Linking System Requirements with Product Performance

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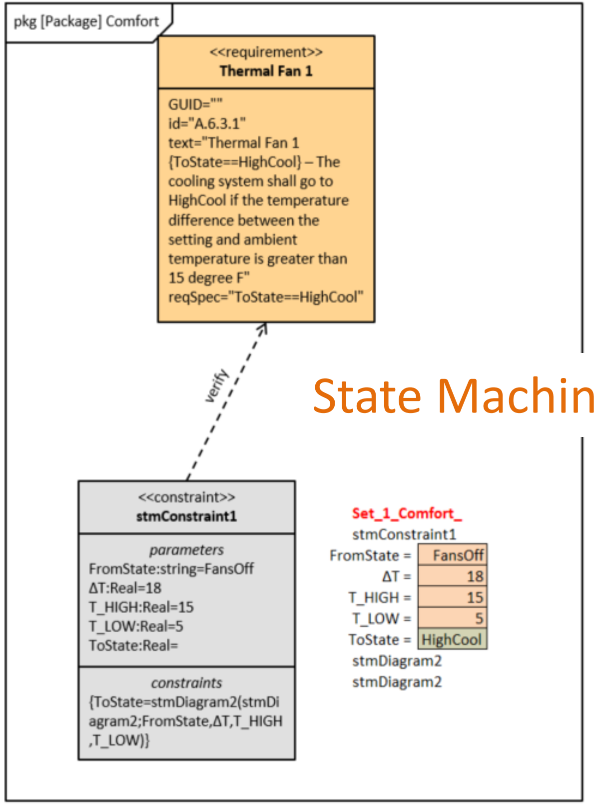
XLDyn

Topics

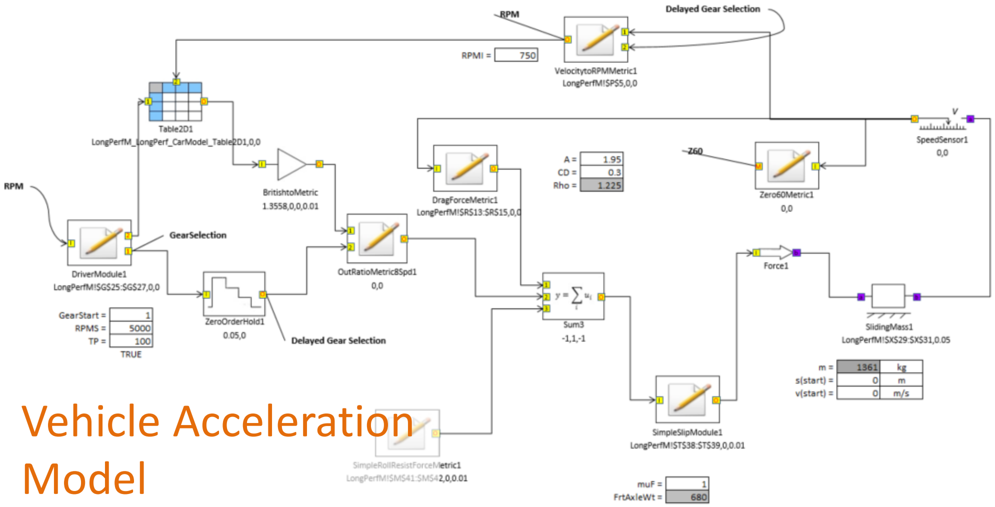
- XLDyn, LLC
- Systems Engineering Vision
- XLSE Key Features
  - Overview
  - Model Creation
  - Requirements and Verification
  - Use Cases
  - Activity Diagrams
  - State Machine Diagrams and Simulation
  - Domain Maps and DFMEA
  - Schematic Diagrams and Reliability
- XL1D Features
- Design Balance Video
- Summary



State Machine Verifier

XLDyn, LLC

- Founded in 2010, our mission is to develop enterprise system engineering tools that are fully integrated with an intuitive and easy to use graphical interface
- Innovations are covered by four U.S. Patents, plus one pending

