February 2019

New Tool and Process to Keep System Documentation Current with the Increasing Pace of Agile Product Development

Jim Allen and Bharath Sundar

Delphi Technologies

Table Of Contents

Overview

- The Automotive industry’s shortening design cycles, increased software content, and new software methodologies like AGILE are impacting systems engineering.
- New control strategies need developed faster through modeling, auto-coded, verified and delivered to customers with accompanying use documentation.
- The fast pace of the AGILE methodology requires Delphi Technologies to work hand-in-hand with our customers and suppliers to develop and refine requirements to make quick interim deliveries.
- Delphi Technologies has created a new tool and process to automate system documentation and link requirements to models.

Challenges

- Get the model, the software for the controls or diagnostic strategy and the documentation manuals in the hands of the customer to test in a short Sprint Design Phase.

- Keep documentation up to date through the design/test/fix cycle and available in the same time frame as the software delivery so the engineers understand how to calibrate the controls or diagnostics strategy.

- Show that the requirements in the corporate deployed requirements management tools are satisfied by the models.

Challenges

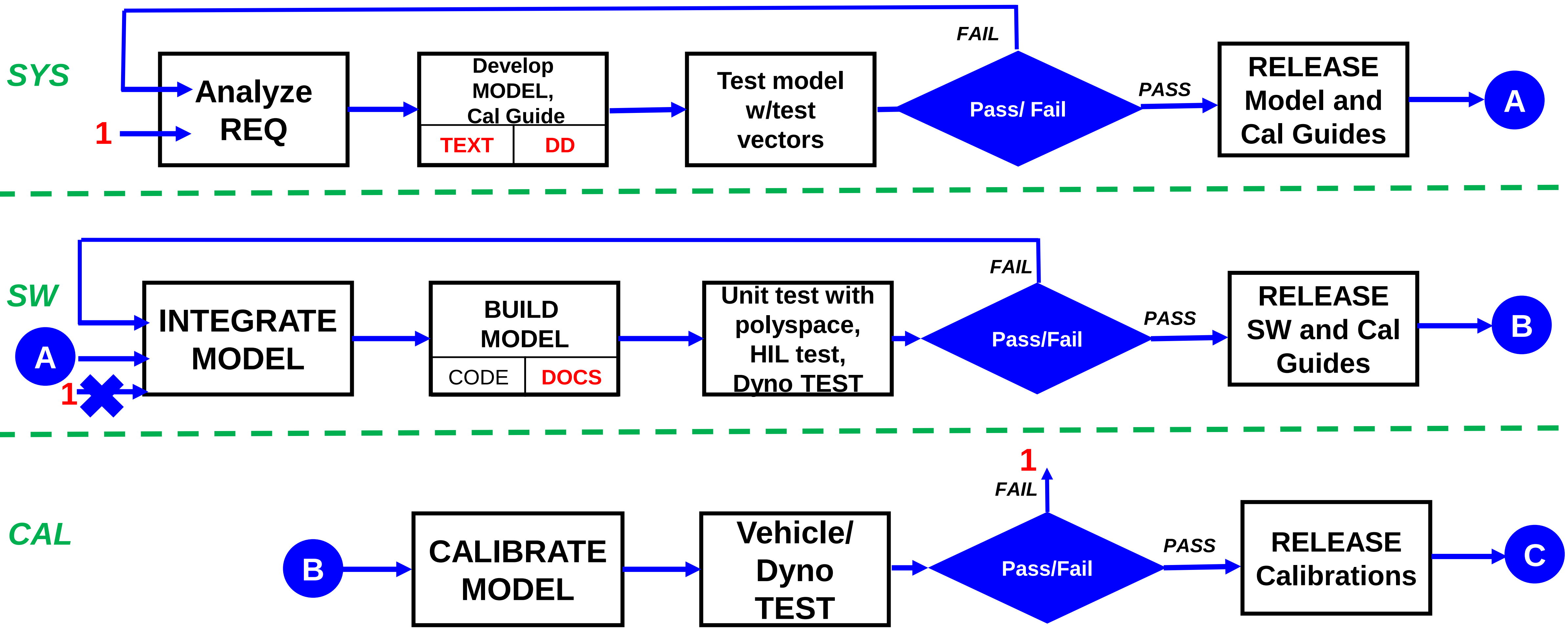
- A typical software release consists of 10 new “Software Change Requests” SCR’s requires about 8 hours to update calibration/tuning guides manually.
- If entire new features are added (like Fuel Level & Range, or Traction Control, or Air Charge Determination), it takes many days.
- Calibration/Tuning Guides are based on SCR’s. Implementation details will often be missed or stated incorrectly through the traditional documentation approach.
- Calibration/Tuning Guides are on the critical path for Systems and Software delivery.

Status Quo with Manual method and Simulink® Report Generator

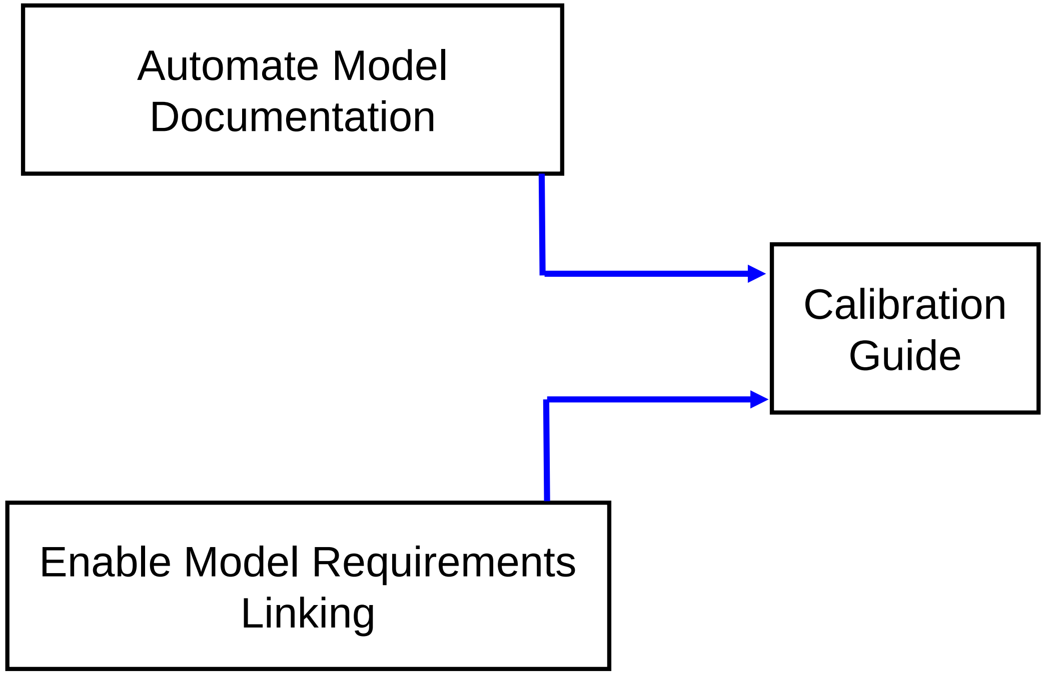
- **Word processing with model screenshots**
  - Take screenshots of the model and include it in a word processing file.
  - *Pro's*: Documentation resides in a common word processing software that is widely available.
  - *Con's*: Time Consuming.

