalEvent	**Signals**
notifyEvent	notified
pauseEvent	
resetEvent	
resumeEvent	
startEvent	
stopEvent	
stopEventA	
stopEventB	
timeupEvent	

Time Event Table

The **Time Event** table is used to create the duration for the timed event.

Enter the event name in the **Timed Event** column, followed by a name for the duration in the **Expression Name** column.

Next, enter the required time duration in the **Duration** column. Assign the duration to the *TimeEvent* by entering the event and expression name in their respective columns.



Time Event & Duration		
Timed Event	**Expression Name**	**Duration**
TimeEvent		

Time Event & Duration		
Timed Event	**Expression Name**	**Duration**
TimeEvent		
TimeEvent	time	

Time Event & Duration		
Timed Event	**Expression Name**	**Duration**
TimeEvent		
TimeEvent	time	
TimeEvent	time	1s

Now we have created the necessary *Events* and *Signal* that will be used to define the *State* and *Transition* for the system.

4.4 Timer Behavior Table

Using the Timer Behavior table, we will define properties, operations and the behavior aspect of the system using *State Machines* and *Activities*.

To create a property, enter the block in the **Block Name** column and its property in the **Block Property** column.

Based on the use case, we will create the operations expected of the system: *restart*, *count-down* and *notify*.

To create operations, enter a name for the operation and the block in the respective columns.

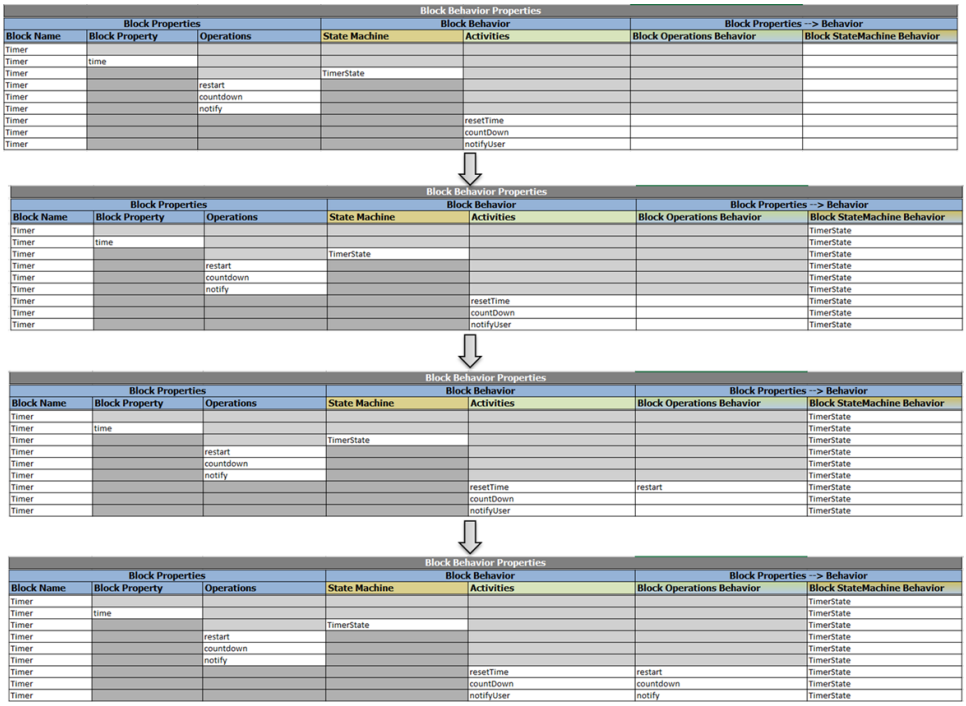
Next, we will create a *StateMachine* to define the system.

Enter the block name in the **Block Name** column and, in the same row, enter a name for the *StateMachine* in the **StateMachine** column. This will create a *StateMachine* for the Timer Block as shown below.

To make sure that the Timer Block exhibits the behavior of the *StateMachine* entered in the previous step, enter the *StateMachine* in the **Block StateMachine Behavior** column. In doing this, we are defining the state machine as a classified behavior.

Next, we create activities based on the operations created for the block.

Enter the block name in the **Block Name** column and the activity name in the **Activities** column, we have now created activities for the block Timer. In the **Block Operations Behavior** column, enter the respective operations for the activities created.



Block Behavior Properties

Block Properties			Block Behavior		Block Properties --> Behavior	
Block Name	Block Property	Operations	State Machine	Activities	Block Operations Behavior	Block StateMachine Behavior
Timer						
Timer	time					
Timer			TimerState			
Timer		restart				
Timer		countdown				
Timer		notify				
Timer				resetTime		
Timer				countDown		
Timer				notifyUser		

Block Behavior Properties

Block Properties			Block Behavior		Block Properties --> Behavior	
Block Name	Block Property	Operations	State Machine	Activities	Block Operations Behavior	Block StateMachine Behavior
Timer						TimerState
Timer	time					TimerState
Timer			TimerState			TimerState
Timer		restart				TimerState
Timer		countdown				TimerState
Timer		notify				TimerState
Timer				resetTime		TimerState
Timer				countDown		TimerState
Timer				notifyUser		TimerState

Block Behavior Properties

Block Properties			Block Behavior		Block Properties --> Behavior	
Block Name	Block Property	Operations	State Machine	Activities	Block Operations Behavior	Block StateMachine Behavior
Timer						TimerState
Timer	time					TimerState
Timer			TimerState			TimerState
Timer		restart				TimerState
Timer		countdown				TimerState
Timer		notify				TimerState
Timer				resetTime	restart	TimerState
Timer				countDown		TimerState
Timer				notifyUser		TimerState

Block Behavior Properties

Block Properties			Block Behavior		Block Properties --> Behavior	
Block Name	Block Property	Operations	State Machine	Activities	Block Operations Behavior	Block StateMachine Behavior
Timer						TimerState
Timer	time					TimerState
Timer			TimerState			TimerState
Timer		restart				TimerState
Timer		countdown				TimerState
Timer		notify				TimerState
Timer				resetTime	restart	TimerState
Timer				countDown	countdown	TimerState
Timer				notifyUser	notify	TimerState

4.5 StateMachine Properties Table

Next, we define the states and region for the *TimerState* we created previously.

Enter the *StateMachine* name followed by the region name in the **Region** column.

Create the Initial and Final states and the states at which the system will exist in respective columns, as shown below.

StateMachine Properties

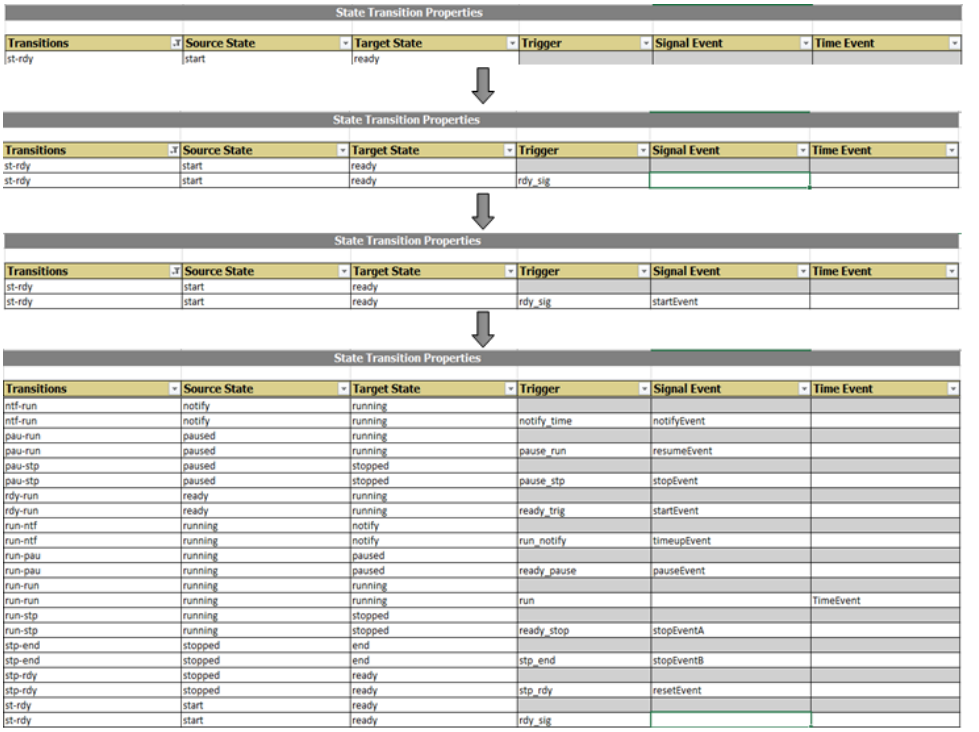
State Machine	Region	Initial State	States	Final State
TimerState				
TimerState	Region			
TimerState	Region	start		
TimerState	Region			end
TimerState	Region		end	
TimerState	Region		notify	
TimerState	Region		paused	
TimerState	Region		ready	
TimerState	Region		running	
TimerState	Region		stopped	

Transition Table

To create a transition between states with triggers, enter a name for the transition in the **Transitions** column (a row will be added with Source and Target state cells highlighted).

Enter the source state in the **Source State** column and the target state in the **Target State** column to create a transition between them.

To add a trigger that starts the transition, enter the transition name and trigger name. The source and target state fields will be updated automatically. To add an event to the trigger, enter the event name in the appropriate column. For example, to assign *startEvent* as a trigger between the start and ready states, enter the transition name, then provide a name for the trigger. Since startEvent is a signal event, it is populated in the **Signal Event** column, as shown.



State Transition Properties

Transitions	Source State	Target State	Trigger	Signal Event	Time Event
st-rdy	start	ready			

State Transition Properties

Transitions	Source State	Target State	Trigger	Signal Event	Time Event
st-rdy	start	ready			
st-rdy	start	ready	rdy_sig		

State Transition Properties

Transitions	Source State	Target State	Trigger	Signal Event	Time Event
st-rdy	start	ready			
st-rdy	start	ready	rdy_sig	startEvent	

State Transition Properties

Transitions	Source State	Target State	Trigger	Signal Event	Time Event
ntf-run	notify	running			
ntf-run	notify	running	notify_time	notifyEvent	
pau-run	paused	running			
pau-run	paused	running	pause_run	resumeEvent	
pau-stp	paused	stopped			
pau-stp	paused	stopped	pause_stp	stopEvent	
rdy-run	ready	running			
rdy-run	ready	running	ready_trig	startEvent	
run-ntf	running	notify			
run-ntf	running	notify	run_notify	timeupEvent	
run-pau	running	paused			
run-pau	running	paused	ready_pause	pauseEvent	
run-run	running	running			
run-run	running	running	run		TimeEvent
run-stp	running	stopped			
run-stp	running	stopped	ready_stop	stopEventA	
stp-end	stopped	end			
stp-end	stopped	end	stp_end	stopEventB	
stp-rdy	stopped	ready			
stp-rdy	stopped	ready	stp_rdy	resetEvent	
st-rdy	start	ready			
st-rdy	start	ready	rdy_sig		

4.6 ActivityNodeTable

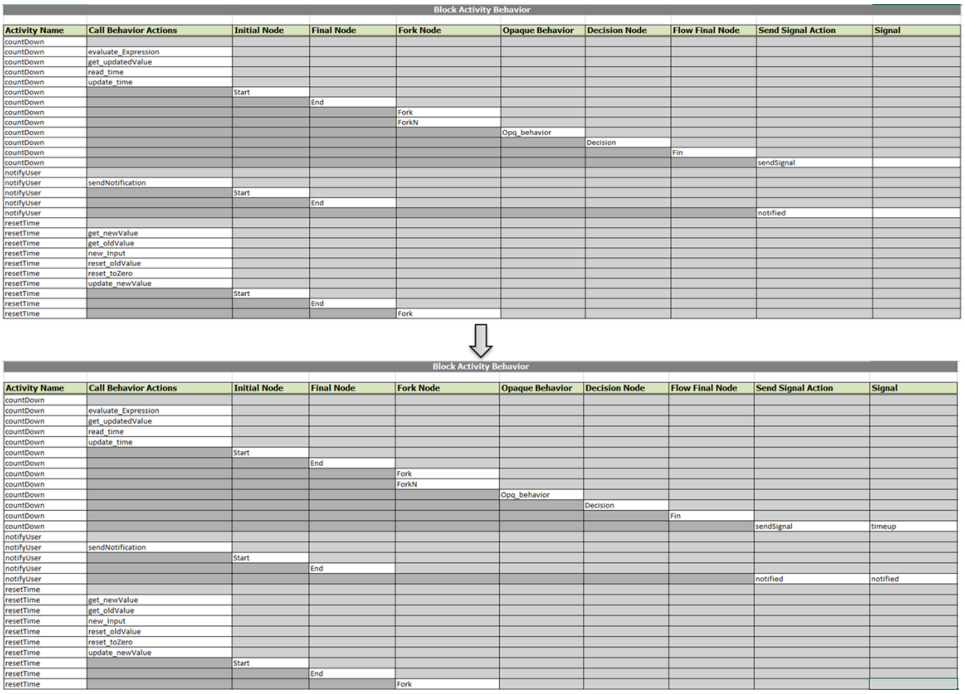
Next, we define the activity created in the **TimerBehavior** table.

To create actions and flow for an activity, enter the name of activity to which the above mentioned elements will be created.

In the **Call Behavior Actions** column, enter a name to create call behavior actions.