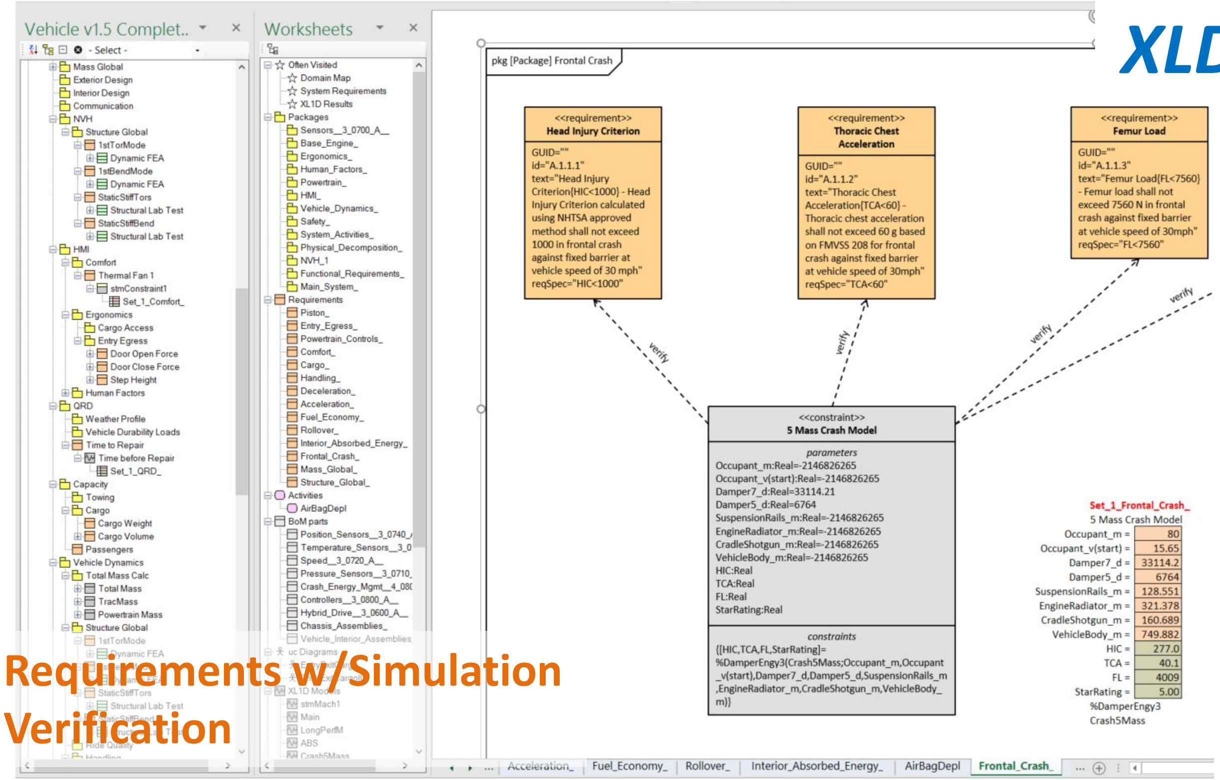


Vehicle Acceleration Model

XLDyn = XLSE + XL1D

XL1D - For authoring/simulating detailed 1D multi-physics systems models

XLDyn, LLC



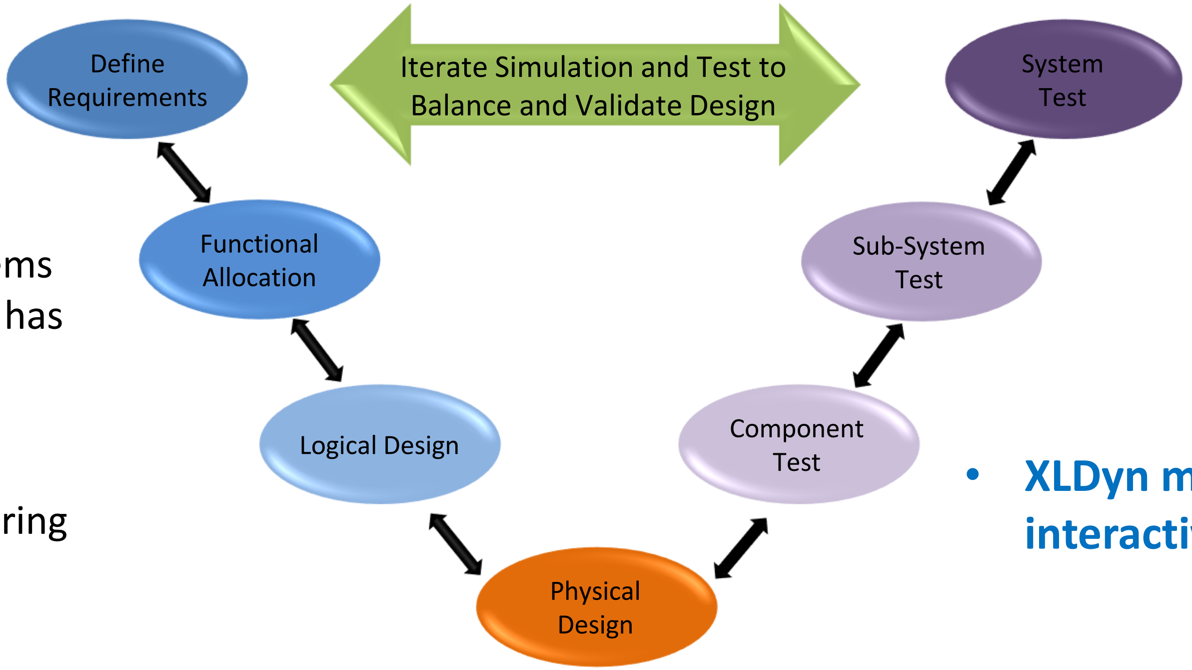
XLDyn = XLSE + XL1D

XLSE – For authoring OMG SysML compliant system models

Requirements w/Simulation Verification

What is Systems Engineering?

- Often described with the "System V", some key elements are:



- Historically Systems Engineering (SE) has been document based
- Model Based Systems Engineering (MBSE) is more visual, but static

- **XLDyn makes MBSE interactive**

XLDyn = Enterprise Solution to MBSE

Enterprise Data

XLDyn Closes the Gap

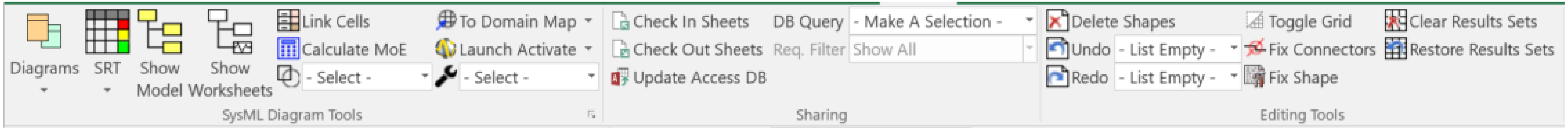
Simulation And Test

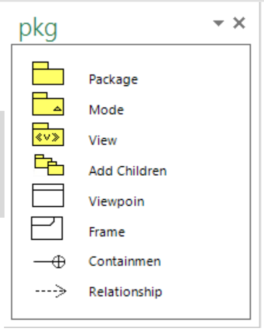
- XLDyn is an actionable tool for engineers to develop, balance, and track designs
- XLDyn supports all verification methods
- Program status is easily available to everyone
- Documentation is byproduct of the development process
- Documentation is critical for team communication
- XLDyn is easy to use: Systems Engineering for everyone