- **Generate PDF using Simulink Report Generator**
  - Automatic screen grabs of the model to generate a .pdf file.
  - *Pro's*: Documentation resides in a common .pdf processing software that is widely available.
  - *Con's*: Static screen grabs of the model makes it difficult to read through models with many layers.

Process Workflow



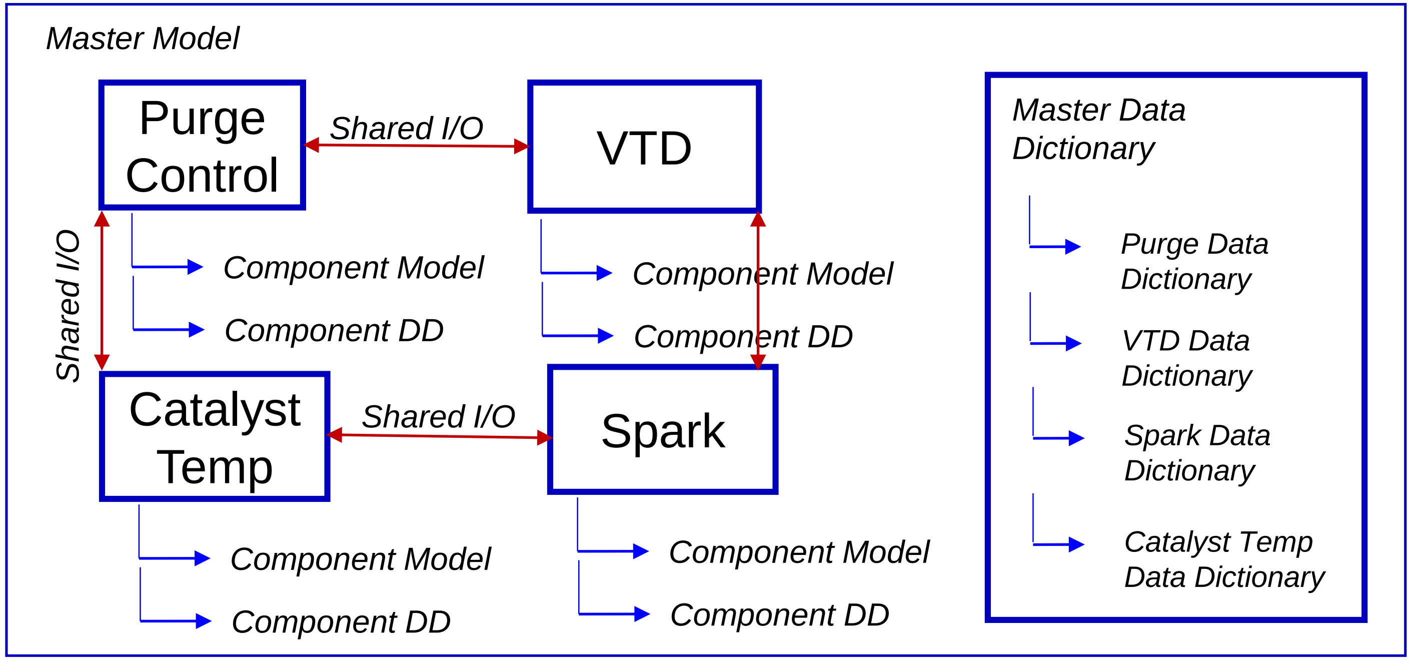
Proposal



- **<u>GOAL:</u>** Automate a calibration guide that shows calibration relevant material with requirement links and coverage.
- Seek to overcome some of the shortfalls of the manual method and the Simulink report generator.
- Introduce automation to simplify and standardize model documentation layout.
- Provide a process to document models early in the Agile design cycle.
- Provide a process to link requirements to Simulink® models using the Polarion®ALM™ connector.

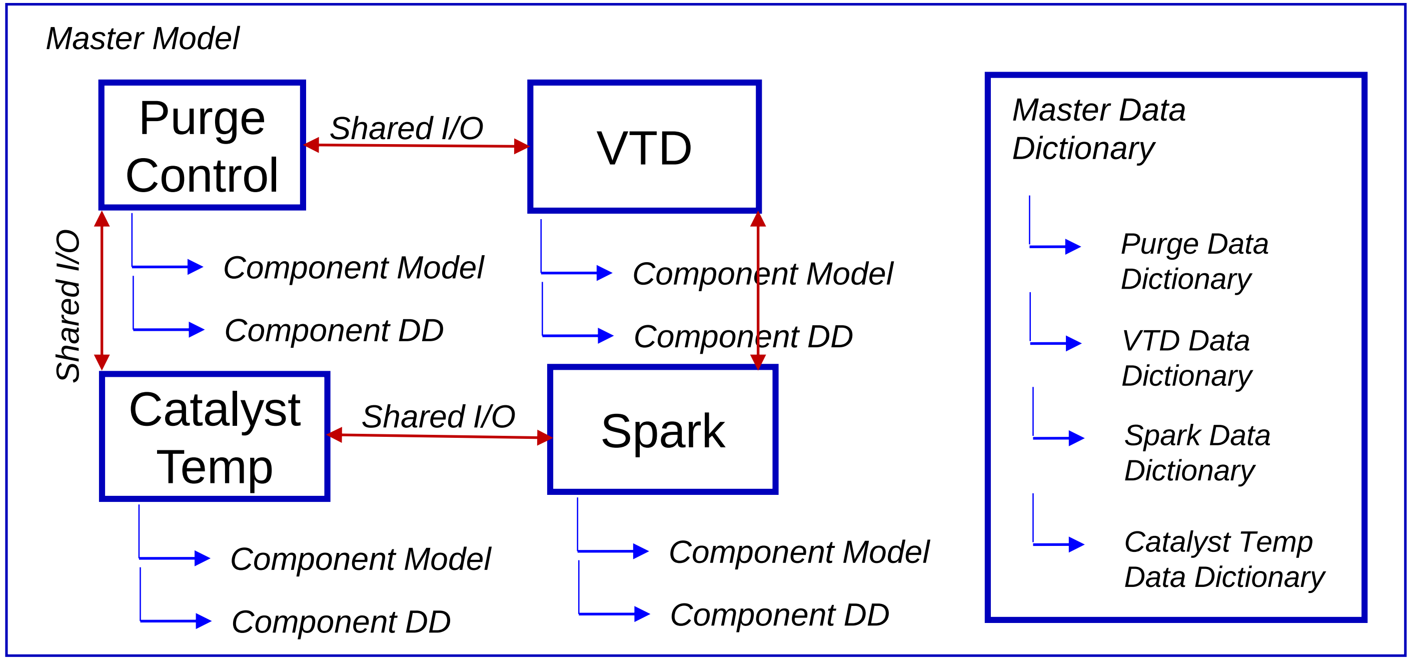
Model-Based Algorithm Architecture

- In order to better understand the auto-generation process, an overview of the model-based algorithm architecture is discussed.
- A typical automotive program consists of over hundred's of controls, diagnostics and security modules.
- Legacy tools tended to use .m scripts for variable declarations instead of native Simulink Data Dictionary (.sldd).