Similarly, this table is used to create initial and final nodes, forks, opaque behaviors, decision nodes, and send signal actions. Each of which can be created by providing a name for the node and its activity.

To assign the signal that will be sent when a signal action is invoked, enter the name in the **Send Signal Action** column and the signal that will be sent in the **Signal** column (signals that were created in *CountDownTimer* table).



Block Activity Behavior

Activity Name	Call Behavior Actions	Initial Node	Final Node	Fork Node	Opaque Behavior	Decision Node	Flow Final Node	Send Signal Action	Signal
countDown									
countDown	evaluate_Expression								
countDown	get_updatedValue								
countDown	read_time								
countDown	update_time								
countDown		Start							
countDown			End						
countDown				Fork					
countDown				ForkN					
countDown					Opq_behavior				
countDown						Decision			
countDown							Fin		
countDown								sendSignal	
notifyUser									
notifyUser	sendNotification								
notifyUser		Start							
notifyUser			End						
notifyUser								notified	
resetTime									
resetTime	get_newValue								
resetTime	get_oldValue								
resetTime	new_Input								
resetTime	reset_oldValue								
resetTime	reset_toZero								
resetTime	update_newValue								
resetTime		Start							
resetTime			End						
resetTime				Fork					

Block Activity Behavior

Activity Name	Call Behavior Actions	Initial Node	Final Node	Fork Node	Opaque Behavior	Decision Node	Flow Final Node	Send Signal Action	Signal
countDown									
countDown	evaluate_Expression								
countDown	get_updatedValue								
countDown	read_time								
countDown	update_time								
countDown		Start							
countDown			End						
countDown				Fork					
countDown				ForkN					
countDown					Opq_behavior				
countDown						Decision			
countDown							Fin		
countDown								sendSignal	timeup
notifyUser									
notifyUser	sendNotification								
notifyUser		Start							
notifyUser			End						
notifyUser								notified	notified
resetTime									
resetTime	get_newValue								
resetTime	get_oldValue								
resetTime	new_Input								
resetTime	reset_oldValue								
resetTime	reset_toZero								
resetTime	update_newValue								
resetTime		Start							
resetTime			End						
resetTime				Fork					

Opaque Behavior Table

This sheet is used to assign *OpaqueBehavior* to an action and define its parameter and equation.

To assign *OpaqueBehavior* to an action, enter the Opaque Behavior created in previous table in the **Opaque Behavior** column.

Note: The available actions will be automatically listed in **Opaque Action** column, as shown below.

To create an equation, enter it in the **Opaque Equation** column.

Opaque Behavior Properties			
Opaque Behavior Name	Parameters	Direction	Opaque Equation
Opq_behavior			

Opaque Behavior Properties			
Opaque Behavior Name	Parameters	Direction	Opaque Equation
Opq_behavior			time_out=t_in-1

To manipulate the parameters and direction, we first need to create links between the actions.

Activity ObjectFlow Table

This table is used to create object flow between activities.

To create object flow between actions, enter the source action name in column E (**Activity Node** column) and its activity in the **ActivityName** column followed by the target action information in column G(**ActivityNode** column) and its activity in the **Activity Name** column.

The object flows between the actions are created, as shown below.

ObjectFlow Table			
Activity Name	**Activity Node**	**Activity Name**	**Activity Node**
countDown			
countDown	get_updatedValue	countDown	Fork
countDown	Fork	countDown	read_time
countDown	Fork	countDown	update_time
countDown	read_time	countDown	ForkN
countDown	evaluate_Expression	countDown	update_time
countDown	ForkN	countDown	evaluate_Expression
countDown	ForkN	countDown	Decision
notifyUser			
resetTime			
resetTime	Fork	resetTime	update_newValue
resetTime	Fork	resetTime	new_Input
resetTime	get_oldValue	resetTime	reset_oldValue
resetTime	reset_oldValue	resetTime	update_newValue
resetTime	new_Input	resetTime	update_newValue
resetTime	reset_toZero	resetTime	reset_oldValue
resetTime	get_newValue	resetTime	Fork

Activity ControlFlow Table

The **Activity Control Flow** table works similar to the **Object Flow** table,

Enter the source action and activity name in the first two columns, followed by the target activity and action name.

ControlFlow Table			
Activity Name	**Activity Node**	**Activity Name**	**Activity Node**
countDown			
countDown	get_updatedValue		
countDown	Fork		
countDown	Start		
countDown	Start	countDown	read_time
countDown	End		
countDown	read_time		
countDown	read_time	countDown	evaluate_Expression
countDown	update_time		
countDown	update_time	countDown	Decision
countDown	evaluate_Expression		
countDown	evaluate_Expression	countDown	update_time
countDown	ForkN		
countDown	Decision		
countDown	Decision	countDown	Fin
countDown	Decision	countDown	sendSignal
countDown	Fin		
countDown	sendSignal		
countDown	sendSignal	countDown	End
notifyUser			
notifyUser	sendNotification		
notifyUser	sendNotification	notifyUser	notified
notifyUser	Start		
notifyUser	Start	notifyUser	sendNotification
notifyUser	End		
notifyUser	notified		
notifyUser	notified	notifyUser	End
resetTime			
resetTime	Fork		
resetTime	Start		
resetTime	Start	resetTime	reset_oldValue
resetTime	End		
resetTime	get_oldValue		
resetTime	reset_oldValue		
resetTime	reset_oldValue	resetTime	update_newValue
resetTime	new_Input		
resetTime	reset_toZero		
resetTime	get_newValue		
resetTime	update_newValue		
resetTime	update_newValue	resetTime	End

Once we have completed the Behavior flow tables, we have to sync the input and output flow of Opaque Behavior and its call action. To do this, go back to the **Opaque Behavior** table.

The Input and Output pins will be displayed as argument and result by default. We change this value based on the Opaque Equation parameter. Rename the argument in both tables to *time_in* and *time_out* instead of *result* and *argument* for the Opq_behavior.

Opaque Behavior Properties			
Opaque Behavior Name	Parameters	Direction	Opaque Equation
Opq_behavior			time_out=time_in-1
Opq_behavior	result	out	time_out=time_in-1
Opq_behavior	argument	in	time_out=time_in-1

Opaque Action-->OpaqueBehavior			
Opaque Action	Opaque Behavior	Input Pin	Output Pin
evaluate_Expression	Opq_behavior		
evaluate_Expression	Opq_behavior	argument	
evaluate_Expression	Opq_behavior		result

Opaque Behavior Properties			
Opaque Behavior Name	Parameters	Direction	Opaque Equation
Opq_behavior			time_out=time_in-1
Opq_behavior	time_out	out	time_out=time_in-1
Opq_behavior	time_in	in	time_out=time_in-1

Opaque Action-->OpaqueBehavior			
Opaque Action	Opaque Behavior	Input Pin	Output Pin
evaluate_Expression	Opq_behavior		
evaluate_Expression	Opq_behavior	time_in	
evaluate_Expression	Opq_behavior		time_out

We have created state machines and activities to define the behavior of the system. As of now *StateMachine* and the activities are defined as separate behaviors of the same system. In the following section, we will define how the system behaves at each state using the activities we created.

4.7 State Behavior Table

The State Behavior table will list the states created in the **StateMachine Properties** worksheet.

Next, we will assign an entry behavior to the system.

In the example, we will create an entry behavior to the running state. Enter the state name in the **State Name** column.

In the **State Entry Behavior** column, enter a name to create an entry behavior (*decrease* in this example).

Next, we will define nodes and actions to the entry behavior, as shown below.

To assign a behavior to the call actions we created in an earlier section, enter the behavior you want to assign in the **Behavior** column adjacent to the call actions.

State Entry Behavior Table					
State Name	State Entry Behavioir	Initial Node	Final Node	Call Behavior Actions	Behavior
end					
notify					
paused					
ready					
running					
stopped					

State Entry Behavior Table					
State Name	State Entry Behavioir	Initial Node	Final Node	Call Behavior Actions	Behavior
end					
notify					
paused					
ready					
running					
stopped					
running	decrease				

State Entry Behavior Table					
State Name	State Entry Behavioir	Initial Node	Final Node	Call Behavior Actions	Behavior
end					
notify					
paused					
ready					
running					
stopped					
running	decrease				
running	decrease	start			
running	decrease		end		
running	decrease			decrease	

State Entry Behavior Table					
State Name	State Entry Behavioir	Initial Node	Final Node	Call Behavior Actions	Behavior
end					
notify					
paused					
ready					
running					
stopped					
running	decrease				
running	decrease	start			
running	decrease		end		
running	decrease			decrease	countDown

State Behavior ControlFlow Table

Creating behavior control flows is similar to creating activity control flows.

Enter the source action and activity in the first two columns and target action and activity in the next column.

State Behavior ControlFlow Table			
State Activity	**State Activity Node**	**State Activity**	**State Activity Node**
decrease			
decrease	end		
decrease	start		
decrease	start	decrease	decrease
decrease	decrease		
decrease	decrease	decrease	end
notify			
notify	start		
notify	start	notify	notify
notify	end		
notify	notify		
notify	notify	notify	end
reset			
reset	start		
reset	start	reset	reset
reset	end		
reset	reset		
reset	reset	reset	end
test			

We have now created the control flows. When we defined a requirement initially, we stated that the system should notify the user when time reaches zero and should continue counting down even after reaching zero. To achieve this, we will set a guard condition to the control flow of the merge node created in earlier sections. In a previous section, we have already create a notify behavior to the state and to send a signal to user.

State ControlFlow Condition Table

In the **ControlFlow Condition** table, existing control flows will be listed based on previous inputs.

To create a guard condition, enter the state activity name in the **State Activity** column followed by the source and target activity node information and enter a guard condition.

State Behavior ControlFlow Condition Table			
State Activity	**State Activity Node (Source)**	**State Activity Node (Target)**	**Control Guard Condition**
resetTime			
countDown			
notifyUser			
countDown	Decision	Fin	
countDown	Decision	sendSignal	
countDown	evaluate_Expression	update_time	
countDown	read_time	evaluate_Expression	
countDown	sendSignal	End	
countDown	Start	read_time	
countDown	update_time	Decision	
notifyUser	notified	End	
notifyUser	sendNotification	notified	
notifyUser	Start	sendNotification	
resetTime	reset_oldValue	update_newValue	
resetTime	Start	reset_oldValue	
resetTime	update_newValue	End	

State Behavior ControlFlow Condition Table			
State Activity	**State Activity Node (Source)**	**State Activity Node (Target)**	**Control Guard Condition**
countDown			
countDown	Start	read_time	
countDown	read_time	evaluate_Expression	
countDown	update_time	Decision	
countDown	evaluate_Expression	update_time	
countDown	Decision	Fin	
countDown	Decision	sendSignal	
countDown	sendSignal	End	
notifyUser			
notifyUser	sendNotification	notified	
notifyUser	Start	sendNotification	
notifyUser	notified	End	
resetTime			
resetTime	Start	reset_oldValue	
resetTime	reset_oldValue	update_newValue	
resetTime	update_newValue	End	
countDown	Decision	Fin	time>0||time<0

State Behavior ControlFlow Condition Table			
State Activity	**State Activity Node (Source)**	**State Activity Node (Target)**	**Control Guard Condition**
countDown			
countDown	Start	read_time	
countDown	read_time	evaluate_Expression	
countDown	update_time	Decision	
countDown	evaluate_Expression	update_time	
countDown	Decision	Fin	
countDown	Decision	sendSignal	
countDown	sendSignal	End	
notifyUser			
notifyUser	sendNotification	notified	
notifyUser	Start	sendNotification	
notifyUser	notified	End	
resetTime			
resetTime	Start	reset_oldValue	
resetTime	reset_oldValue	update_newValue	
resetTime	update_newValue	End	
countDown	Decision	Fin	time>0||time<0

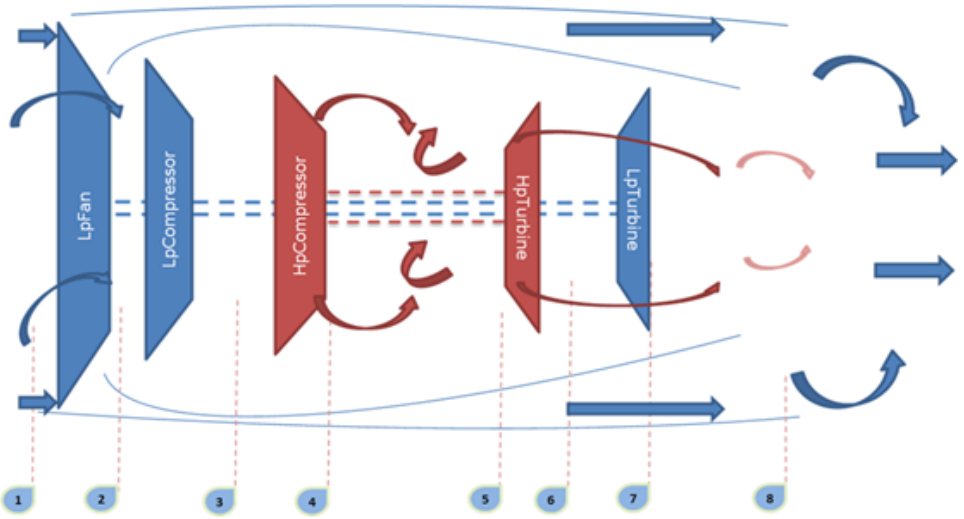
State Behavior ControlFlow Condition Table			
State Activity	**State Activity Node (Source)**	**State Activity Node (Target)**	**Control Guard Condition**
countDown			
countDown	Start	read_time	
countDown	read_time	evaluate_Expression	
countDown	update_time	Decision	
countDown	evaluate_Expression	update_time	
countDown	Decision	Fin	
countDown	Decision	Fin	time>0||time<0
countDown	Decision	sendSignal	
countDown	Decision	sendSignal	time=0
countDown	sendSignal	End	
notifyUser			
notifyUser	sendNotification	notified	
notifyUser	Start	sendNotification	
notifyUser	notified	End	
resetTime			
resetTime	Start	reset_oldValue	
resetTime	reset_oldValue	update_newValue	
resetTime	update_newValue	End	

5 Turbofan Engine Model

5.1 Introduction

This example model is used to identify design points of a turbofan engine. MapleMBSE and Cameo Systems Modeler™ were used to create a turbofan example model. The design point calculations are based on ideal gas turbine cycle analysis.
Initially, a mission statement is defined to specify the scope of the model and to identify design points at Mach number 0.8 and operating altitude between 35000ft to 45000ft with a bypass ratio between 6-8.