XLSE Overview

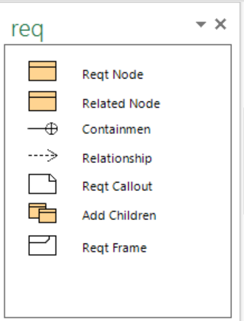
- XLSE uses Microsoft Excel® as the Graphical User Interface
- Diagrams can be moved and copied/pasted anyplace in the workbook. Utility functions simplify the modeling process making tasks intuitive and simple
- Extensive model navigation tools

XLSE Tool Bar





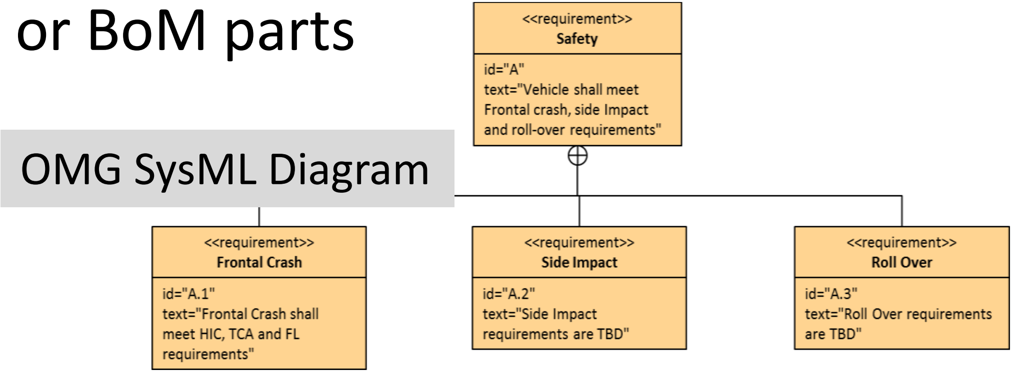
Package Diagram Pallet



Requirement Diagram Pallet

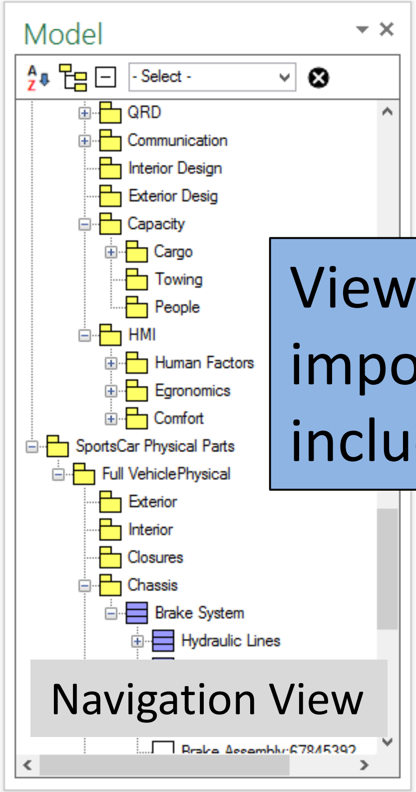
XLSE Overview

- XLSE is a Model Based Systems Engineering Tool
  - Manages requirements status throughout the design cycle
  - Provides design balance tools to create optimal designs
  - Can be used at system, subsystem, or component level
  - Model is fully synchronized when adding or editing requirements or BoM parts