Model-Based Algorithm Architecture

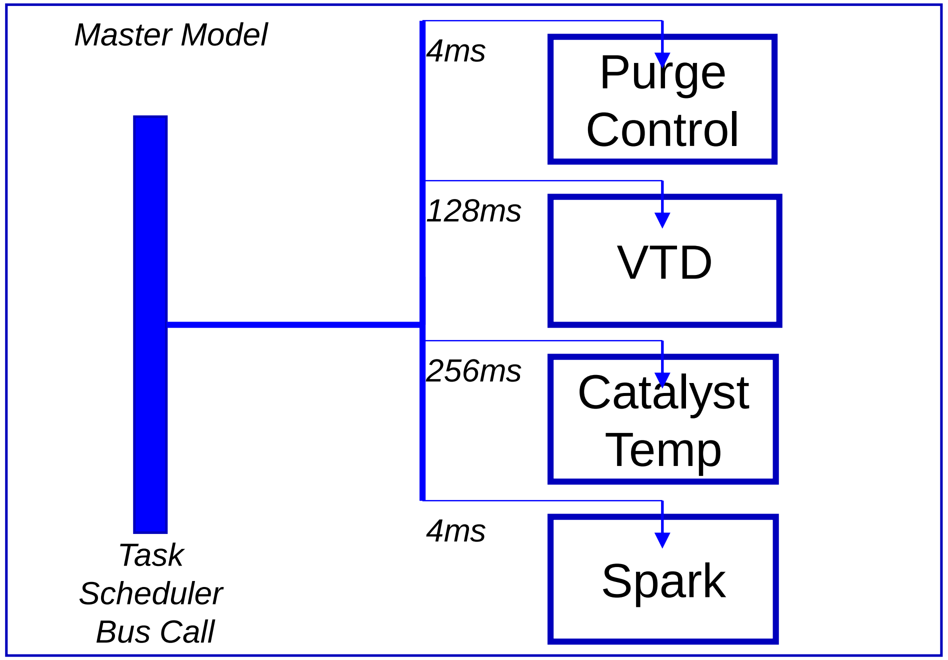
- The Master Model consists of various components that interact with each other to execute specific functions.
- Every component contains its own respective data dictionary (.sldd) also known as a component data dictionary.
- The Master Model also has it’s own data dictionary (.sldd), also known as Master data dictionary, that is essentially a concatenation of all the individual component data dictionaries (.sldd).



Model-Based Algorithm Architecture

- The Master Model also consists of task schedulers that will call on the specific modules at specified execution rates.

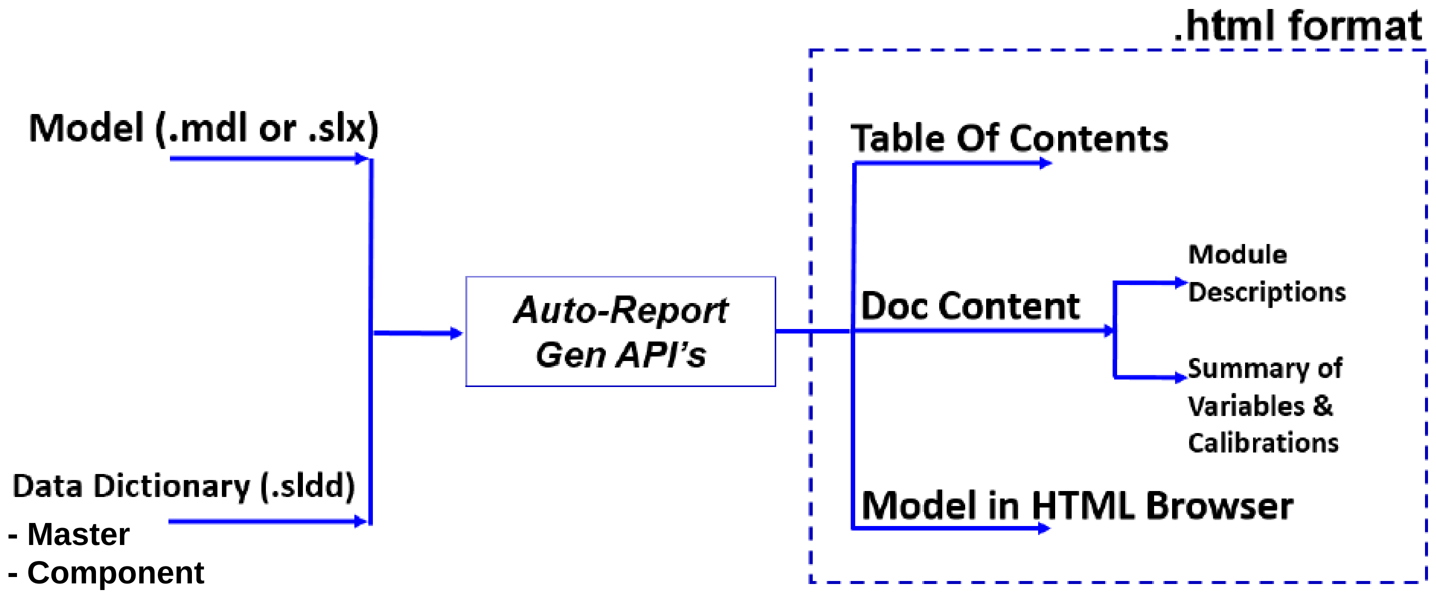
- Some popular scheduled calls:
  - Initialization Calls
  - 4,8,16,32,64,128,256,512,1000 ms.
  - Event based calls.



Model-Based Design Documentation Process Overview

- The auto-generation of calibration guides from models hinges on two important components.
  - Model
    - Component Model
  - Data Dictionary
    - Master Data Dictionary
    - Component Data Dictionary

- The output is a HTML document that includes the documentation and an interactive rendition of the model in an embedded web-view with two-way hyperlinks between the calibration guide content and the model.