5.2 Turbofan Model



The turbofan system is defined as shown in the diagram above. The system consists of a twin-spool configuration, with a high pressure turbine driving a high pressure compressor, a low pressure turbine driving a low pressure compressor, and a fan. Temperature and pressure are identified at the design points, as shown in the figure. The primary goal is to identify the design points with optimum SFC (specific fuel consumption) value.

5.3 Requirements

Once the mission statement is defined, system requirements for the turbofan are also stated for each subcomponent in terms of target efficiency, pressure ratio etc., which have to be satisfied. The **SystemRequirements** worksheet in MapleMBSE is used to define the specifications and target values that have to be achieved. In addition to the system specifications,

analysis requirements are created to define the input values which will be used to analyze the model.

To maintain traceability between system level requirements and mission level requirements, the **DeriveRequirements** worksheet in MapleMBSE is used to create derived relationships between requirements.

5.4 ValueType

The **ValueTypesTable** and **UnitQuantityKindTable** worksheets are used to define units and type of values that will be used to define the system. These valuetypes are used to specify the type of value properties of the system to be modeled.

5.5 Constraint Blocks

Constraint blocks are created and constraints that will be used in the system are captured using the **ConstraintProperties** worksheet. Similar to value types, these blocks are used to specify the type the constraint property of the system that will be defined.

5.6 System Model

The Turbofan Blackbox is used to specify the properties of the turbofan in terms of values, subcomponents and ports through with the system will interact.

Once the subcomponents are created we now define the values and constraint properties, then type them to valuetypes and the constraint block created. A specific worksheet view is created in MapleMBSE to show components values, constraints and their types.

An Analysis block is created to provide value exchange between the subcomponents. The Analysis block provides the default values with which the analysis is performed and also receives the results of analysis.

5.7 Results

The **InstanceResults** table is used to display the results of analysis performed in the model using simulation toolkit in Cameo Systems modeller. In MapleMBSE the results are mapped to Excel graph for visualization. This results worksheet is treated as read-only and used to only visualize the results of analysis at different altitudes.

To create a new instance:

1. Create a new instance specification by providing a name in the Instance Specification column in **InstanceTable** worksheet and type "Analysis Block" as the name of the block in the Instance of Block column.
2. Define the feature and corresponding value with which the new analysis has to be performed, required input values to be created are *ByPassRatioA* and *targetEfficiency_hpTurbine*.
3. Once the analysis block is defined, specify the inlet properties by creating a new instance for the InletConditions block, similar to the above method. The required values in this case are Ta(inlet static temperature in K) and Pa (inlet static pressure in bar).
4. Commit the changes to the No Magic Server.
5. Open the model in Cameo or Magic Draw, then create a new block diagram in the NewInstance package, drag and drop the analysis block instance.
6. Drop the inletConditions instance into the analysis instance to create a new feature instance for the Analysis block.
7. Right-click the analysis instance and select simulate to run the analysis.
8. Export the results of analysis as new instance into the Result package under NewInstance then commit to the No Magic Server.
9. Reload MapleMBSE to see the results in the **NewInstanceResults** worksheet.

To maintain the traceability between the requirements and the modeled system modeled, use **VerifyRequirementsMatrix** to have a verify relationship between system requirements and value properties of the block. By creating this verify relation, now we have traceability from system values to system requirements and from system requirements to mission requirements.

The **RequirementsTraceability** worksheet displays all the requirements from the model and its relationships such as trace, verify, derived with other model elements.

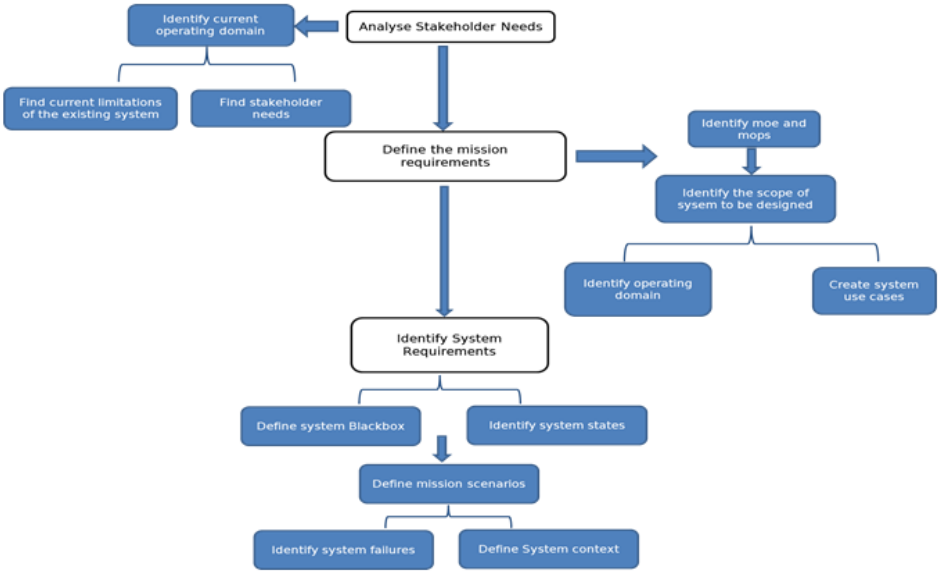
5.8 References

1. Cohen, H. Rogers. G. and Saravanamuttoo, H. (1996). Gas turbine theory. Harlow: Pearson education.
2. Sanford Friedenthal. (2015). A Practical Guide to SysML, 3rd Edition. Morgan Kaufmann Publishers.

6 UAV Model

6.1 Introduction

This model uses the Object Oriented System Engineering Method (OOSEM) to design a conceptual model of an Unmanned Aerial Vehicle (UAV). The primary use of UAV in consideration is to assist forest fire fighting operations in remote areas. The sample model shows a part of the OOSEM workflow to identify system requirements.



6.2 Analyze Stakeholder Needs

To identify the needs of stakeholders, in this case the fire department, the current operating domain is modeled to find the existing limitations and expectations of the fire department. The existing domain is captured using the block definition diagram represented in a table format in the **OperatingDomain** worksheet. A causal analysis is performed to identify the factors that are of interest to the fire department operation [6]. This causal analysis also reveals the present limitations in the fire department operation. At this stage, we have identified the needs of stakeholder based on which we will derive the mission requirements.

6.3 Mission Requirement

To determine the scope and mission of the UAV model, we first identify the measure of effectiveness based on the stakeholder needs analysis. Secondly, we define the operating domain in which the system to be modeled will operate. The operating domain is represented using a block diagram and shown in table format using the **OperatingDomainUAV** worksheet. We identify the use cases to determine the high level behavior of the system and its interaction. Next, from the measure of effectiveness and the operating domain, we can define the Mission Requirements and stakeholder requirements from the stakeholder needs that we identified.

6.4 System Requirements

Before identifying the system requirements, we define units, and interfaces that will be used by the system of interest. A separate package called Interface is create using the **InterfaceTable** to contain the flows and signals that will be used in the model.

System Behavior

To find the system requirements, we initially define the UAV blackbox that displays: ports through which the system interacts, its parts, and its values. In addition, we also define the operations that are expected of the system, and the method to achieve it in terms of activities. The **UAVBlackBox** worksheet displays the model elements mentioned above. Now we define the system behavior and represent states at which the system will operate and its events. On identifying the mission profile of UAV, we create detailed states at which the system should operate. Following this, we use activities to define system behavior. Based on the use cases, we create the activities since our mission is to control forest fires and we are still in the conceptual phase. We define system behavior based on this activity.

Weight Estimation

Once we have defined the system behavior we need to determine the system specification in order to create the system requirements. To identify the general design requirements the weight of the UAV is first estimated followed by sizing and identifying critical parameters. The **WeightEstimationTable** worksheet displays the value properties and constraint properties need to estimate the weight of UAV. This worksheet also has tables created in excel that displays specifications of similar aircraft and estimation constants from historical data [1]. Based on the mission profile the parameter values can be altered based on payload, range, endurance, etc. when satisfactory values are determined the values are updated to WeightEstimationBlock and saved to the model in the No Magic Server.

Wing Area Estimation

To determine the sizing we initially create the constraints using the **WingAreaConstraint** worksheet. Similar to the weight estimation worksheet, the **WingAreaEstimation** worksheet is used to find wing area by iterating key parameters. Using the matching plot technique [2] Wing loading vs Thrust loading is plotted from which we identify the wing area.
We have estimated the weight and wing area based on which other design parameters can be further evaluated. This example model covers the conceptual phase from stakeholder need analysis to identify system requirements.

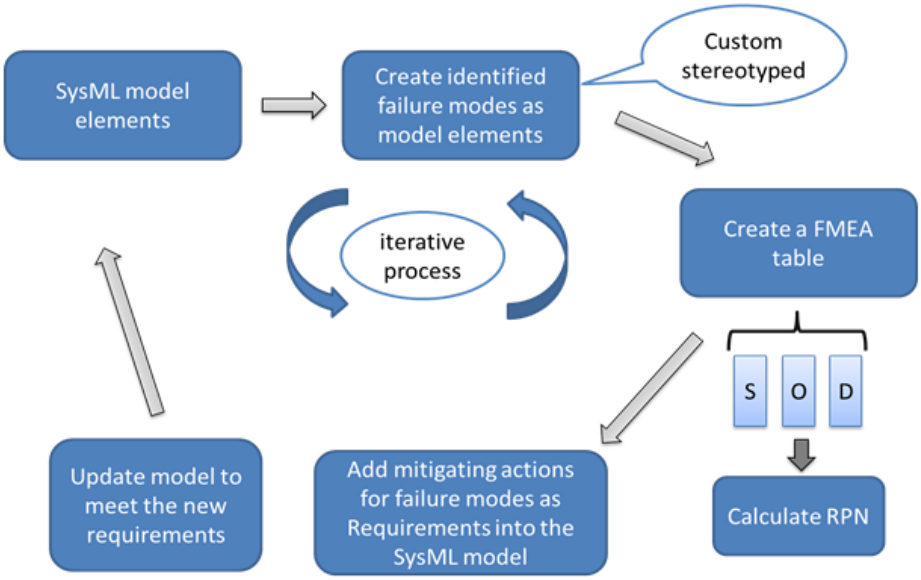
6.5 References

1. Austin, R. (2010). Unmanned air vehicles: UAVS design, development, and deployment. Chichester, West Sussex, and U.K.: Wiley.
2. Raymer, D. P. (1992). Aircraft design: A conceptual approach. Washington, D.C.: AIAA.
3. Sadraey, M. H. (2017). Unmanned aircraft design: A review of fundamentals. San Rafael, CA: Morgan & Claypool.
4. Sadraey, M. H. (2013). Aircraft design: A systems engineering approach. Hoboken, NJ: Wiley.
5. Simard, A. J., & Forster, R. B. (1972). A survey of air tankers and their use. Ottawa: Forest Fire Research Institute.
6. Sanford Friedenthal. (2015). A Practical Guide to SysML, 3rd Edition. Morgan Kaufmann Publishers.
7. GLOBAL HAWK SYSTEMS ENGINEERING CASE STUDY.pdf. (n.d.). Retrieved from https://www.scribd.com/document/409826283/GLOBAL-HAWK-SYSTEMS-ENGINEERING-CASE-STUDY-pdf
8. Firefighting Aircraft Recognition Guide - California - PDF Free Download. (n.d.). Retrieved from https://docobook.com/-firefighting-aircraft-recognition-guide-california.html

7 FMEA Template

7.1 Introduction

This model is used to perform FMEA analysis by accessing SysML model elements from a No Magic server. This example shows a FMEA process to identify possible failure modes of system functions defined in conceptual design of a UAV; however this template can be used to perform FMEA on different model elements by specifying appropriate path and elements in the configuration file.



The FMEA process is performed as shown in the figure, system functions from the model are accessed and failure modes are identified. Further we identify severity, occurrence and detection for the failure modes and calculate the RPN (Risk Priority Number). Mitigating actions for identified failures are created as new requirements. The complete process is saved back to the teamwork cloud model.

7.2 FMEA

The **FMEAMatrix** worksheet is used to identify new failure modes for the system function and to create a dependency (identifiedFM). Once we create new failure modes, we use the **FMEATable** worksheet to provide a detailed analysis of the potential failure by specifying S, O and D from which RPN is calculated.