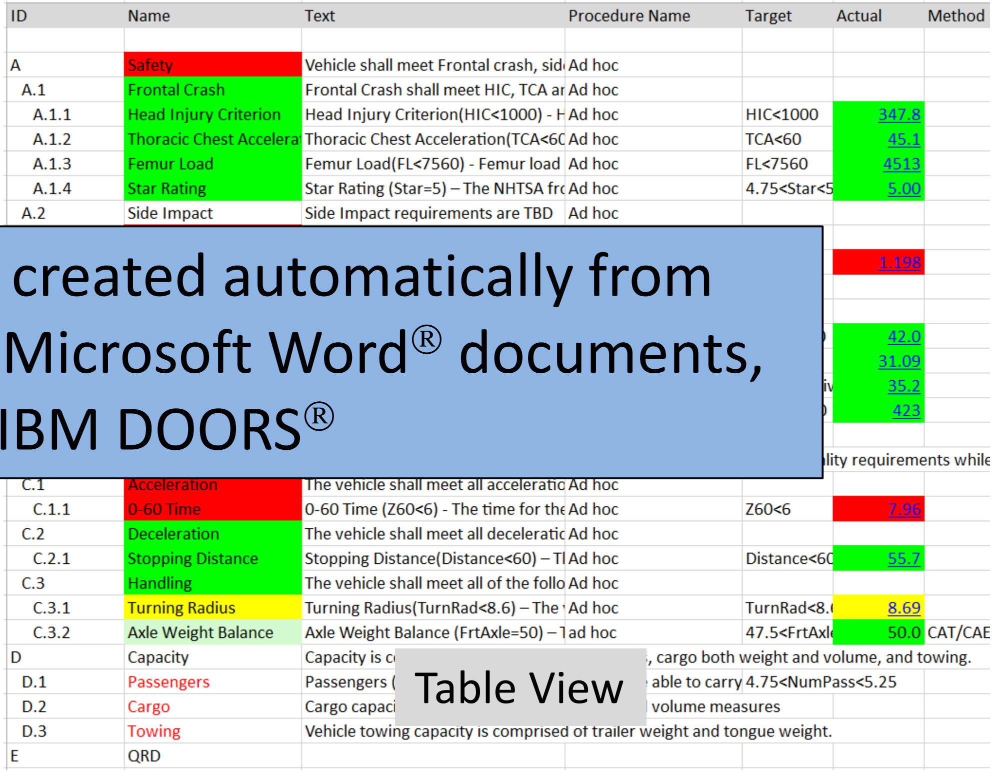


OMG SysML Diagram

XLSE Overview



Navigation View



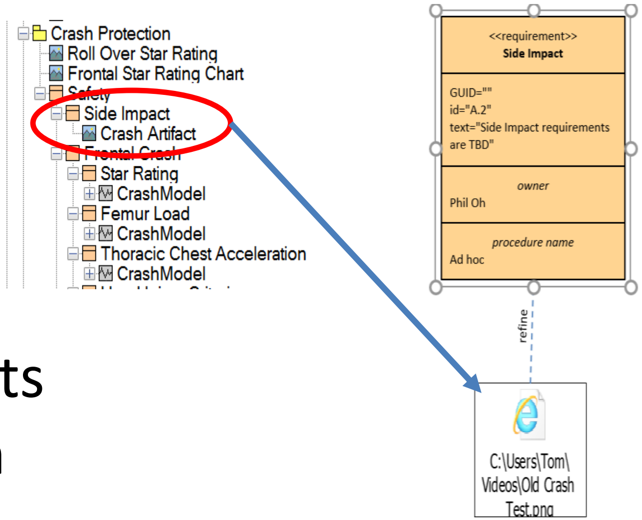
ID	Name	Text	Procedure Name	Target	Actual	Method
A	Safety	Vehicle shall meet Frontal crash, sid	Ad hoc			
A.1	Frontal Crash	Frontal Crash shall meet HIC, TCA ar	Ad hoc			
A.1.1	Head Injury Criterion	Head Injury Criterion(HIC<1000) - H	Ad hoc	HIC<1000	347.8	
A.1.2	Thoracic Chest Accelera	Thoracic Chest Acceleration(TCA<6C	Ad hoc	TCA<60	45.1	
A.1.3	Femur Load	Femur Load(FL<7560) - Femur load	Ad hoc	FL<7560	4513	
A.1.4	Star Rating	Star Rating (Star=5) – The NHTSA frc	Ad hoc	4.75<Star<5	5.00	
A.2	Side Impact	Side Impact requirements are TBD	Ad hoc			
					1.198	
					42.0	
					31.09	
					35.2	
					423	
		lity requirements while				
C.1	Acceleration	The vehicle shall meet all acceleratio	Ad hoc			
C.1.1	0-60 Time	0-60 Time (Z60<6) - The time for the	Ad hoc	Z60<6	7.96	
C.2	Deceleration	The vehicle shall meet all deceleratic	Ad hoc			
C.2.1	Stopping Distance	Stopping Distance(Distance<60) – Tl	Ad hoc	Distance<6C	55.7	
C.3	Handling	The vehicle shall meet all of the follo	Ad hoc			
C.3.1	Turning Radius	Turning Radius(TurnRad<8.6) – The	Ad hoc	TurnRad<8.(	8.69	
C.3.2	Axle Weight Balance	Axle Weight Balance (FrtAxle=50) – T	ad hoc	47.5<FrtAxl	50.0	CAT/CAE
D	Capacity	Capacity is c… , cargo both weight and volume, and towing.				
D.1	Passengers	Passengers (… able to carry		4.75<NumPass<5.25		
D.2	Cargo	Cargo capaci… volume measures				
D.3	Towing	Vehicle towing capacity is comprised of trailer weight and tongue weight.				
E	QRD					

Table View

Views are created automatically from imported Microsoft Word® documents, including IBM DOORS®

XLSE Overview

- Document your work by attaching objects to the diagram blocks including:
  - *Word Documents, PowerPoint,*
  - *Excel, Visio, Video, PDF, etc.*

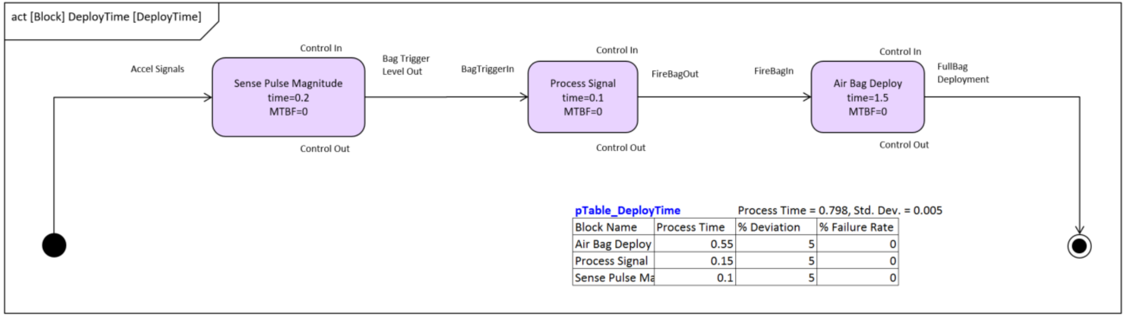


- XLSE automatically updates requirements status with verifier results in the System Requirement Table (SRT)