Design of Model to include Documentation properties

Model Requirements

- Add an introduction to the model.
- Add calibration guide content or images to subsystems.
- Prioritize Order Of Appearance for subsystems.
- Add calibration guide content to StateFlow charts
- Conceal Intellectual property

Data Dictionary Requirements

- Assign classes to model data.
- Add model data to the data dictionary.

Images

Table Of Contents

PCFC_Lib Calibration Guide

PCFC_Lib

The catalyst's efficiency is demonstrated by its ability to oxidize CO and hydrocarbon emissions. The Post Catalyst Fuel Control (PCFC) algorithm compares the output signals of the front and rear oxygen sensors to determine whether the output of the rear sensor is beginning to match the output of the front oxygen sensor. The PCFC strategy is in place to help reduce emissions while trying to maintain fuel economy.

Please review the image in this system to understand the O2 sensor configuration:
1) 2-Into-1:

- Two O2 Sensors Pre-Cat & One O2 Sensor Post Cat.

2) 2-Into-2:

- Two O2 Sensors Pre-Cat & Two O2 Sensors Post-Cat.

All calculations are done on a per bank basis. The function select PCFC (FuncSelect_PCFC) determines their enablement.
The function select is used to select 0,1 or 2 sensors.

PCFC

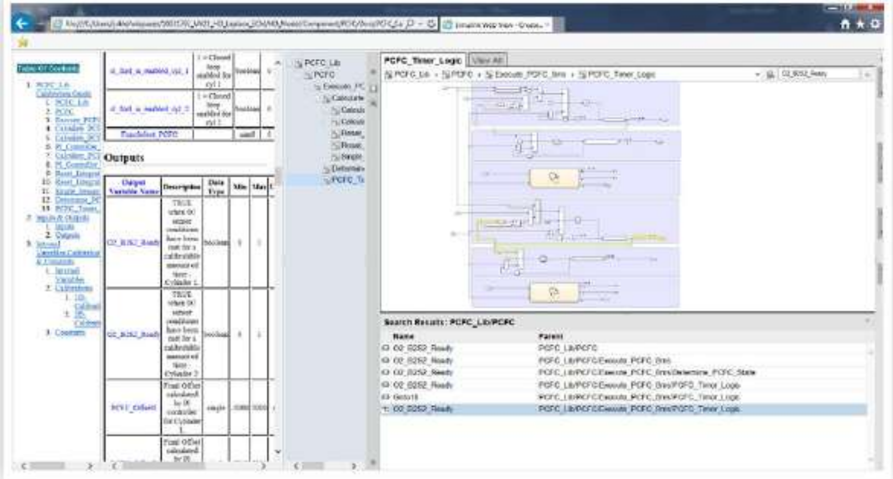
Familiarize yourself with all the inputs and outputs of PCFC algorithm.

Execute_PCFC_8ms

The PCFC algorithm executes at 8ms.

Calculate_PCFC_Offsets

Determines PCFC Offset Calculation for Cylinder 1 & Cylinder 2.



Inputs & Outputs

Inputs

Input Variable Name	Description	Data Type	Min	Max	Units
Engine_Speed	Engine speed averaged over 720 deg.	single	0	14000	rpm
HAL_O2C_AnalogIn_Raw	O2 reading in mV	single	0	5000	mV
HAL_O2D_AnalogIn_Raw	O2 reading in mV	single	0	5000	mV
MAP_Load_F	Input variable for Engine Load front cylinder	single	0	256	kPa
MAP_Load_R	Returns MAP load	single	0	256	kPa
cl_fuel_is_enabled_cyl_1	1 = Closed loop enabled for cyl 1	boolean	0	1	bit
cl_fuel_is_enabled_cyl_2	1 = Closed loop enabled for cyl 2	boolean	0	1	bit

Outputs

Output Variable Name	Description	Data Type	Min	Max	Units
O2_B1S2_Ready	TRUE when O2 sensor conditions have been met for a calibratable amount of time - Cylinder 1	boolean	0	1	bit
O2_B2S2_Ready	TRUE when O2 sensor conditions have been met for a calibratable amount of time - Cylinder 2	boolean	0	1	bit
PCFC_Offset1	Final Offset calculated by PI controller for Cylinder 1	single	-5000	5000	mV
PCFC_Offset2	Final Offset calculated by PI controller for Cylinder 1	single	-5000	5000	mV

1D-Calibrations

F2D_PCFC_IGain_Lookup1

	Name	Units	Description
Table	F2D_PCFC_IGain_Lookup1		Integral Gain Table for Cylinder 1
BreakPoints 1	F2D_PCFC_IGain_Lookup_Engine_Speed_BP	rpm	Integral Gain Engine Speed BreakPoints for Cylinder 1 & Cylinder 2

F2D_PCFC_IGain_Lookup2

	Name	Units	Description
Table	F2D_PCFC_IGain_Lookup2		Integral Gain Table for Cylinder 2
BreakPoints 1	F2D_PCFC_IGain_Lookup_Engine_Speed_BP	rpm	Integral Gain Engine Speed BreakPoints for Cylinder 1 & Cylinder 2