7.3 Recommended Action

In this process, recommended actions are captured as requirements that can be saved back to the model. The **RequirementFMEAMatrix** worksheet is used to create a custom dependency (deriveFMEA) between identified FMEA and recommended actions. The **FMEARequirementTable** worksheet is used to add specification to the new requirements created as a result of this analysis.

To use the custom FMEA template:

1. Add the TWCSysML.mdzip model to the No Magic server.
2. In Cameo Systems Modeler or Magic Draw, Right-click CustomStereotypes profile→ Project Usage →Export Packages to New Server project.
3. In desired project File→ Project Usage →Server Project select the exported profile from previous step.
4. Update path in the MSE file to get model elements.

7.4 References

1. Kratzke, R. (2018). Failure Modes Effects Analysis in MBSE. [ebook] Available at: https://www.incose.org/docs/default-source/texas-gulf-coast/tgcc-conference-2018/2018-papers/kratzke-2018-incose-presentation-(for-public-distribution).pdf?sfvrsn=db4796c6_2 [Accessed 22 May 2019].
2. Publishing, R. (2019). Failure Mode and Effect Analysis - FMEA - and Criticality Analysis - FMECA. [online] Weibull.com. Available at: https://www.weibull.com/basics/fmea.htm [Accessed 22 May 2019].

8 Interface Definition Template

8.1 Introduction

This template is used to show details regarding the interfaces between the systems. ICD templates in MapleMBSE can be customized to display information that is relevant to the end users. This example shows different worksheets that can be used to update or review interfaces and add documentation/comments.

The InterfaceTable worksheet shows the components of a simple Tablet structure, its ports and interface type. This is a review only sheet and not to be updated.

Component	Interface_Port	Port_Kind	Conjugated	Interface_Port	Port_Kind	Conjugated	Interface_Type
Audio Output				audioS	ProxyPort	FALSE	If_audioOut
Tablet System	buttonIN	FullPort	FALSE				
Tablet System	buttonIN	FullPort	FALSE				PCB_Button
Tablet System	hdmi_in	FullPort	FALSE				
Tablet System	hdmi_in	FullPort	FALSE				HDMI
Tablet System				touchInterface	ProxyPort	FALSE	If_Touch
Tablet System				inCharger	ProxyPort	FALSE	If_Charger
Tablet System				MIC	ProxyPort	FALSE	If_inMic
Tablet System				blueToothInterface	ProxyPort	TRUE	If_Bluetooth
Tablet System				headPhoneJack	ProxyPort	FALSE	If_HeadPhone
Tablet System				wifiInterface	ProxyPort	FALSE	in_WiFi
Tablet System				light_in	ProxyPort	FALSE	If_camera
Camera System				light	ProxyPort	FALSE	If_camera
Input System				touchInterface	ProxyPort	FALSE	If_Touch
Input System				tscreen	ProxyPort	TRUE	If_Touch
Controller System				tscreen	ProxyPort	FALSE	If_Touch
Controller System				inCharger	ProxyPort	FALSE	If_Charger
Controller System				hdmi	ProxyPort	FALSE	If_HDMI
Controller System				bltM	ProxyPort	TRUE	If_Bluetooth
Controller System				hP	ProxyPort	FALSE	If_HeadPhone
Controller System				audioM	ProxyPort	FALSE	If_audioOut
Controller System				micM	ProxyPort	FALSE	If_inMic
Controller System				pblM	ProxyPort	FALSE	If_powerBacklight
Controller System				wifi	ProxyPort	FALSE	In_WiFi
Controller System				cpwr	ProxyPort	FALSE	VIN
Power System	pwr	FullPort	FALSE				
Power System	pwr	FullPort	FALSE				PCB_Button
Power System				vpwr	ProxyPort	FALSE	VIN
Display Device				pblS	ProxyPort	TRUE	If_powerBacklight
Receiver				wifiIn	ProxyPort	FALSE	in_WiFi
Receiver				wifi	ProxyPort	TRUE	in_WiFi

The InterfaceClasses worksheet shows the interface definitions that are used in the previous worksheet and can be used to add description or comments to the interfaces.

The ItemFlow worksheet is also a review only sheet that displays a list of all the item flows in the project and their related components.

8.2 The InterfaceRequirements Matrix

The InterfaceRequirements matrix shows the relation between the interface requirements and the interfaces of the components of the tablet

		Component	Tablet System	Tablet System	Tablet System	Tablet System	Tablet System	Tablet System	Tablet System
ID	Name	Interface Name / Specification	touchInterface	inCharger	MiC	blueToothInterface	headPhonejack	wifiInterface	light_in
IREQ1	HDMI	The device must be capable of using HDMI cables to connect with TV.							
IREQ2	Touch S	The device should have a capacitive touch screen	X						
IREQ3	Back Lig	The device should have back light with adjustable brightness							
IREQ4	SD Card	The device must have means to extend internal storage with external storage							
IREQ5	Head Ph	The device should have 3.5MM jack and bluetooth to connect with audio devices					X		
IREQ6	LCD Disp	The display should be LCD							

8.3 ComponentsInteractionTable

The ComponentsInteractionTable displays the list of components of an Arduino controlled robot and its interfaces, this worksheet shows a list of columns that can be updated by the user to add the new interface in terms of ports and define its direction.

Component	Port	Direction
Battery	-veBattery	inout
Battery	+veBattery	inout
Motor Driver	2Y	inout
Motor Driver	2A	inout
Motor Driver	4Y	inout
Motor Driver	1A	inout
Motor Driver	GND	inout
Motor Driver	4A	inout
Motor Driver	VCC1	inout
Motor Driver	VCC2	inout
Motor Driver	GND2	inout
Motor Driver	1Y	inout
Motor Driver	1.2EN	inout
Motor Driver	GND4	inout
Motor Driver	3Y	inout
Motor Driver	GND3	inout
Motor Driver	3A	inout
Motor Driver	3.4EN	inout
Servo motor	+veservo1	inout
Servo motor	-veservo1	inout
Microcontroller	GND	inout
Microcontroller	A0	inout
Microcontroller	A3	inout
Microcontroller	A2	inout
Microcontroller	5V	inout
Microcontroller	3.3V	inout
Microcontroller	A5	inout
Microcontroller	A1	inout

8.4 References

1. Karban, R., Troy, M., Brack, G. L., Dekens, F. G., Michaels, S. B., & Herzig, S. (2018). Verifying Interfaces and generating interface control documents for the alignment and phasing subsystem of the Thirty Meter Telescope from a system model in SysML. Modeling, Systems Engineering, and Project Management for Astronomy VIII. doi: 10.1117/12.2310184
2. Model-based Interface Control Documents (icd) Donatas Mazeika- Saulius - https://blog.nomagic.com/model-based-interface-control-documents-icd/

9 Cost Analysis

9.1 Introduction

This example shows how MapleMBSE can be used to access key parameters of a turbofan engine from a SysML model and do a trade-off with different material types.

9.2 Results

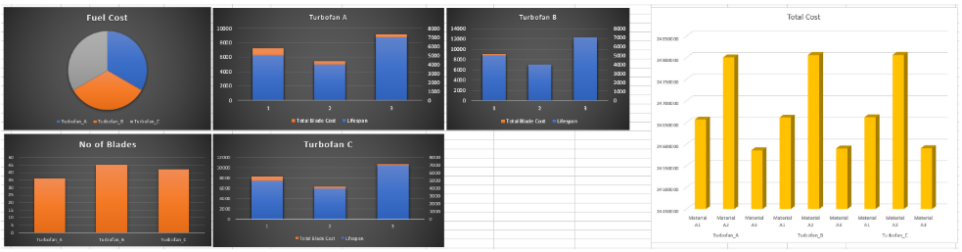
The Cost Analysis worksheet has two different tables displayed in worksheet: results from the preliminary analysis table shows value properties and its value based on which the cost estimations are done, and the other table displays material properties and cost.

Results from preliminary Analysis		
Turbofan_A	SFC	0.06923
Turbofan_A	Efficiency	0.8765
Turbofan_A	no_of_blades	36
Turbofan_A	Fnet	4963.51
Turbofan_B	SFC	0.06886
Turbofan_B	Efficiency	0.88755
Turbofan_B	no_of_blades	45
Turbofan_B	Fnet	4989.81
Turbofan_C	SFC	0.06853
Turbofan_C	Efficiency	0.87547
Turbofan_C	no_of_blades	42
Turbofan_C	Fnet	5013.7

Quote From Supplier		
Material A1	lifespan	5000
Material A1	no_of_visits	4
Material A1	cost_per_visit	70000
Material A1	cost_per_blade	200
Material A2	lifespan	4000
Material A2	no_of_visits	6
Material A2	cost_per_visit	70000
Material A2	cost_per_blade	150
Material A3	lifespan	7000
Material A3	no_of_visits	3
Material A3	cost_per_visit	70000
Material A3	cost_per_blade	255

9.3 Visualization

Updating the values will automatically update related tables and graphs based on which we can identify the cost-effective material and key-value property which will affect the overall cost of the engine.



10 Variant Management Template

10.1 Introduction

Variant management is used to identify the multiple variants in the product line and their dependencies to manage complexity. This example shows a simplified view into identifying the variants in a Tablet model by which the user can create new features to the tablet parts and use it to create different variations for a tablet.

Component	FeatureName / Parts	10MP	12 MP	4500mAh	5MP	7300mAh	8600mAh	AMOLED	MLED
Tablet	WiFi Antenna								
Tablet	Camera	X	X		X				
Tablet	TouchScreen Panel								
Tablet	Battery			X		X	X		
Tablet	Speaker								
Tablet	Processor								
Tablet	Power Button								
Tablet	MIC								
Tablet	LED							X	X

10.2 FeatureMatrix

The FeatureMatrix shows the different features and their respective parts to which the feature is related. For example, the 10MP feature is related to the part Camera of the tablet. To create a new feature user can add a new entry in the FeatureName row and assign it to the corresponding part. The VariantMatrix displays the available configuration that was created in the model. To add a new variant the user can provide a unique name in the VariantModel row and built it using the available features. VariantTable shows the information from VariantMatrix in a tabular view for review.

Component	Parts	VariantModel* / Features	Model A	Model B
Tablet	Camera	5MP		
Tablet	Camera	12 MP	X	
Tablet	Camera	10MP		X
Tablet	Battery	7300mAh	X	X
Tablet	Battery	8600mAh		
Tablet	Battery	4500mAh		
Tablet	LED	AMOLED	X	X
Tablet	LED	MLED		

10.3 VariantCheckTable

The VariantCheckTable is a validation to identify conflicts in the feature selection. To verify the selections first the user has to sort the table. Right-click inside the table to Sort Vertically. In case of conflicts, the row will be highlighted as shown.

Variant_Models	Features	Parts
Model A	7300mAh	Battery
Model A	12 MP	Camera
Model A	AMOLED	LED
Model B	7300mAh	Battery
Model B	10MP	Camera
Model B	AMOLED	LED
Model B	*MLED*	*LED*

The last row is highlighted because Model B has features AMOLED & MLED which are selected by the user belongs to the same part LED.

10.4 References

Chami, Mohammad & Forlingieri, Marco & Oggier, Philipp. (2017). Model-Based Variability Management Solution with SysML.

11 Default Value Generation

11.1 Introduction

This is a MapleMBSE feature that is used to generate default values or a sequence of text that is pre-defined in the configuration file. Use TWCSysML-DefaultValue.MSE to view how default generation works. This sample has two worksheets: the BlocksTable and the AutoGenerateTable. Using the BlocksTable sheet, a user can create components and sub-components. In the Components column, provide the name of a component and the name of a subcomponent. Once the Component and subcomponent have been entered, the other fields will be automatically populated. This is illustrated in the default value generation example, where a new Chassis component is created.

Component*	PartPropertyName^	SubComponent*	Aggregation^	Multiplicity^
Car				
Car	partProperty1	Door	composite	0..1
Car	partProperty3	Engine	composite	0..1
Car	partProperty2	Wheel	composite	0..1
Door				
Engine				
Wheel				
Chassis				

11.2 Generating the Default Values

Add Chassis as a part to Car as shown below.

Component*	PartPropertyName^	SubComponent*	Aggregation^	Multiplicity^
Car				
Car	partProperty1	Door	composite	0..1
Car	partProperty3	Engine	composite	0..1
Car	partProperty2	Wheel	composite	0..1
Door				
Engine				
Wheel				
Chassis				
Car		Chassis		

New value in other columns are generated automatically as shown and these generated values can be edited if needed.

Component*	PartPropertyName^	SubComponent*	Aggregation^	Multiplicity^
Car				
Car	partProperty1	Door	composite	0..1
Car	partProperty3	Engine	composite	0..1
Car	partProperty2	Wheel	composite	0..1
Door				
Engine				
Wheel				
Chassis				
Car	partProperty4	Chassis	composite	0..1

AutoGeneratedTable shows a simple BOM template using with when the name of a part is entered rest of the column are auto-generated with a default value.