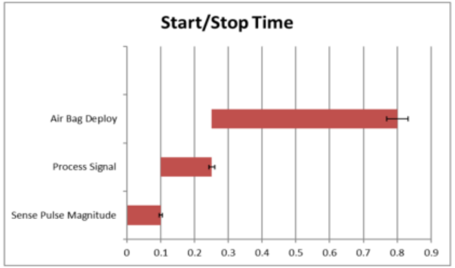
ID	Name	Text	Procedure N	Target	Actual	Target Wt	Actual Wt	Change Histc	Comments	Method	Owner	Assigned To	Notified	Due Date	Last Updated
A.3.2	Deceleration	Deceleration – The vehicle shall meet all deceleration requirements													
A.3.2.1	Stopping Distance	Stopping Distance{Distance<60} – The vehicle shal		Distance<60	56.4										
A.3.3	Handling	Handling – The vehicle shall meet all of the following handling criteria.													
A.3.3.1	Turning Radius	Turning Radius{TurnRad<8.6} – The vehicle turning		TurnRad<8.6	8.25										
A.3.3.2	Axle Weight Balance	Axle Weight Balance {FrtAxle=50} – Tl	CAE 50	47.5<FrtAxle	49.0					CAT/CAE Request		thomas.tecc	Jul 21, 2017	Jul 31, 2017	21-Jul-17
A.3.4	Ride Quality	Ride Quality – Vehicle shall be best in class for smooth and rough road ride metrics													
A.4	Capacity	Capacity – Capacity is comprised of number of passengers, cargo both weight and volume, and towing.													
A.4.1	Passengers	Passengers {NumPass==5} – The vehicle must be a		NumPass==5											
A.4.2	Cargo	Cargo – Cargo capacity is comprised of both weight and volume measures													
A.4.2.1	Cargo Volume	Cargo Volume {CargoVol>1.0} – Avail	ad hoc	CargoVol>1.(	1.100					CAT/CAE Request		thomas.tecc	Jul 20, 2017	Jul 30, 2017	20-Jul-17

XLSE Overview

- XLSE includes the following SysML diagrams:
  - Package *(pkg)*
  - Block Definition *(bdd)*
  - Internal Block *(ibd)*
  - Parametric *(par)*
  - Activity *(act)*
  - Requirement *(req)*
  - State Machine *(stm)*
  - Use Case *(uc)*
- XLSE's Parametric, Activity, and State Machine diagrams are actionable. Change parameters and run simulations from the diagrams



Block Name	Process Time	% Deviation	% Failure Rate
Air Bag Deploy	0.55	5	0
Process Signal	0.15	5	0
Sense Pulse Ma	0.1	5	0



Model Creation: ‘One Click’

- SysML requirements diagrams can be created with ‘One Click’
- The Systems Requirement Document(SRD) can be imported from enterprise data sources
- The SRD contains requirements and if desired BoM data (assembly/parts with cost, weight, and MTBF), and activities
- Including parts data allows cost rollup and automates the creation of the Domain Map and DFMEA diagrams and charts.

Human Powered Vehicle Requirements and Assemblies

A **Functional Requirements –** What the HPV must do or be

A.1 **Load/ Unload**- The vehicle shall accommodate 1 rider and cargo

A.1.1 **Rider** – Accommodate students from 1.4 meters to 2.2 meters tall and between 40 kg and 130kg in mass

A.1.1.1 **Student Height**(1.4<riderheight<2.2) – Accommodate passengers between 1.4 meters and 2.2 meters in height.

A.1.1.2 **Student Weight**(40<riderweight<130) – Accommodate passengers between 40 kg and 130 kg

A.1.2 **Ingress** – Students within the size/ mass range shall be able to open the door and sit down on the seat confidently while the vehicle is stationary

A.1.2.1 **Open Effort**(OpenEft<4) - Energy to open the door shall not exceed 4 joules

B **Physical Decomposition** – Parts required to build the HPV

B.1 Body & Structure – Includes frame, body, door and parts attached thereto

B.1.1 Frame Assembly (1-0100-A) - $0

B.1.2 Body Assembly (1-0200-A) - $0

B.1.3 Door Assembly (1-0300-A) - $0

B.1.4 Headlamp Assembly (1-0400-A) - $0

B.1.5 Headlamp Switch Cable Assembly (1-0500-A) - $0

B.1.6 Taillamp Assembly (1-0600-A) - $0

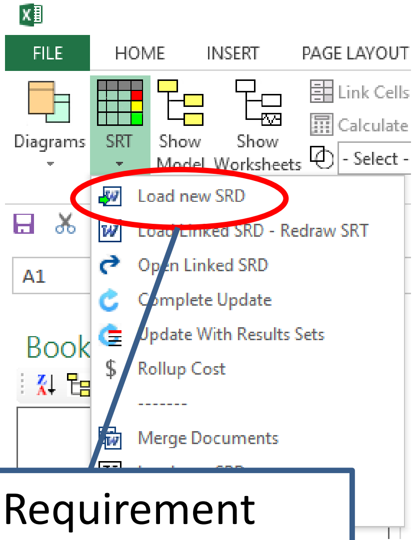
B.1.7 Front Indicator Assembly (1-0700-A) - $0

B.1.8 Rear Indicator Assembly (1-0800-A) - $0

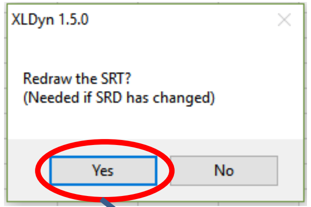
B.1.9 Rear View Mirror Assembly (1-0900-A) - $0

Model Creation: 'One Click'

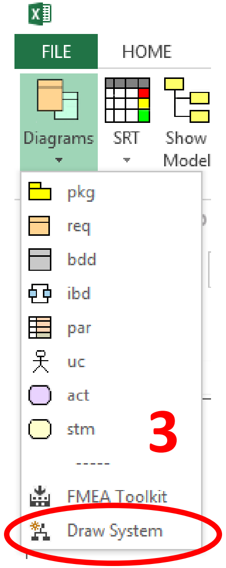
- Model Creation Steps



System Requirement Document (SRD) **1** includes Requirements and BoM



Yes to create the System Requirements Table (SRT). SRT provides a summary of **2** requirements status