2D-Calibrations

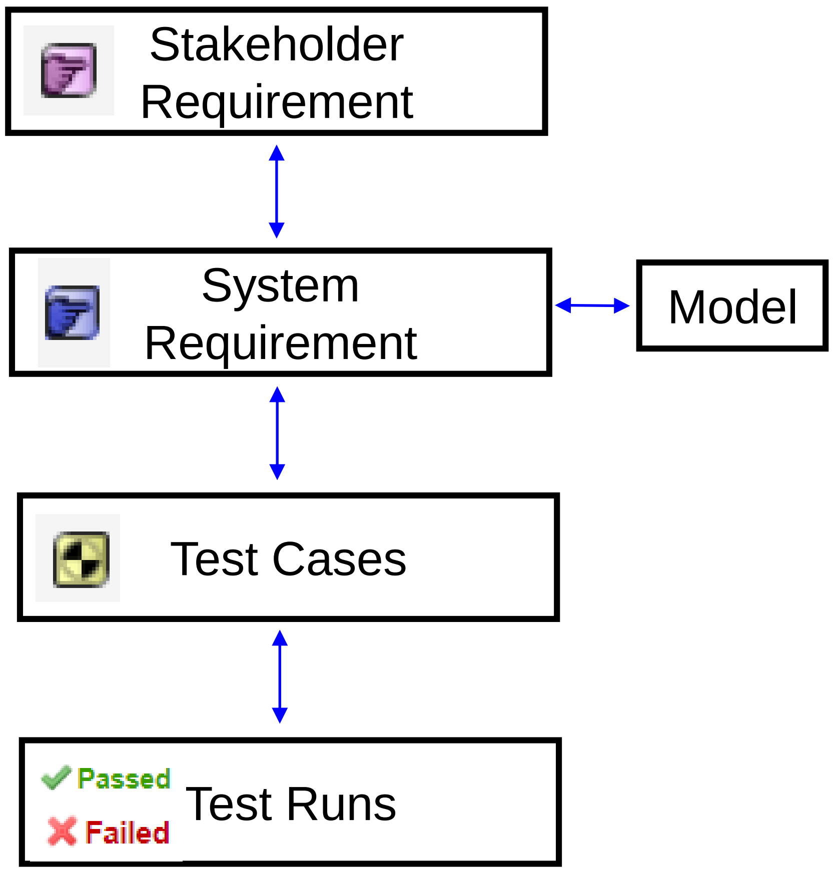
F3D_PCFC_FreezeLookup1

	Name	Units	Description
Table	F3D_PCFC_FreezeLookup1		Freeze Lookup table that disables PI Controller for Cylinder 1 Offset
BreakPoints 1	F3D_PCFC_FreezeLookup1_EngineSpeed_BP	rpm	Freeze Lookup Engine Speed BreakPoints for Cylinder 1 & Cylinder 2
BreakPoints 2	F3D_PCFC_FreezeLookup1_MAPLoad_BP	kPa	Freeze Lookup MAP Load BreakPoints for Cylinder 1 & Cylinder 2

Requirements Management Process

Polarion®ALM™

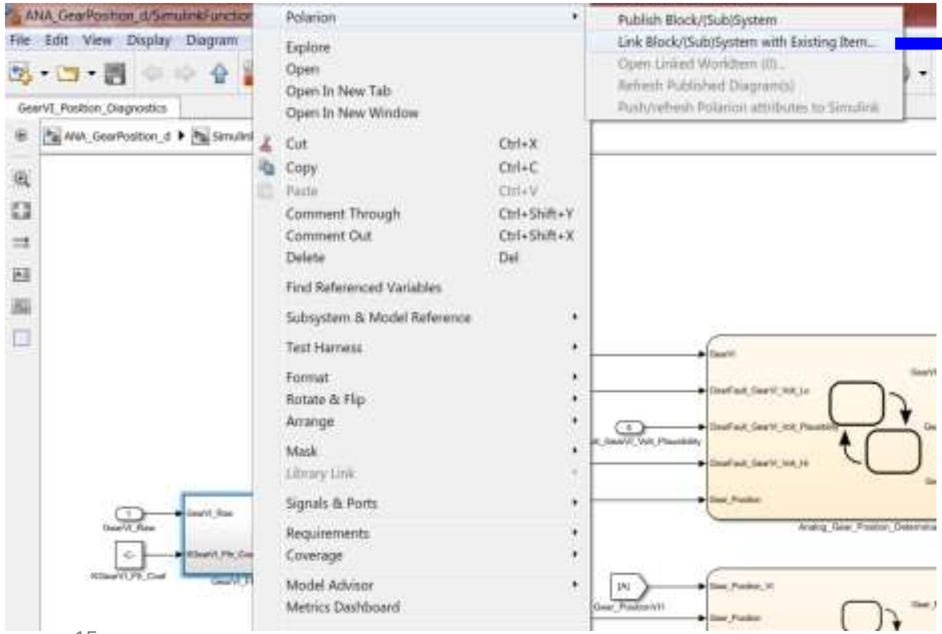
- Polarion®ALM™ is a web-interface tool that manages requirements.
- Requirements traceability hinges upon two-way links between Stakeholder Requirements, System Requirements, Test Cases and Test Runs.
- Simulink® models link to System Requirements in Polarion®ALM™ .
- Requirements definitions:
  - Stakeholder Requirement = Customer Requirement
  - System Requirement = Detailed algorithmic interpretation of the Customer Requirement.
  - Test Cases = Functional Test Plan that outlines how to run the test.
  - Test Runs = Pass or Fail indication of the test case.

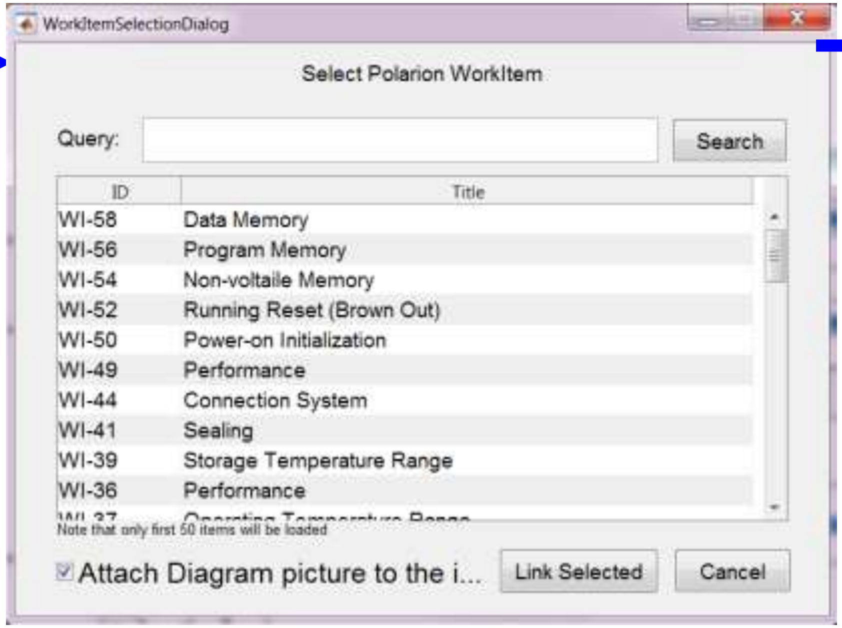


Requirements Linking Process

Polarion®ALM™ to MATLAB ® Setup

1. **In order to link a requirement in *Polarion®ALM™* to a model object in Simulink® perform the following steps:**
2. **Right click on a object or subsystem in MATLAB Simulink. Go To Polarion -> Link Block/Subsystem with Existing Item**
3. **If your “WorkItemSelectionDialog” is populated with Work ID’s from your project.**
4. **Once the requirement is linked, a .slmx requirements traceability file is generated.**