PartName*	PartID^	Description^	Quantity^	Price^	Per^	MaterialType^
Battery	BT344A4	3500mAh, Li-ion	1	25	EA	RawMaterial
Camera	CA344A55	PrimaryCamera 12MP / Image Stabilization/	1	30	EA	RawMaterial
Display	PT4341T34	5.5 AMOLED, 455p,Touch Screen'	1	90	EA	RawMaterial
Enclosure	PT3456A23	Al enclosure	1	50	EA	RawMaterial
Memory	PT33A343	*description	1	0	EA	RawMaterial
Processor	SN453G45	Snapdragon, QuadCore 2.5GHz	1	30	EA	RawMaterial
EarPhone	*partID	*description	1	0	EA	RawMaterial

12 Instance View

12.1 Introduction

This template is used to view different instances of blocks and their value properties and allows the user to directly edit or create a new instance of the block.

12.2 The MatrixTemplate Worksheet

The MatrixTemplate worksheet displays the instances in the columns and rows represent the blocks and their value properties. The intersection of row and column displays the value of the block with respect to its instance. To create a new instance enter a name for the instance in the Instances column. MapleMBSE will automatically create all the instances hierarchically and display the related values in the cells which can be updated. New slot values can be added to the empty cells, based on the value types defined. To delete a slot select the cell and click on delete button. MapleMBSE will automatically parse these inputs to the right value types.

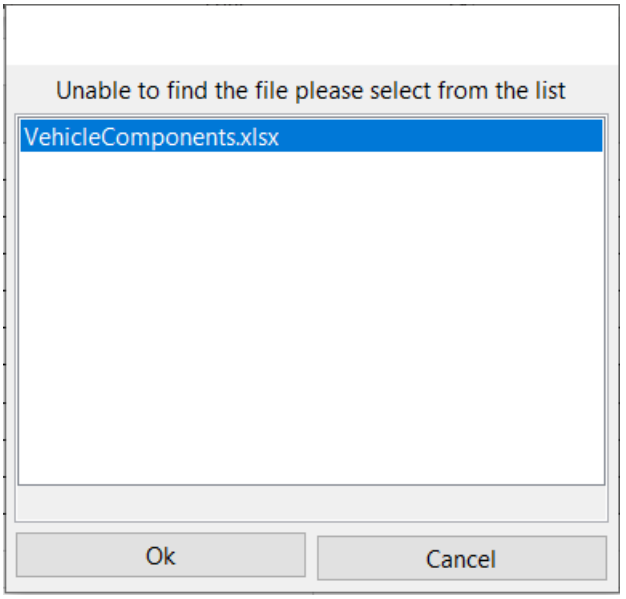
In the image below, the L1 Sub-Component Column shows the subcomponents name along with their multiplicity []. The component's multiplicity can be changed using the InstanceMulti Table. In this example, vehicle_instance1 is used as reference Instance to increase or decrease the multiplicity.

Notes:

- When a user enters a string value and expected value is Real the cell will be updated with default value as ‘0’.
- This template is used only when the structure of the block for which is the instance is created is determined previously.

Top Level Component	L1 Sub-Component	Instances / ValueProperty	vehicle_instance1	vehicle_instance2	vehicle_instance3	vehicle_instance4
Vehicle	Battery[1]	estimated	0	0	0	0
Vehicle	Battery[1]	weight	50	50	50	50
Vehicle	Brakes[1]	estimated	0	0	0	0
Vehicle	Brakes[1]	weight	22	22	22	22
Vehicle	Engine[1]	estimated	0	0	0	0
Vehicle	Engine[1]	weight	350	350	350	350
Vehicle	Front Axle	estimated	0	0	0	0
Vehicle	Front Axle	weight	354	354	354	354
Vehicle	Fuel Tank[1]	estimated	0	0	0	0
Vehicle	Fuel Tank[1]	weight	15	15	15	15
Vehicle	Radiator	estimated	0	0	0	0
Vehicle	Radiator	weight	12	12	12	12
Vehicle	Rear Axle	estimated	0	0	0	0
Vehicle	Rear Axle	weight	350	350	350	350
Vehicle	Steering[1]	estimated	0	0	0	0
Vehicle	Steering[1]	weight	34	34	34	34
Vehicle	Suspension[1]	estimated	0	0	0	0
Vehicle	Suspension[1]	weight	23	23	23	23
Vehicle	Transmission	estimated	0	0	0	0
Vehicle	Transmission	weight	342	342	342	342
Vehicle		attachment	Vehicle	Vehicl	Vehicl	Vehicl
Vehicle		color	Black	Black	Black	Black
Vehicle		estimated	0	0	0	0
Vehicle		totalweight	90	90	90	90

In the cell with hyperlinks, as shown in the Vehicle attachment property (see above figure), a user can open the files by clicking on the hyperlink. An empty cell can only be referred to existing files in other cells. When the file name is misspelled, a dialog box will appear as below, with the list of files. Note that the files opened are read-only and cannot be edited.



Clicking cancel will display invalid attachment

Top Level Component	L1 Sub-Component	Instances / ValueProperty	vehicle_instance1	vehicle_instance2	vehicle_instance3	vehicle_instance4
Vehicle	Battery	estimated	0	0	0	0
Vehicle	Battery	weight	50	50	50	50
Vehicle	Brakes	estimated	0	0	0	0
Vehicle	Brakes	weight	22	22	22	22
Vehicle	Engine	estimated	0	0	0	0
Vehicle	Engine	weight	350	350	350	350
Vehicle	Front Axle	estimated	0	0	0	0
Vehicle	Front Axle	weight	354	354	354	354
Vehicle	Fuel Tank	estimated	0	0	0	0
Vehicle	Fuel Tank	weight	15	15	15	15
Vehicle	Radiator	estimated	0	0	0	0
Vehicle	Radiator	weight	12	12	12	12
Vehicle	Rear Axle	estimated	0	0	0	0
Vehicle	Rear Axle	weight	350	350	350	350
Vehicle	Steering	estimated	0	0	0	0
Vehicle	Steering	weight	34	34	34	34
Vehicle	Suspension	estimated	0	0	0	0
Vehicle	Suspension	weight	23	23	23	23
Vehicle	Transmission	estimated	0	0	0	0
Vehicle	Transmission	weight	342	342	342	342
Vehicle		attachment	VehicleC	VehicleC	VehicleC	invalid Attachment
Vehicle		color	Black	Black	Black	Black
Vehicle		estimated	0	0	0	0
Vehicle		totalweight	90	90	90	90

12.3 Instance Multiplicity Table

This worksheet is used to increase or decrease the multiplicity of the reference Instance (vehicle_instance1): To increase multiplicity of a part in the Multiplicity of Instance column, update the number to the desired value, and then this will add new sub-instances as below.

Component	Parts	Multiplicity of Instance
Vehicle	Battery[1]	1
Vehicle	Brakes[1]	1
Vehicle	Engine[1]	1
Vehicle	Front Axle	1
Vehicle	Fuel Tank[1]	1
Vehicle	Radiator	1
Vehicle	Rear Axle	1
Vehicle	Steering[1]	1
Vehicle	Suspension[1]	1
Vehicle	Transmission	1

Component	Parts	Multiplicity of Instance
Vehicle	Battery[1]	4
Vehicle	Brakes[1]	1
Vehicle	Engine[1]	1
Vehicle	Front Axle	1
Vehicle	Fuel Tank[1]	1
Vehicle	Radiator	1
Vehicle	Rear Axle	1
Vehicle	Steering[1]	1
Vehicle	Suspension[1]	1
Vehicle	Transmission	1
Vehicle	Battery[2]	4
Vehicle	Battery[3]	4
Vehicle	Battery[4]	4

13 Spacecraft Model

13.1 Introduction

The template files in the Spacecraft model files folder require the Spacecraft SysML model, which can be downloaded from http://sysml-models.com/spacecraft/models.html. (Note that the use of this model is subject to the terms and conditions set by the copyright holders.)

The templates in the folder provide a different view of the model in tabular format.

13.2 SPCUseCase Template

The **Mission Failure Modes** worksheet shows the mission for the Spacecraft system and associated mission breakdowns. Identified failure modes for the activities are displayed in the **Failure Modes** column. The **Operational Usecase** worksheet displays the use cases, included and extended use cases.

Activity	Mission Activities	Mission Activities	Failure Modes
Perform Mission	Launch S/C		
Perform Mission	Launch S/C		Launch Failure
Perform Mission	Maintain Spacecraft Operations		
Perform Mission	Maintain Spacecraft Operations		Maintain Operations Failure
Perform Mission	Deploy Mechanisms		
Perform Mission	Deploy Mechanisms		Deploy Mechanism Failure
Perform Mission	Separate from L/V		
Perform Mission	Separate from L/V		Separation Failure
Perform Mission	Control Trajectory		
Perform Mission	Control Trajectory	Control Acceleration	Acceleration Control Failure
Perform Mission	Control Trajectory	Control Attitude-p	Steady State Attitude Control Failure
Perform Mission	Control Trajectory	Control Attitude-p	Attitude Rate Control Failure
Perform Mission	Control Trajectory	Control Attitude-p	Attitude Control Failure
Perform Mission	Control Trajectory	Control Attitude	Attitude Control Failure
Perform Mission	Control Trajectory		Trajectory Failure
Perform Mission	Provide Observation Data		
Perform Mission	Provide Observation Data		Provide Data Failure
Perform Mission			Mission Failure

The **RequirementsTree**, **FRMatrix** and **RequirementTreeSPC** worksheet show the spacecraft requirements displayed in the model.

13.3 SPCValueType Template

This template has worksheets that display all the signals and value types that are available in the Spacecraft model. The **Signals** worksheet displays the components signals and its reception. The **IO definitions** worksheet has the interface definitions the parameters that types the interface and its owner. In the table below the I-O Definition command is typed by the argument from Manage Power. The table displays only the parameters of the Behavior that are of type displayed in the first column.

I-O Definitions	Typed By	Name
Alert Message		
Attitude Adjust Command		
Command		
Command	argument	Manage Power
Command		Generate System Commands
Control		
Earth Track Data		
Earth Track Data	result	Sense Earth Horizon Angle
Earth Track Data	argument	Generate Reaction Wheel Spin Command
Electrical Power		
Emissions		
Fire Data		
Fluid		
Fuel		
Fuel TLM		
Gnd CMD		
GPS Data		
Heater Control		
IMU Data		
IMU Data	argument	Generate Reaction Wheel Spin Command
IMU Data	result	Sense Spacecraft Angular Rate
LV to SC Data		

13.4 SPCStructure template

This template displays the structural aspect of the Spacecraft System. The **MissionContext** worksheet shows the hierarchy of where the Spacecraft system and its subsystems are defined in the operating environment.
In the **BlackBox** worksheet the Value column displays the value properties of the Spacecraft System while the Operations column has the list of operations for the Spacecraft. The Ports column lists the different interfaces with which the system interacts with the external envir-

onment. The Behaviors column shows the system behavior as activities.

Spacecraft	Values	Operations	Ports	Behaviors
Spacecraft	cost			
Spacecraft	data capacity			
Spacecraft	deltaV			
Spacecraft	life			
Spacecraft	mass			
Spacecraft	max radiation level			
Spacecraft	pointing accuracy			
Spacecraft	power			
Spacecraft	probability of detection			
Spacecraft	probability of false alarm			
Spacecraft	reliability			
Spacecraft	size			
Spacecraft		collect observation data		
Spacecraft		return observation data		
Spacecraft		receive ground command		
Spacecraft		provide telemetry data		
Spacecraft		control attitude		
Spacecraft		control acceleration)		
Spacecraft		control thermal environment		
Spacecraft		provide electrical power		
Spacecraft		manage faults		
Spacecraft		control separation		
Spacecraft		provide structural integrity		
Spacecraft		deploy antenna		
Spacecraft		deploy solar array		
Spacecraft			solar radiation i/f	
Spacecraft			em radiation i/f	
Spacecraft			observation sensor i/f	
Spacecraft			thrust i/f	
Spacecraft			gnd cmd & data i/f	
Spacecraft			LV electrical i/f	
Spacecraft			LV mechanical i/f	
Spacecraft			thermal radiation i/f	
Spacecraft			star tracker i/f	
Spacecraft			inertial sensor i/f	
Spacecraft			impact i/f	
Spacecraft			gps i/f	
Spacecraft			horizon tracker i/f	
Spacecraft			drag i/f	
Spacecraft			sun tracker i/f	
Spacecraft			magnetometer i/f	
Spacecraft				Control Thermal Environment
Spacecraft				Manage Faults
Spacecraft				Provide Telemetry Data
Spacecraft				Receive Ground Command
Spacecraft				Deploy Antenna
Spacecraft				Deploy Solar Array
Spacecraft				Control Attitude
Spacecraft				Control Separation
Spacecraft				Control Acceleration
Spacecraft				Track Orbit
Spacecraft				Collect Observation Data
Spacecraft				Provide Electrical Power

The **Constraint Parameter** worksheet displays the constraints from the model. The **Physical Decomposition** worksheet shows the hierarchy of the components of the spacecraft. The **Spacecraft ConnectorMatrix** and **Spacecraft Connector** worksheets display the same information but as different views.