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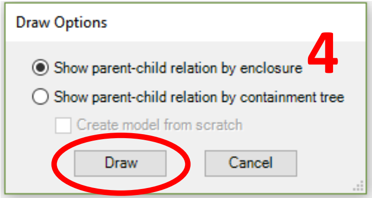
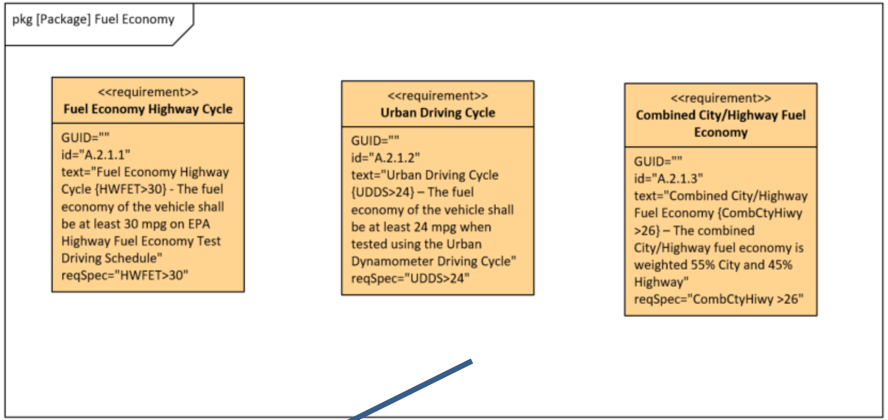


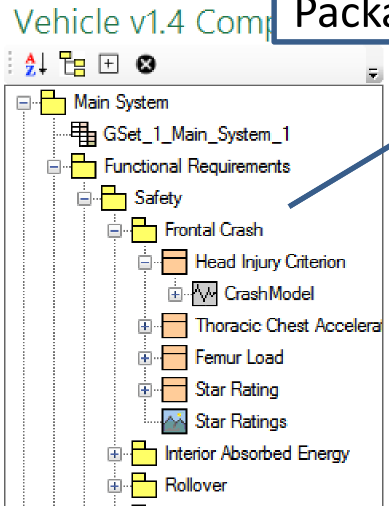
4

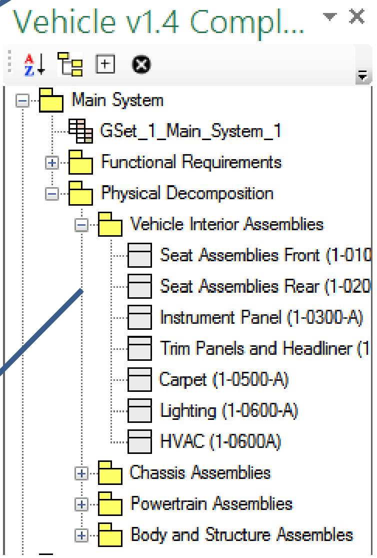
Model Creation: 'One Click'

- XLDyn® 's patented method creates SysML requirement, BoM, and Activity diagrams for the *entire* system

Functional Tree Structure: Packages and Requirements







SysML Requirement nodes created

Physical Tree Structure: BoM Assemblies and Parts

Requirements Verification

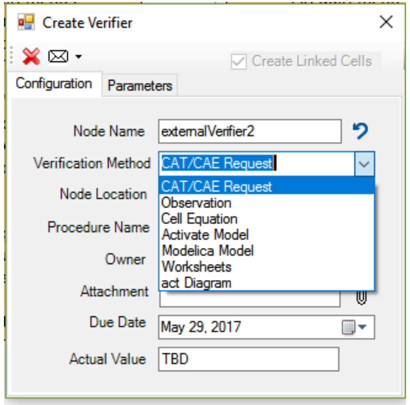
- Verification checks if requirements are met for a given set of design parameters and operating conditions
- XLSE has two classes of verifiers:
  - Internal: Perform simulation or retrieve test data directly from the diagram. *3rd Party simulation tools can be easily added.*
  - External: Generate and track work request for test or large scale simulation
- Multiple verifiers for a requirement:
  - Verification methods can change over the life of a product program
  - Simple models, design rules followed by detailed simulation and test
  - XLSE allows engineers to change verifiers and track the history of the methods and values

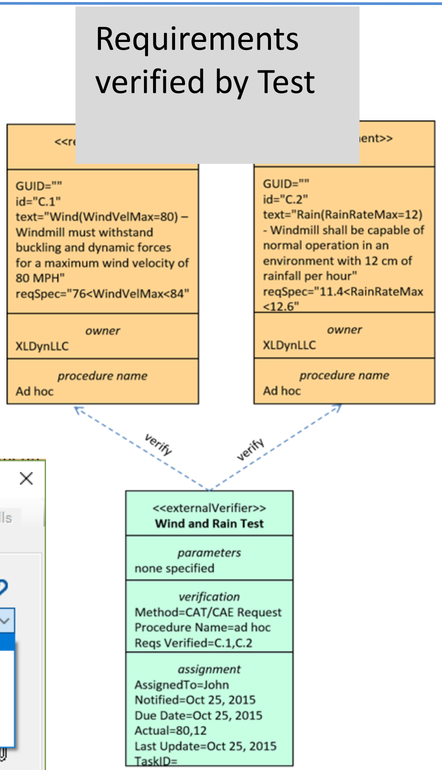
XLDyn® Verification Methods

Verification methods supported by XLDyn®

- *Cell Equations – Simple equations or Macros*
- *Worksheets* – Link the input/output cells of a worksheet to the results set
- *CAT/CAE Request*[1] – Automated e-mail request for a test or simulation. Automatic updated to SRT when work is completed
- *Observation*[1] – Automated e-mail request to make a simple observation, *e.g.* verify label is installed