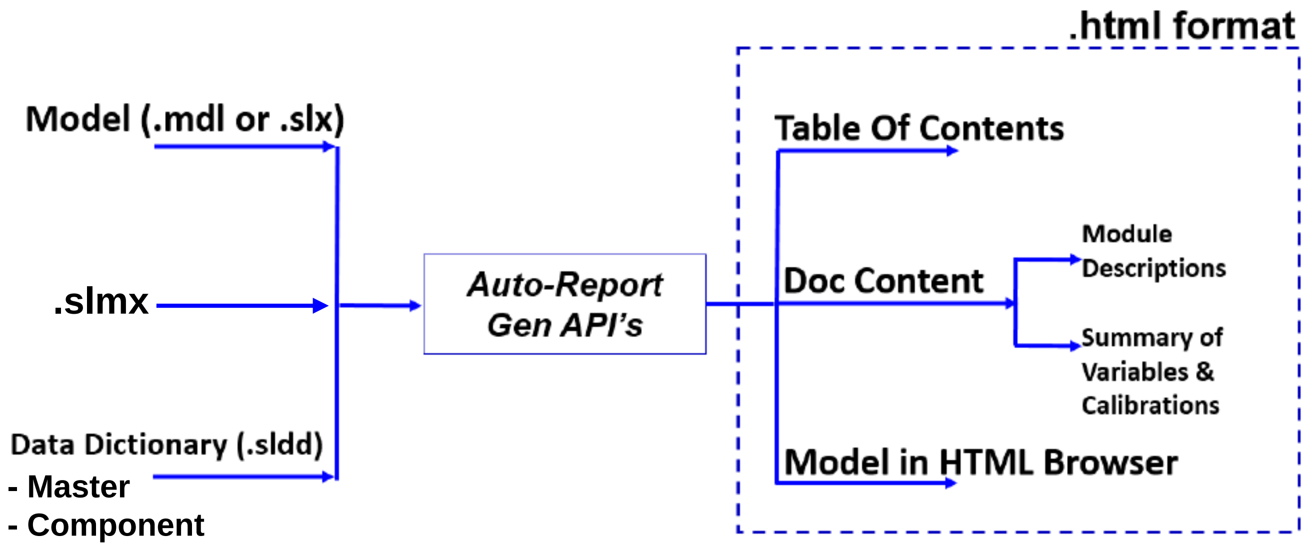




.SLMX MATLAB Traceability file.

Requirements Linking Process

Polarion®ALM™ to MATLAB ® Setup



- In an Agile environment, it is important to convey algorithm development progress during interim deliveries.
- A summary of linked requirements and % coverage can be automatically populated in the auto-generated calibration guide of the model.
- This is performed using the "rmi" api function – Requirements Management Interface.

Requirements Linking Process

HTML Output

Table Of Contents

Linked Requirements

Summary of Polarion Links

Polarion Work Item #	Req. Keyword
Polarion: WI-50638	ID: WI-50638; Title: Barometric_Pressure shall be stored in non-volatile memory in preparation for th...; Type: Software Requirement; Severity: Should Have
Polarion: WI-50639	ID: WI-50639; Title: Barometric_Pressure shall be updated when the timer condition is met: IF Baro_Up...; Type: Software Requirement; Severity: Should Have
Polarion: WI-50641	ID: WI-50641; Title: Timer: Baro_Update_Delay_Timer shall increment every 130 ms (limit 33.4 sec) whe...; Type: Software Requirement; Severity: Should Have
Polarion: WI-50648	ID: WI-50648; Title: Barometric_Pressure is updated when the timer condition is met: IF Baro_No_Run_U...; Type: Software Requirement; Severity: Should Have
Polarion: WI-50649	ID: WI-50649; Title: Baro_No_Run_Update_Delay_Timer increments every 130 ms (limit 33.4 sec) when the...; Type: Software Requirement; Severity: Should Have
Polarion: WI-50650	ID: WI-50650; Title: Baro_Default Default value for baro if memory is lost. 0 to 256 kPa typ. 98.9 kP...; Type: Software Requirement; Severity: Should Have

Requirements Coverage

# of Linked Objects	# of Unlinked Objects	% Req. Coverage
73	81	47

Conclusions

- At Delphi Technologies we created our own tool and process using MATLAB and SIMULINK Report Gen API's.
- The auto-generation of calibration guides from models has streamlined systems and overall program workflow in the AGILE Development Process by building on engineering effort that is performed upstream of the process.
- The result has made it quicker to deliver accurate and current documentation by 75%.

Thank you

APPENDIX

Model-Based Design Documentation Process Overview

- The foundation of the automation philosophy is based on the literature titled: “Model Description Documentation Recommended Practice for Ground Vehicle System and Subsystem Simulation”.

- The literature discusses fifteen types of documentation guidelines out of which seven types have been pre-selected for the auto-generation of the calibration guides.

- The seven types that are chosen:
  - Model title
  - High level description of model
  - Feature and capabilities
  - External interface variables (or inputs and outputs)
  - Internal variables
  - Parameters and calibration procedures
  - Detailed functional description

Model-Based Design Documentation Process Overview

- The fundamental building blocks for the auto-generation process is dependent on the model and data dictionary and it’s respective components.

- A model consists of the following:
  - Blocks – Main elements used to build models. Examples – Add, subtract, divide etc.
  - Subsystems – Grouping of blocks to create a hierarchical model comprising of many layers.
  - Stateflow Charts – Modeling sequential logic based on state machines and flow charts.

Model-Based Design Documentation Process Overview

- A data dictionary consists of the following:
  - Class – Type of signal – Variable, Calibration or Constant.
  - Name – Signal name.
  - Data Type – Boolean, integer, float etc.
  - Definition File – C file that defines this variable, calibration or constant.
  - Description – Purpose of this type of variable, calibration or constant.
  - Header File – C header file that defines this variables calibration or constant.
  - Min – Minimum value of variable, calibration or constant.
  - Max – Maximum value of variable, calibration or constant.
  - Value – Typical value assigned to calibration.
  - Units – Units associated with the variable, calibration or constant.

Model-Based Design Documentation Process Overview

- To facilitate code generation, Simulink allows a modeler to assign a class name to variables, calibrations and constants that share similar characteristics.

- The calibration guide generation can use these classes to distinguish between constants, variables and calibrations.

- For example, the model's data dictionary can facilitate these distinctions by assigning model data to the following standard classes:
  - Variables defined as "Simulink.Signal" or "mpt.Signal" class.
  - Calibrations defined as "mpt.Parameter" class.
  - Constants defined as "Simulink.Parameter" class.

Conclusions

Future Work

- Provide further enhances to the HTML documentation by providing clickable two-way links between signals summarized in the table(s) and the embedded web-view of the model.

- Work with *Polarion®ALM™* to further enhance the ability to better calculate requirements coverage.

- Establish a process and automation methodology to include simulation results of a model in the documentation to better understand an algorithms viability.