Components	Components	GN&C SW	GN&C SW	GN&C SW	GN&C SW	GN&C SW	GN&C SW	GN&C SW	GN&C SW	GPS Unit	GPS Unit	Horizon Tracker	Horizon Tracker	Inertial Measurem	Inertial Measurem	Magnetometer	Magnetometer	Reaction Wheel	Reaction Wheel	Star Tracker	Star Tracker	Sun Tracker	Sun Tracker
Components	Ports	p5	p2	p6	p7	p8	p1	p3	p4	p1	gps i/f	p1	horizon tracker i/f	p1	intertial reference i/f	p1	magnetometer i/f	p1	torque i/f	p1	star tracker i/f	sun tracker i/f	p1
GN&C SW	p5											X											
GN&C SW	p2													X									
GN&C SW	p6																			X			
GN&C SW	p7									X													
GN&C SW	p8																	X					
GN&C SW	p1																						
GN&C SW	p3															X							
GN&C SW	p4																						X
GPS Unit	p1				X																		
GPS Unit	gps i/f																						
Horizon Tracker	p1	X																					
Horizon Tracker	horizon tracker i/f																						
Inertial Measurement Ur	p1		X																				
Inertial Measurement Ur	intertial reference i/f																						
Magnetometer	p1							X															
Magnetometer	magnetometer i/f																						
Reaction Wheel	p1					X																	
Reaction Wheel	torque i/f																						
Star Tracker	p1			X																			
Star Tracker	star tracker i/f																						
Sun Tracker	sun tracker i/f																						
Sun Tracker	p1								X														

The **GNCInformationFlow** and **GNC_InterfaceMatrix** worksheets show only the details of the GNC Subsystem. The **GNC Subsystem** worksheet shows all the relevant information of the different components.

14 Telescope Model

14.1 Introduction

The TMT model is available to download from: https://github.com/Open-MBEE/TMT-SysML-Model

(Note that the use of this model is subject to the terms and conditions set by the copyright holders).The Template files in the TMT model folder provide a different view of the telescope model. Using these templates with a model as big as the TMT, makes viewing the model elements in a tabular format easier to visualize.

These templates will provide a compact view into the model. Since the TMT is a fairly large model, before using the template, increase the RAM allocated to MapleMBSE. Refer to the user guide and enable cache at login.

14.2 TMT_Predicate Template

This template is for review only and not for editing the model content. The predicates are defined in the configuration file that effectively query the model based on Boolean conditions and will display the results that match these conditions. In the **Requirements** worksheet all the requirements in the TMT model is displayed. In the **PredicateFilter** worksheet, only the requirements that don't have Rationale are displayed. The **AcceptedRequirements** worksheet will list the requirements that as a tagged value as "Accepted".

ID*	Name	Tag = Accepted
3	Ambient Operating Temperature	Accepted
5	APS User GUI	Accepted
6	APS Responsibility	Accepted
7	APS Starlight	Accepted
8	APS Acquisition Camera FOV and plate scale	Accepted
9	Segment Measurement Error	Accepted

The **ValueProperty** worksheet has the value properties that don't have a datatype. The IDs of these values are displayed so that they can be easily found by searching in the modeling tool.

Value Property	Component	ID
A/D bit	CCD Detector	_17_0_2_3_41e01aa_1379087596098_221406_43317
arrayLength	Procedure Executive and Analysis Sc	_18_0_5_c0402fd_1470084213608_649914_168690
Decision Consequence	M&S Risk Assessment	_17_0_1_382a051a_1302712866646_684048_15580
ditExposure	PEAS PIT Tracking	_18_0_5_c0402fd_1463788548563_320834_148611
Electron Well size	CCD Detector	_17_0_2_3_41e01aa_1379087638392_256325_43321
Input Pedigree	M&S Credibility Assessment	_17_0_1_382a051a_1302712866646_787170_15584
M&S Management	M&S Credibility Assessment	_17_0_1_382a051a_1302712866647_296612_15588
People Qualifications	M&S Credibility Assessment	_17_0_1_382a051a_1302712866647_22710_15589
Pixel Pitch	CCD Detector	_17_0_2_3_41e01aa_1379087570399_162103_43313
Results Influence	M&S Risk Assessment	_17_0_1_382a051a_1302712866645_224565_15579
Results Robustness	M&S Credibility Assessment	_17_0_1_382a051a_1302712866647_549076_15586
Results Uncertainty	M&S Credibility Assessment	_17_0_1_382a051a_1302712866647_9514_15585
Use History	M&S Credibility Assessment	_17_0_1_382a051a_1302712866647_106737_15587
Validation	M&S Credibility Assessment	_17_0_1_382a051a_1302712866646_736398_15583
Verification	M&S Credibility Assessment	_17_0_1_382a051a_1302712866646_150481_15582

Similarly, the constraint blocks with parameters that don't have a type are shown in the **ConstraintParameterType** worksheet. The qualified name for these constraint blocks is displayed so you can find them easily in the modeling tool.

Constraint Block	QualifiedName	Parameter
constraint	StructureA::constraint	s
Constraint Y	Tests, Examples, and Braindumps::RKA	cp1
Constraint Y	Tests, Examples, and Braindumps::RKA	cp2
Constraint Y	Tests, Examples, and Braindumps::RKA	cp3
Convert Meters to Percent	TMT::Project::Work Packages::Telescop	diameter
Convert Meters to Percent	TMT::Project::Work Packages::Telescop	cbe
Convert Meters to Percent	TMT::Project::Work Packages::Telescop	cbeInPercent

14.3 TMT Activity Template

This template will display the information of activities of the APS system. The **APSInterchangFunction** worksheet lists the different packages with activatations that send signals to Component ports. In the figure below, Sub-Package cmd_M1CS has activities that are defined in the Activity Column. Calibrate Warping Harness has a Send Signal action, Calibrate Warping Harness cmd, that is received by port PEAS2M1CSOut which owned by Procedure Executive and Analysis Software.

Package	Sub-Package	Activity	Send Signal	To Port	Block
External	Cmd_M1CS	Calibrate Warping Harness	Calibrate Warping Harness Cmd	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M1CS	Get Segment WH Pos	Get Segment WH Pos Cmd	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M1CS	Get_Installed_Segment	Get installed_Segment_Query	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M1CS	Save M1CS Configuration	Take Snapshot Cmd	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M1CS	Send Segment PTT	Move Segment PTT Cmd	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M1CS	Send Segment WH Cmd	Move Segment WH Cmd	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M1CS	Set WH Strain	Set WH Strain Cmd	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M1CS	Turn Warping Harnesses Off	Turn WH Off Cmd	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M1CS	Turn Warping Harnesses On	Turn WH On Cmd	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M1CS	Zeroing Sensor Readings	offloadSensorOffsets Cmd	PEAS2M1CSOut	Procedure Executive and Analysis Software
External	Cmd_M3CS	Send M3 Offset	M3Offset Cmd	PEAS2TCSOut	Procedure Executive and Analysis Software

The ActivityDecomposition worksheet shows activity breakdown up to 4 level.

Top Level Activity	Sub-Activity 1	Sub-Activity 2	Sub-Activity 3	Sub-Activity 4
Rigid Body and Segment Figure correction	Setup APS, Acquire and Start Guiding	Configure APS for SH Test	Center Shear Plate	
Rigid Body and Segment Figure correction	Setup APS, Acquire and Start Guiding	Configure APS for SH Test	Center Shear Plate	Adjust Shear Plate PEAS

Right-click on the table and select **create merged view** to create a worksheet that will remove the redundant entries. Note that this new worksheet is only an excel sheet created to simplify the view and is not linked with the MapleMBSE syncview.

Top Level Activity	Sub-Activity 1	Sub-Activity 2	Sub-Activity 3	Sub-Activity 4
Rigid Body and Segment Figure correction	Setup APS, Acquire and Start Guiding	Configure APS for SH	Center Shear Plate	
				Adjust Shear Plate PEAS

14.4 Signal Interface

This worksheet is similar to the **APSInterchangeFunctions** worksheet but table displays the APSComponents and their interface (ports) which receive a signal and source of the signal in the Send Action column

14.5 TMT_OBSE Template

This template file has the views of TMT Observatory System. TMTObservatorySystem shows the components of the observatory system. Conceptual design template displays the Components and their attributes like ports and values. The Owned Behaviors column has the list of behaviors that are performed by the system.

Components	Ports	Values	Signal	Owned Behaviors
Alignment and Phasing System				
AO Sequencer				
AO Sequencer	AOSeq2ESW			
AO Sequencer	AOSeq2ESW			
AO Sequencer			AcquirePointing	
AO Sequencer			AcquireDone	
AO Sequencer				Pointing acquisition
BTO				
Common Services				
Common Services	CS2PEASIn			
Common Services	CS2PEASOu			
Common Services			QueryCompleted	
Common Services				SendAck
Data Management System				
DM				
Enclosure				
ESEN				
ESW Seq				
ESW-ACQ				
ESW-ACQ		numloop		
ESW-ACQ		i		

14.6 TMTInstance

The results of instances from the TMT model for different scenarios are shown in their respective worksheets. For example, in the CalibrationsDurationInstances worksheet, the components and their value properties are displayed. The column represents the different instances for the calibration scenario and the intersecting cell has a value for that instance of the component in the rows.

Components	Instances / Values	calibrations Duration Scenario at 2017.10.18 19.22	calibrations Duration Scenario at 2017.10.26 11.56
Acquisition Pointing and Tracking Assembly	ditSetup	5	5
APS Mission Conceptual	maxPhasingTime	300	300
APT Loop	terminate	FALSE	FALSE
Executive Software	adjustGC	FALSE	FALSE
Executive Software	askOperator	FALSE	FALSE
Executive Software	pErr	1	1
Executive Software	tAcquisition	33	37
Executive Software	tAcquisitionStart	8219	8249
Executive Software	TBD	10	10
M3 Alignment Maximum Time	m3AlignmentTimeLimit	36000	36000
Maintenance Alignment Maximum Time	maintenanceAlignmentTimeLimit	1800	1800
Off-Axis Acquisition Maximum Time	offAxisAcquisitionTimeLimit	36000	36000
On-axis alignment maximum time for Post Segme	postSegXchgTimeLimit	7200	7200
Peak Power Limit Requirement JPL	powerPeakLimitEnclosure	8100	8100
Peak Power Limit Requirement JPL	powerPeakLimitSummitFacilityBuildi	4100	4100
Peak Power Limit Requirement TMT	powerPeakLimitEnclosure	8500	8500
Peak Power Limit Requirement TMT	powerPeakLimitSummitFacilityBuildi	4200	4200
PEAS PIT Tracking	ditExposure	4	4
PEAS PIT Tracking	numStopAck	0	0

The **TMTInterfaceView** template has the view of interface definitions and connectors between the components of the APS system. The **APSConceptual** worksheet has a matrix view of the interface between the APS components. The SSCAssociationClass worksheet shows a view of the AssociationBlock and their flow properties.

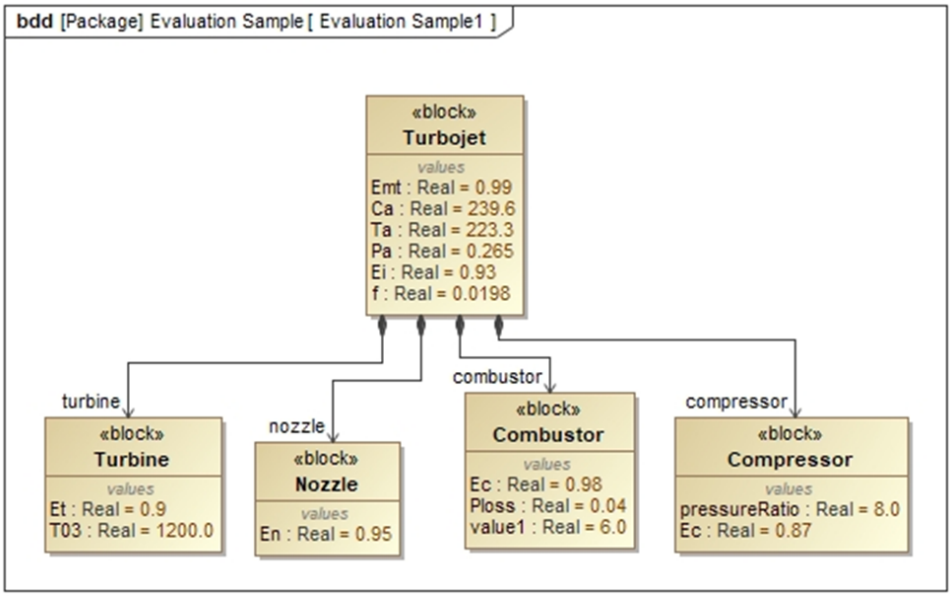
15 Turbojet Model: Formula Evaluation

15.1 Introduction

A Turbojet Cycle Analysis context block as shown below is defined in the model. This context block has all the constraints that are used to calculate the specific fuel consumption (SFC). The inputs that can be changed to compute the best sfc are defined as value properties in the component blocks. Instance specifications are created for the Turbofan Cycle Analysis and these instances hold the values for that specific instance of the turbojet system.

15.2 Instance Specifications and Constraint Properties

This example is used to calculate turbojet design points using the formula evaluation feature. In this example, the user can see the block hierarchy used to define the turbojet system model. The design point calculations are based on ideal gas turbine cycle analysis. To use the formula evaluation, the following conditions are to be met: The formulas are defined in constraint properties, instances are created based on a top-level analysis context. These instances hold the components and its value properties in form of slots. A parametric diagram is used to define the constraints between these properties.