[1] Requires Microsoft Outlook





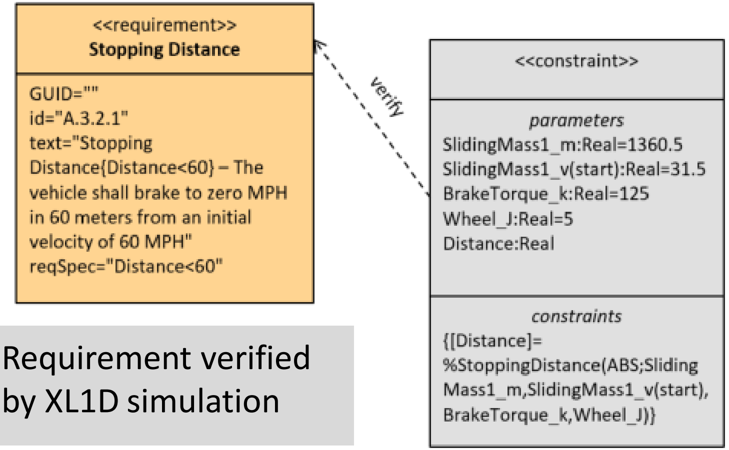
XLDyn® Verification Methods

Verification methods supported by XLDyn®

- *XL1D Model*[2] – Use a XL1D model including reliability
- *Activate Model*[3] – Use a *solidThinking Activate* model.
- *Modelica Model*[4] – Use a Modelica model
- *act Diagram*[5] – Calculate process time using an activity diagram
- *stm Diagram*[6] – Determine system state for parameters and conditions

- Radius
- Force
- Friction

$T > 90\ Nm$



Requirement verified by XL1D simulation

Set_1_Deceleration_
Brake Model ABS

SlidingMass1_m =	1360.5
SlidingMass1_v(start) =	31.5
BrakeTorque_k =	125
Wheel_J =	5
Distance =	56.4

%StoppingDistance
ABS

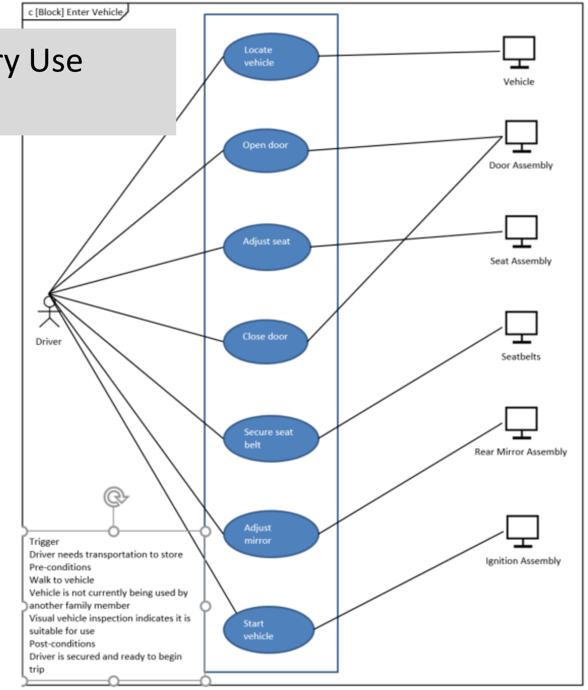
Simulation run from Diagram View

[2] Requires XL1D model in workbook
[3] Requires Activate models in Activate model library
[4] Requires OpenModelica solver and Modelica models in Modelica model library
[5] Requires Activity diagram in workbook
[6] Requires State diagram and XL1D mode.

XLSE Use Case Diagrams

- Use Cases can be imported from a Word document or created directly in XLDyn
- Use Cases can be associated with other diagrams such as requirements

Vehicle Entry Use Case



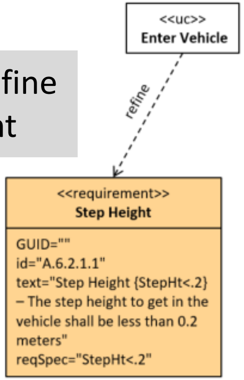
Word Document

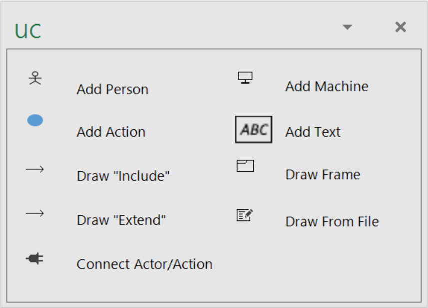
HPV

A Enter Vehicle

- A.1 Description – Enter vehicle and prepare for riding
- A.2 Pre-conditions
  - A.2.1 Proper vehicle has been located
  - A.2.2 Vehicle is not currently being used by someone else
  - A.2.3 Visual vehicle inspection indicates it is suitable for use
- A.3 Post-conditions
  - A.3.1 Gear is stowed and secured
  - A.3.2 Passenger is ready to begin trip
- A.4 Trigger
  - A.4.1 Passenger needs transportation
- A.5 Actors
  - A.5.1 Passenger
  - A.5.2 +Door Assembly
  - A.5.3 +Rear Mirror Assembly
  - A.5.4 +Seat Assembly
  - A.5.5 +Cargo Compartment
- A.6 Activities
  - A.6.1 Stow cargo
  - A.6.2 Open door
  - A.6.3 Adjust seat
  - A.6.4 Close door
  - A.6.5 Adjust mirror