Code Snippets

Code Snippets

Create a subsection for each subsystem

- To create subsections for each subsystem various API functions need to be used.
- Use the find_system function to get a list of the subsystems in the model.
- Then use the get_param function to extract the description field of each subsystem. Then iterate through the subsystems, using the append function to add the description to the HTML guide

```
%% Create a section for each subsystem.
blockPaths = find_system(diagHandle, 'SearchDepth', 0);
% Extract subsystem description
blockDescription = get_param(blockPaths,'Description');
p = Paragraph(blockDescription); % Convert to Paragraph
for path = blockPaths'
    p.Style = {WhiteSpace('preserve')}; % Append Descriptions to document
    append(sdd,p);
end
```

Code Snippets

Generate tables from the data dictionary

- **Section 2 of the guide is populated with the help of the data dictionary. The code shows the variety of functions required to extract the relevant information from the data dictionary.**
- **getSection gets the section of the data dictionary**
- **The find_system function is used to get the model's input and output blocks**
- **The information is then used to create a table of the inputs and outputs containing their descriptions and signal (i.e.variable) attributes.**
- **The FormalTable function is used to create an empty table that is then populated with the input and output data.**
- **Once the table is populated, the table is appended to the HTML guide. A similar approach is used to generate the internal tables in section 3.**

```
dDataSectObj =
getSection(myDictionaryObj,'Design
Data');
modelName = h.ExportOptions.Diagrams;
inport_blocks =
find_system(modelName,'SearchDepth', 2,
'BlockType', 'Inport');
inputData = get_param(inport_blocks,
'Name');
outport_blocks = find_system(modelName,
'SearchDepth', 2, 'BlockType',
'Outport');
outputData = get_param(outport_blocks,
'Name');
Entries_mpt = find(dDataSectObj,'-
value','-class','mpt.Signal');
Entries_simulinksignal =
find(dDataSectObj,'-value','-
class','Simulink.Signal');
table_input = FormalTable({'Input
Variable Name', 'Description','Data
Type','Min','Max','Units'},InputTable);
append(h,table_input);
```

Requirements Linking Process

Polarion®ALM™ to MATLAB ® Setup

1. **Polarion Read/Write Access Privileges**
2. **MATLAB ® 2013a or higher.**
3. **MATLAB ® Simulink Requirements v 1.0.**
4. **Simulink to Polarion Connector -> Available through** *Polarion®ALM™*

Requirements Linking Process

Polarion®ALM™ to MATLAB ® Setup

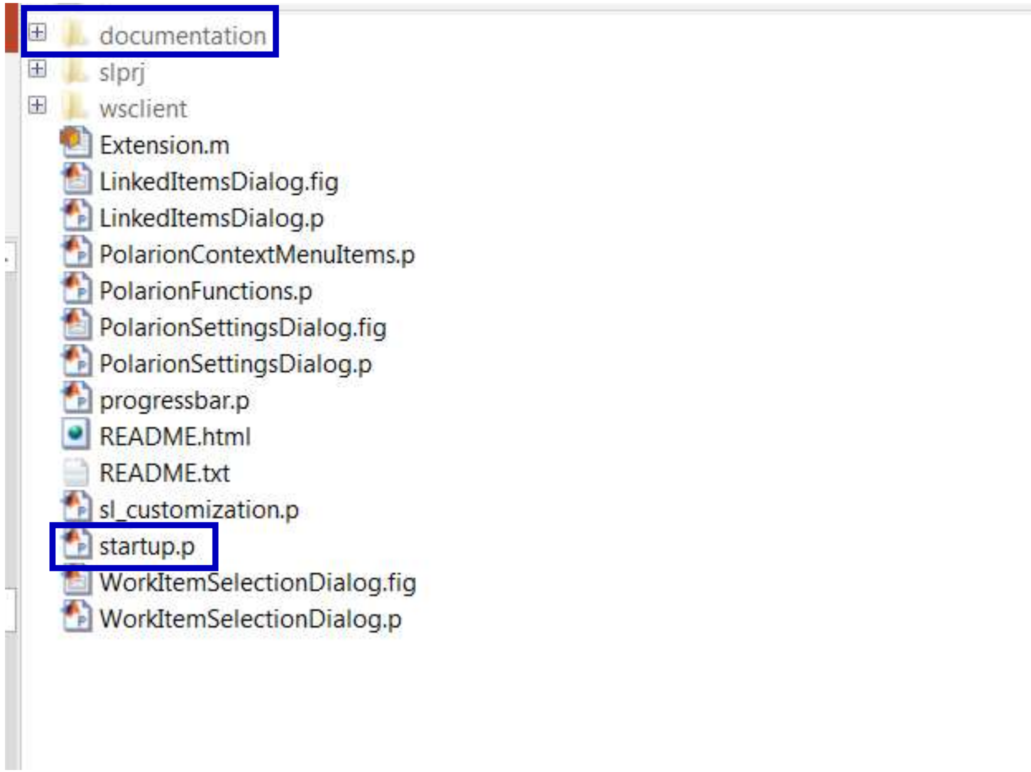
1. **Simulink to Polarion Connector is a zip file. Once downloaded, unzip the contents of the file.**

2. **The unzipped file will have many items in it. The most important are startup.p & documentation:**
    1. **Documentation is the help guide.**
    2. **Startup.p is the initialization file.**

3. **Open MATLAB.**

4. **Type "run startup.p" in the command window.**

5. **You should see the following confirmation:**




```
Polarion-addon initialization finished
```

Code Snippets

List of supporting API’s (Application Program Interface)

- Simulink®, the MATLAB® Report Generator™, and the Simulink® Report Generator™ provide API’s that facilitate development of MATLAB® programs capable of generating calibration guides from models.

- These APIs consist of functions that extract and format data from a model. The table lists some of the API functions used to autogenerate the example guide.

API Name	API Description
createDiagramLink	Create a two-way link between guide content and a Web View element..
get_param	Return the name of a specified model or block object.
find_system	Find blocks, charts, signals and other model elements.
append	Append text, tables, images, lists, figures, etc., to a document container.
getSection	Get section of a data dictionary.
FormalTable	Define a table that has a body and optionally a table header, a table footer, or both

Requirements Housing Process

Example

The ECM shall provide a means to control fuel enrichment during transient events that minimizes engine out emissions during transient throttle opening.
SW, ✔ Approved

↕

AE Truncation for Decreasing Load
If throttle position decreases more than **AE_Neg_Throttle_Disable** per fuel event, then the AE_Fuel[x] accumulators are cleared.