Component	Sub-Component	Value Name	Default Value
Turbojet	Combustor	Ec	0.98
Turbojet	Combustor	Ploss	0.04
Turbojet	Compressor	pressureRatio	8
Turbojet	Compressor	Ec	0.87
Turbojet	Nozzle	En	0.95
Turbojet	Turbine	Et	0.9
Turbojet	Turbine	T03	1200
Turbojet Cycle Anal	Turbojet	Emt	0.99
Turbojet Cycle Anal	Turbojet	Ca	239.6
Turbojet Cycle Anal	Turbojet	Ta	223.3
Turbojet Cycle Anal	Turbojet	Pa	0.265
Turbojet Cycle Anal	Turbojet	Ei	0.93
Turbojet Cycle Anal	Turbojet	f	0.0198

The component hierarchy worksheet shows the top-level components and their value properties. The instance matrix displays the instance specification of the top-level Turbojet Cycle Analysis

15.3 Instance Matrix

Formula evaluation can be used in the worksheet that displays the instance matrix with slots. The rows of the matrix display the components and their value properties. The columns display the names of the instances. The matrix displays the value in the slots corresponding to the value properties and instances. The inputs and output values are not explicitly defined but is understood based on the objective defined in the template or based on experience.

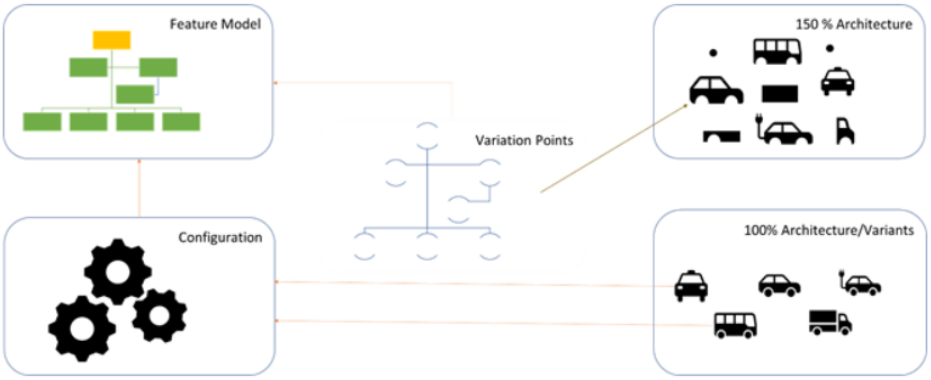
Components	Name / Specification	turbojet Cycle Analysis3	turbojet Cycle Analysis4	turbojet Cycle Analysis1	turbojet Cycle Analysis2
Combustor	Ec	0.98	0.97	0.975	0.98
Combustor	Ploss	0.04	0.04	0.04	0.04
Compressor	Ec	0.87	0.88	0.89	0.87
Compressor	pressureRatio	8	7	7.5	8
Nozzle	En	0.95	0.95	0.95	0.95
Turbine	Et	0.9	0.93	0.9	0.95
Turbine	T03	1200	1250	1200	1300
Turbojet	Ca	239.6	239.6	239.6	239.6
Turbojet	Ei	0.93	0.93	0.93	0.93
Turbojet	Emt	0.99	0.99	0.99	0.99
Turbojet	f	0.0198	0.0198	0.0198	0.0198
Turbojet	Pa	0.265	0.265	0.265	0.265
Turbojet	Ta	223.3	223.3	223.3	223.3
Turbojet Cycle Analysis	Cp	1005	1005	1005	1005
Turbojet Cycle Analysis	Cpg	1148	1148	1148	1148
Turbojet Cycle Analysis	g	1.4	1.4	1.4	1.4
Turbojet Cycle Analysis	gc	1.33	1.33	1.33	1.33
Turbojet Cycle Analysis	R	0.287	0.287	0.287	0.287
Turbojet Cycle Analysis	sfc	0.12111692	0.11500965	0.12019785	0.10977919

The input values of existing slots can be changed based on these values, the output values will be calculated. New instances can be created by adding a name for the instance in the column. To run the formula evaluation, use the shortcut Ctrl + Shift + K or Add-ins select MapleMBSE and Formula Evaluation. MapleMBSE will use excel to call the values and update the matrix.

16 Variant Management:MBPLE with MapleMBSE

16.1 Introduction

Model-Based Product Line Engineering (MBPLE) is used to capture the 150% model that is defined with all the features and different options a user has to configure a variant of a product. This example requires the MBPLE profile to be used in the project. In MBPLE, the user defines the Feature Model with all the available options. In the configuration part, the user selects a set of features that make up the product variant. The 150% model is defined and linked with the variation points that link the Feature model and 150% model from which, based on the configuration defined, a user can generate a variant.



16.2 Feature Model

The RootFeatureTable worksheet displays the Root Feature Group and all of its features in a hierarchy. This sheet is used to add new features to the feature Groups.

RootFeature	Features L1	Features L2	Features L3
Vehicle	Tires		
Vehicle	Seat		
Vehicle	Engine		
Vehicle	Engine	V-Engine	
Vehicle	Engine	V-Engine	Engine Size
Vehicle	Engine	V-Engine	V Type
Vehicle	Engine	Injection	
Vehicle	Engine	turboCharged	
Vehicle	Engine	Inline Engine	
Vehicle	Engine	Inline Engine	Engine Capacity
Vehicle	Engine	Inline Engine	Inline Type
Vehicle	Fuel Tank		
Vehicle	Body		
Vehicle	Interior		
Vehicle	Interior	Steering wheel	
Vehicle	Interior	CruiseControl	
Vehicle	Interior	Vehicle audio	
Vehicle	Interior	Heated Seats	
Vehicle	Interior	Speedometer	
Vehicle	Transmission		
Vehicle	Transmission	Automatic Transmission	
Vehicle	Transmission	Manual transmission	
Vehicle	Brake		
Vehicle	Chassis		
Vehicle	Wheel		
Vehicle	Head Lights		

The Existence_List worksheet displays the types or variations for the feature. To add a new type to a feature, enter the feature name in Feature Group Column and type in the Feature Column.

FeatureGroup	Features
Automatic Transmission	Automatic Manual Transmission
Automatic Transmission	Continuously Variable Transmission
Automatic Transmission	Dual-Clutch Transmission
Body	Hatchback
Body	Sedan
Body	Sports Car
Body	SUV
Brake	Ceramic Brake Pads
Brake	Organic brake pads
Brake	Semi-Metallic Brake Pads
Chassis	Conventional chassis
Chassis	Unibody chassis
CruiseControl	AdaptiveCruiseControl
CruiseControl	Semi-autonomous cruise control

16.3 Configurations

Next, define the configuration of the Feature Model. In the configuration, the user specifies the model with features that will define a variant. The ConfigurationMatrix worksheet displays existing configurations. To add a new configuration, enter a name for the configuration in the column.

Root Feature	Feature Group	Root Feature	Feature Group	Base Model SUV	DemoModel	GSModel	GTModel	Sports Car	SUV
Vehicle	Engine	V-Engine	Engine Size					6.4 litre	
Vehicle	Engine	V-Engine	V Type					V8	
Vehicle	Engine	Inline Engine	Engine Capacity	2 Litre					2.5 Litre
Vehicle	Engine	Inline Engine	Inline Type	Straight-6					Straight-6
Vehicle	Engine		V-Engine					Configuration::v-Engine	
Vehicle	Engine		Injection	Direct Injection	Direct Injection	Port Injection	Direct Injection	Direct Injection	Direct Injection
Vehicle	Engine		turboCharged		TRUE	TRUE	TRUE	TRUE	TRUE
Vehicle	Engine		Inline Engine	Configuration::inline Engine_Base					Configuration::inlin
Vehicle	Interior		Steering wheel	Adjustable Steering V	Tilt Steering Wheel	Adjustable Stee	Adjustable Steering Wh	Tilt Steering Whee	Adjustable Steering
Vehicle	Interior		CruiseControl	AdaptiveCruiseContr	AdaptiveCruiseContr	AdaptiveCruise	Semi-autonomous crui	AdaptiveCruiseCo	AdaptiveCruiseCont
Vehicle	Interior		Vehicle audio	Full Range	Full Range	Component	Component	Component	Full Range
Vehicle	Interior		Heated Seats	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
Vehicle	Interior		Speedometer	Analog speedometer	Digital speedometer	Analog speedor	Digital speedometer	Digital speedomet	Analog speedomete
Vehicle	Transmission		Automatic Transmission	Automatic Manual Transmission			Continuously Variable Transmission		Continuously Variat
Vehicle	Transmission		Manual transmission		6-speed manual tran	6-speed manual transmission		6-speed manual transmission	
Vehicle			Tires	All-season Tires	All-season Tires	All-season Tire	All-season Tires	Performance Tires	All-season Tires
Vehicle			Seat	4 Seater	2 Seater	2 Seater	4 Seater	2 Seater	4 Seater
Vehicle			Engine	Configuration::engine	Configuration::demo	Configuration::(	Configuration::GTEngi	Configuration::eng	Configuration::engi
Vehicle			Fuel Tank	45 liters capacity	45 liters capacity	45 liters capaci	55 liters capacity	55 liters capacity	55 liters capacity
Vehicle			Body	SUV	SUV	SUV	SUV	Sports Car	SUV
Vehicle			Interior	Configuration::interic	Configuration::demo	Configuration::(	Configuration::GTInter	Configuration::inte	Configuration::inter
Vehicle			Transmission	Configuration::transn	Configuration::demo	Configuration::(	Configuration::GTTrans	Configuration::trai	Configuration::trans
Vehicle			Brake	Organic brake pads	Organic brake pads	Organic brake p	Semi-Metallic Brake Pa	Semi-Metallic Bra	Organic brake pads
Vehicle			Chassis	Unibody chassis	Conventional chassi	Conventional ch	Conventional chassis	Unibody chassis	Unibody chassis
Vehicle			Wheel	Steel	Steel	Steel	Alloy	Alloy	Alloy
Vehicle			Head Lights	LED Lights	LED Lights	LED Lights	LED Lights	LED Lights	LED Lights

MapleMBSE will automatically populate the column with the default values. The user can select different value for a Feature by using the drop down menu in applicable cells. The TransmissionConfigMatrix, InteriorConfigMatrix and EngineConfigMatrix offer a similar view but give the user better control over individual configuration of the features.

		Configurations -->				
Root Feature	Feature Group	GSMatrix	GTTransmission	transmission	transmission1	transmission2
Transmission	Automatic Transmission		Continuously Variat	Continuously Variable Transn		Automatic Manual
Transmission	Manual transmission	6-speed manual transmission			6-speed manual transmission	

		Configurations -->				
Root Feature	Feature Group	GSInterior	GTInterior	interior	interior1	interior2
Interior	CruiseControl	AdaptiveCruis	Semi-auton	AdaptiveCr	AdaptiveC	AdaptiveCruiseCont
Interior	Heated Seats	TRUE	TRUE	TRUE	TRUE	FALSE
Interior	Speedometer	Analog speed	Digital spee	Analog sp	Digital sp	Analog speedomete
Interior	Steering wheel	Adjustable St	Adjustable S	Adjustable	Tilt Steeri	Adjustable Steering
Interior	Vehicle audio	Component	Component	Full Range	Componer	Full Range

		Configurations -->				
Root Feature	Feature Group	engine	engine1	engine2	GSEngine	GTEngine
Engine	Injection	Direct Injec	Direct Injectio	Direct Inje	Port Injection	Direct Injection
Engine	Inline Engine	Configuration::inline Engi		Configuration::inline Engine_Base		
Engine	turboCharged	TRUE	TRUE		TRUE	TRUE
Engine	V-Engine		Configuration::v-Engine			

16.4 Variation Points

In the previous sections you defined the Features and configuration from which the variants can be created. The 150% model is already defined and our goal now is to link the Feature model with the 150% model.
The Existence worksheet lists all the existence that can be linked to the Feature Model using the Feature Impact relations.

Existence
2 Litre
2 Seater
2.5 Litre
3 Litre
3.5 litre
4 Seater
6.4 litre
AdaptiveCruiseControl
Adjustable Steering Wheel

The FeatureImpactTable links the existence with the Feature Model as shown in the image below. In the example below, the Variation Point/Existence 2 Litre links the Feature Group Engine Capacity. The Test for column allows the user to select the type of feature that the variation point represents.

Variation Point	Feature	Test For
2 Litre		
2 Litre	Engine Capacity	2 Litre
2 Seater		
2 Seater	Seat	2 Seater
2.5 Litre		
2.5 Litre	Engine Capacity	2.5 Litre
3 Litre		
3 Litre	Engine Capacity	3 Litre
3.5 litre		
3.5 litre	Engine Size	3.5 litre

The next step is to apply the Existence to the 150% model. ExistenceMatrix shows the Existence in the rows of the matrix and Components in the column, “X’ in the intersecting cell represents that an existence is applied to a component.

Components / Existence/Variation	2 Litre	2 Seater	2.5 Litre	3 Litre	3.5 litre	4 Seater	6.4 litre	AdaptiveCruiseControl	Adjustable Steering Wheel	Alloy Wheel	All-season Tires	Analog speedometer	Automatic Manual Transmission
2 Litre	X												
2 Seater		X											
2.5 Litre			X										
3 Litre				X									
4 Seater						X							
45 liters capacity													
55 liters capacity													
65 liters capacity													
6-speed manual transmission													
AdaptiveCruiseControl								X					
Adjustable Steering Wheel									X				
Alloy										X			
All-season Tires											X		
Analog speedometer												X	
Automatic Manual Transmission													X

16.5 Vehicle Analysis

The Analysis worksheet is used to find the time it takes for a vehicle to reach a certain speed in the 1st and 2nd gear. The values time, time_1, time_2, a1 and a2 are calculated and results are updated when Formula evaluation function is used. The user can update the other values and run the evaluation when needed. The matrix display instances of the 150% model. The block and value properties that are needed for the analysis are in the rows of the matrix. The instances are displayed in the column. Add a new instance and enter the values that are necessary, to run the evaluation use the shortcut Ctrl + Shift + K or Add-ins-> MapleMBSE->Evaluate Formula. If the evaluation is successful, you will see a dialog box the current worksheet was successfully evaluated.

Component	Property \ Instance	vehicle
Tires	diameter	0.6
Transmission	finalDrive	3
Transmission	gearRatio_1	4
Transmission	gearRatio_2	2.5
Transmission	peakTorque	140
Vehicle	a1	2.487
Vehicle	a2	0.667
Vehicle	avgTorrque	0.8
Vehicle	massBudget	1500
Vehicle	speedLoss	0.5
Vehicle	speedLoss_2	1.2
Vehicle	time	15.85
Vehicle	time_1	3.351
Vehicle	time_2	12.5
Vehicle	VRange	30
Vehicle	vRange_2	30

17 Downloading sysML Diagrams

17.1 Introduction

Using the MapleMBSE plugin a user can view the downloaded SysML diagram in the MapleMBSE template. To configure the plugin please refer to the **Getting Started with the MapleMBSE sysML Diagram Plugin** section of the **MapleMBSE Installation and Licensing Guide**.

17.2 TWCsysML Example

To view the diagram of the TWCSysML example, launch the TWCSysML-Diagrams file and connect to the project. Note that the same project should be opened in CSM/MD for the diagrams to be downloaded. Click on the hyperlink to open the diagram.

PackageName	Diagram	Type
Cost Analysis	Diagram Cost Analysis	SysML Block Definition Diagram
Evaluation Sample	Diagram Analysis Context	SysML Block Definition Diagram
Evaluation Sample	Diagram Evaluation Sample	SysML Block Definition Diagram
Evaluation Sample	Diagram Turbojet	SysML Block Definition Diagram
Hierarchy	Diagram Hierarchy	SysML Block Definition Diagram
Instances	Diagram Instances	SysML Block Definition Diagram
InstanceView	Diagram InstanceView	SysML Block Definition Diagram
Interface	Diagram Interface1	SysML Block Definition Diagram
Interface	Diagram Interface2	SysML Block Definition Diagram
NestedHierarchy	Diagram NestedHierarchy	SysML Block Definition Diagram
Obstacle Avoiding Robot	Diagram Context	SysML Block Definition Diagram
PM	Diagram PM	SysML Block Definition Diagram
Requirements	Diagram Requirements	Requirement Diagram
Structure	Diagram Structure	SysML Block Definition Diagram
Structure_Logical	Diagram Tablet_Logical	SysML Block Definition Diagram
Structure_Physical	Diagram Tablet_Structure	SysML Block Definition Diagram
Structure_Physical	Diagram Variant model	SysML Block Definition Diagram
Tablet	Diagram Tablet	Profile Diagram

Note: In case of an error, you will see the "Unable to connect to MapleMBSE plugin" dialog.

18 Relations Matrix

18.1 Verify Matrix with Hierarchy

Verify Matrix with Hierarchy

This example displays the **Verify** relation between **Component Value** property and **Requirements**. The rows display the Component Turbofan and its subcomponents, displaying the value properties in Column H. The column displays the Requirements in a nested hierarchy as shown below.

Verify :: Block Value Property --> Requirements		System Requirements / Value Property	Analysis 14	Analysis 14	Analysis 14	Analysis 14	Analysis 14	Analysis 14	System R 15	System R 15	System R 15	System R 15	System R 15	System R 15	System R 15	System R 15	System R 15	System R 15	System R 15	System R 15
			Analysi 14	Analysi 14	Analysi 14	Analysi 14	Analysi 14	Analysi 14	TwinSp 15	TwinSp 15	High Pr 15	High Pr 15	High Pr 15	High Pr 15	High Pr 15	High Pr 15	High Pr 15	High Pr 15	High Pr 15	High Pr 15
omponent Block	Component Parts		Heating V 14.1.4	Inlet Effici 14.1.5	InterTurbi 14.1.6	Bypass Ra 14.1.7	air to fuel 14.1.8	14.1.9		Spool Effic 15.1.1		Turbine Ef 15.2.1	Disk Coolir 15.2.2	HPT vane 15.2.3	Active Cle 15.2.4		High Press 15.3.1	Bleed Air 15.3.2	Tip Clearal 15.3.3
TurboFan Engine																				
TurboFan Engine	Combustor																			
TurboFan Engine	Combustor	mf_fuel																		
TurboFan Engine	Combustor	T05																		
TurboFan Engine	Combustor	P05																		
TurboFan Engine	Combustor	m_afmixture																		
TurboFan Engine	Combustor	mf/ma					X													
TurboFan Engine	Combustor	efficiency_combustion																		
TurboFan Engine	Combustor	pressure_loss																		
TurboFan Engine	Combustor	P0in_combustor																		
TurboFan Engine	Combustor	T0in_combustor																		
TurboFan Engine	Combustor	m_incombustor																		
TurboFan Engine	Combustor	Cp_air																		
TurboFan Engine	Combustor	Cp_fuel																		
TurboFan Engine	Combustor	heating value	X																	
TurboFan Engine	Combustor	m_bleed_acc																		
TurboFan Engine	Combustor	Btair								X								X		X
TurboFan Engine	High Pressure Axial Compres																			
TurboFan Engine	High Pressure Axial Compres	P04																		
TurboFan Engine	High Pressure Axial Compres	target Efficiency iof HPC															X			
TurboFan Engine	High Pressure Axial Compres	T04																		
TurboFan Engine	High Pressure Axial Compres	W_hpc																		

18.2 Multiple Relations in Matrix

The TWCSysML-RelationMatrix.MSE contains the MultipleRelationMatrix worksheet. Using this view, users can add different types of relations between elements in the same view. Two types of relations are shown here: Verify relation (VER) and Satisfy relation (SAT). To add a new VER dependency, in the matrix cell, enter VER and then click enter. This will add a new verify relation.

VER: Verify Relation, SAT: Satisfy Relation																			
	ID* -->	6.8.2	5.1.1	6.6	6.2	6.7.3	6.5.1	5	5.1.4	6.2.4	6.8.1	5.1.5	6.7	6.3.3	6.3.2	5.1	5.1.2
Components*	Requirement / ValueProperty*	Combustion Efficiency	Perform Trade-off Analysis at	Low Pressure Compressor	High Pressure Turbine	ACC MassFlow	Nozzle Efficiency	Analysis	Heating Value	Active Clearance Control	Combustion Pressure Loss	Inlet Efficiency	Low Pressure Turbine	Tip Clearance	Bleed Air	Analysis Specs	Nozzle Exit Conditions
Combustor	mf/ma																
Combustor	efficiency_combustion	VER															
Combustor	pressure loss										VER						
Combustor	P0in_combustor																
Combustor	T0in_combustor																
Combustor	m_incombustor																
Combustor	Cp_air																
Combustor	Cp_fuel																
Combustor	heating value								VER								
Combustor	m_bleed_acc																
Combustor	Btair													VER	VER		
Nozzle_fan																	SAT
Nozzle_fan	P02/Pc																
Nozzle_fan	P02/Pa																
Nozzle_fan	Tfanexit																
Nozzle_fan	Pexit																
Nozzle_fan	Vexit_fan																VER
Nozzle_fan	Aexit																
Nozzle_fan	F_fan																VER
Nozzle_fan	efficiency_nozzle						VER										

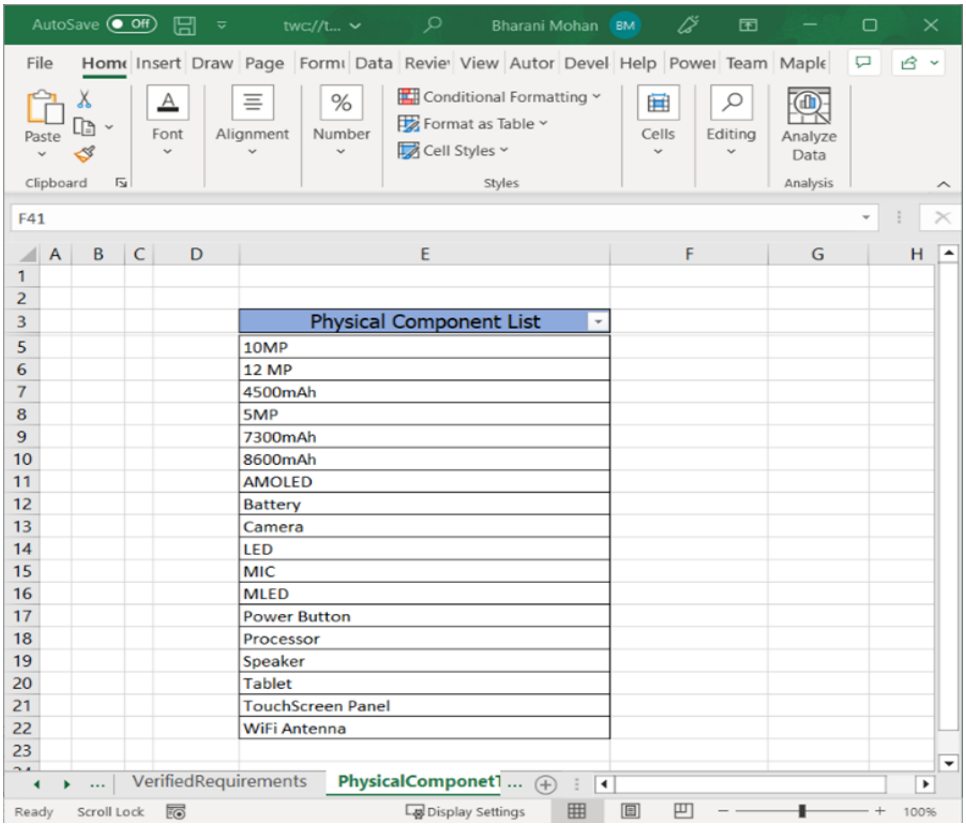
It is also possible to add multiple dependencies between the same elements. For example, to add a satisfy relation between efficiency Combustion of Combustor and requirement 6.8.2 Combustor Efficiency, in the cell with VER, type VER, SAT and press Enter.

VER: Verify Relation, SAT: Satisfy Relation												
	ID* -->	6.8.2	5.1.1	6.6	6.2	6.7.3	6.5.1	5	5.1.4	6.2.4	6.8.1
Components*	Requirement / ValueProperty*	Combustion Efficiency	Perform Trade-off Analysis at	Low Pressure Compressor	High Pressure Turbine	ACC MassFlow	Nozzle Efficiency	Analysis	Heating Value	Active Clearance Control	Combustion Pressure Loss
Combustor	mf/ma										
Combustor	efficiency combustion	VER,SAT									
Combustor	pressure loss										VER
Combustor	P0in combustor										
Combustor	T0in combustor										
Combustor	m incombustor										
Combustor	Cp air										
Combustor	Cp fuel										
Combustor	heating value								VER		
Combustor	m bleed acc										
Combustor	Btair										
Nozzle fan											
Nozzle fan	P02/Pc										
Nozzle fan	P02/Pa										
Nozzle fan	Tfanexit										
Nozzle fan	Pexit										
Nozzle fan	Vexit fan										
Nozzle fan	Aexit										
Nozzle fan	F fan										
Nozzle fan	efficiency nozzle						VER				

19 Predicates

19.1 Introduction

In addition to the predicate samples in TMT folder, new enhancements to predicates defined with stereotypes now allow you to add new elements to the model. Worksheet Requirements displays all the requirements that are defined in the model. VerifiedRequirement shows only the requirements which have verified Dependency. The ValueProperty and Constraint-ParameterType worksheets display elements without a datatype defined. The Physical Components table displays components that are “Blocks” with “Physical” stereotype. To add a new element in the last two type a component name.



20 Matrices With Different Element Types

20.1 Introduction

When using matrices to illustrate relationships between elements, it is common to use the same type of elements in either the rows or the columns. For example, when representing a 'Satisfy' dependency, Requirements could be displayed in relation to either Classes or Value Properties. However, grouping different types of elements and displaying existing relations has traditionally been challenging.

With the recent feature update, it is now possible to group elements based on certain criteria and display them in the rows or columns of matrices. The **TWCSysML-MultipleTypes** example illustrates this capability by displaying Requirements in the rows and Blocks along with Value Properties in the columns at the same level. This is achieved by grouping Blocks and Properties and then displaying them together. It's important to note that the columns will not allow new elements to be added to the model

ID*	Name	Specification\Type	Combustor	Compressor	Nozzle	Turbine	Turbojet	Turbojet Cycle Analysis	Property Ca	Property Pa	Property Ploss	Property pressureRatio	Property R	Property sfc	Property T03	Property Ta
		Name	Class	Class	Class	Class	Class	Class	Property	Property	Property	Property	Property	Property	Property	Property
94	Turbojet Configuration	The Turbojet shall have basic single spool configuration					X									
95	Combustor loss	The maximum loss of pressure in combustor shall be 0.04									X					
96	Turbine Maximum Temperature	The maximum temperature of the turbine inlet should be 1200K													X	
97	Compressor Pressure Ratio	The minimum pressure ratio of the compressor shall be 8										X				

Index

M

P

R

S

T

U

V

W