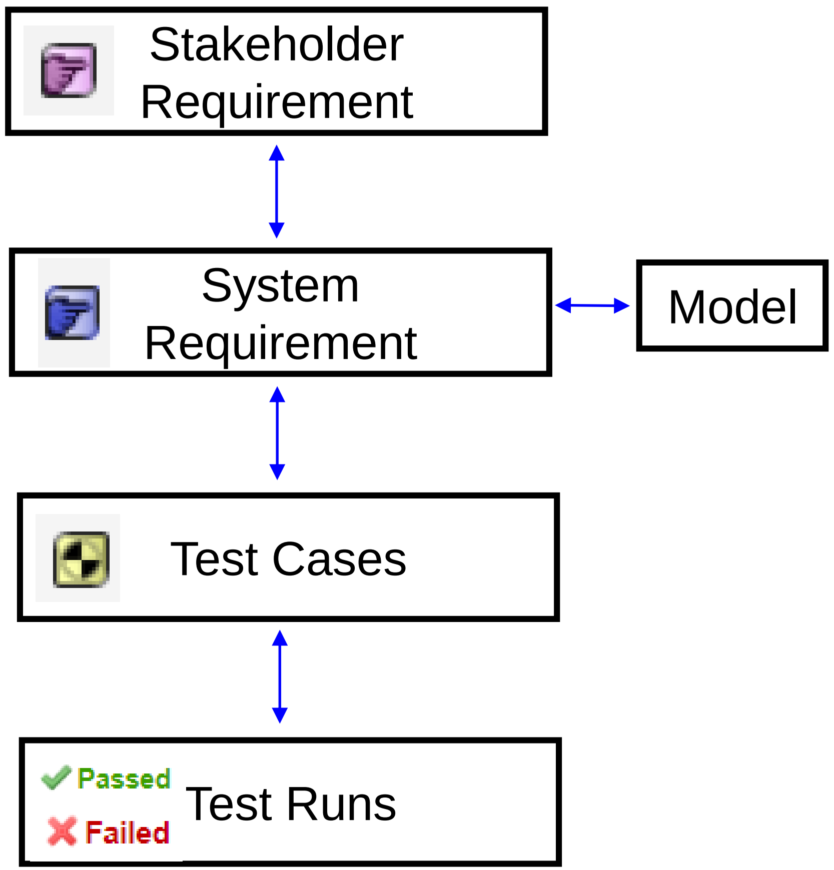
↕

2.1.2 FC: Test for AE Truncation for decreasing load – AE Cleared

1. Set AE_Throttle_Filter_Coef_Fast = 0
2. Set AE_Throttle_Filter_Coef_Slow = 0

↕

Test Result	Test Run
✔ Passed	ECM_DEL_POC_21L_015_000 - ECM_DEL_POC_21L_015_000

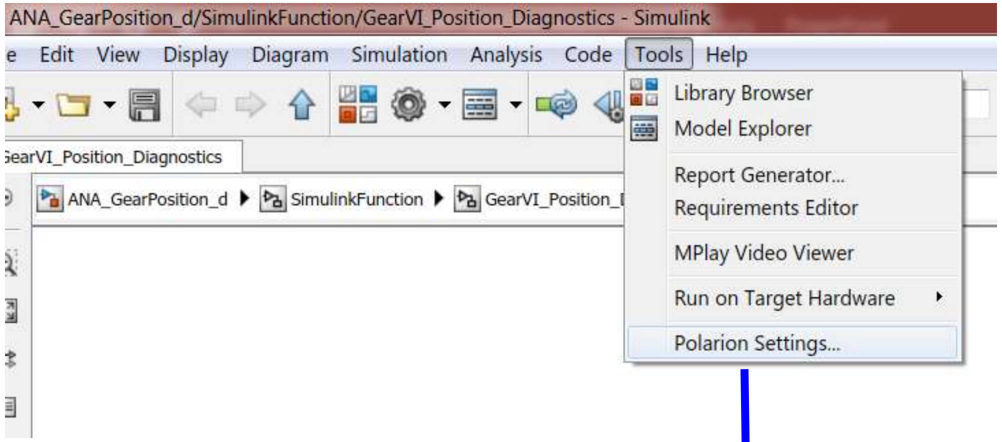


Requirements Linking Process

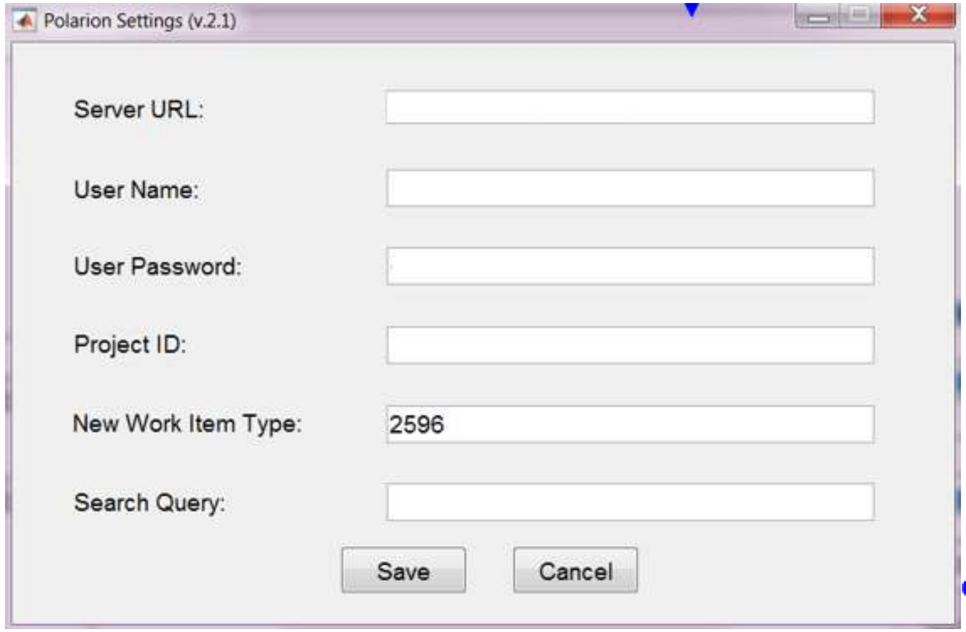
Polarion®ALM™ to MATLAB ® Setup

1. **In order to verify that the Polarion Connector has been added to Simulink, open up an existing, blank or demo Simulink model in MATLAB.**

2. **Go to Tools in the top right corner and Polarion Settings will be available to choose as an option. This shows that the Polarion Connector has been installed successfully.**



3. **Once you click the Polarion settings option, the following pop-up window will display as shown on the right:**



Requirements Linking Process

Polarion®ALM™ to MATLAB ® Setup

```
function appendRequirements(h)
    import mlreportgen.dom.*
    append(h,mlreportgen.dom.Heading(1,'Linked Requirements'));
    modelName = h.ExportOptions.Diagrams;
    blockPaths = find_system(modelName, 'SearchDepth', 5);

    for i=1:length(blockPaths)
        reqts = rmi('get', blockPaths{i});
        if ~isempty(reqts)
            x=reqts.description;
            y=reqts.keywords;
            reqtTable(i,1) = cellstr(x); % Polarion Work ID
            reqtTable(i,2) = cellstr(y); % Polarion Keyword
        end
    end
```

```
%% Requirements Converage
% Find Linked vs unlinked requirements and calculate requirements
% coverage
total = length(blockPaths);
linked_WI = length(fullValz);
unlinked_WI = total-linked_WI;
req_pctcov = (linked_WI/total)*100;
req_pctcov_rounded = round(req_pctcov,0);
req_cov = [linked_WI unlinked_WI req_pctcov_rounded];
h_reqCoverage = append(h, mlreportgen.dom.Heading(2, 'Requirements Coverage'));
```