Use Case to Refine Requirement

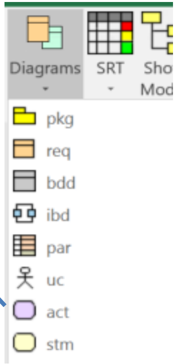




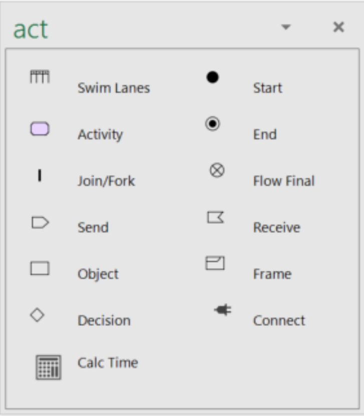
XLSE Activity Diagram

- Activity diagrams are graphical workflows of stepwise activities and actions.
- In XLDyn, Activity diagrams can be created from a library or manually from the pallet

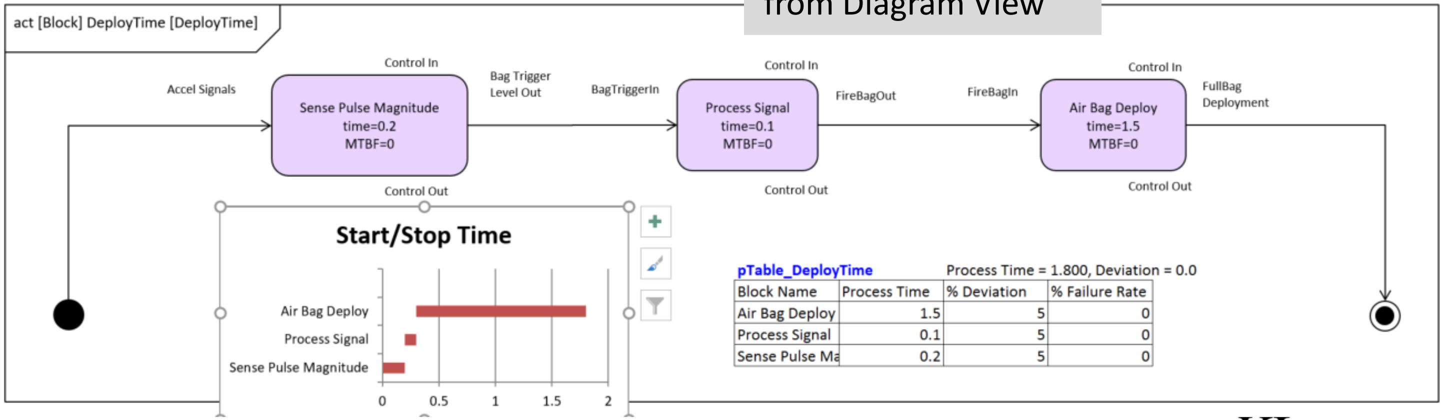
Choose act



act pallet



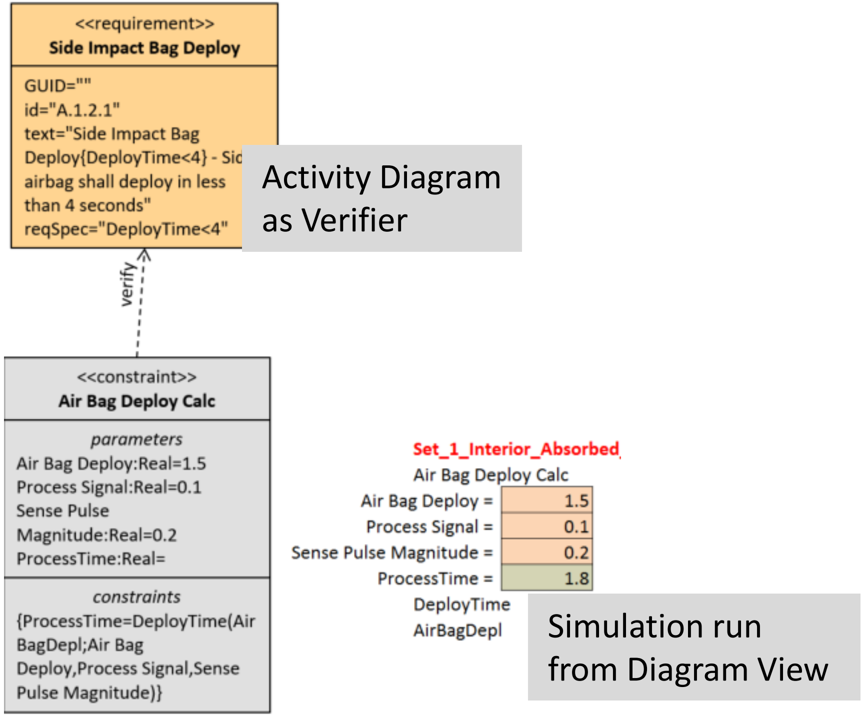
Air Bag Deployment Time Simulation run from Diagram View



Block Name	Process Time	% Deviation	% Failure Rate
Air Bag Deploy	1.5	5	0
Process Signal	0.1	5	0
Sense Pulse Ma	0.2	5	0

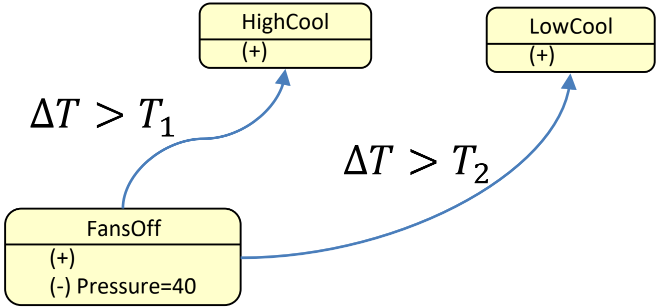
XLSE Activity Diagram

- Activity diagrams can be used as a verifier, design parameters can be varied and simulations performed
- Monte Carlo or Reliability simulations can also be performed



XLDyn State Diagram

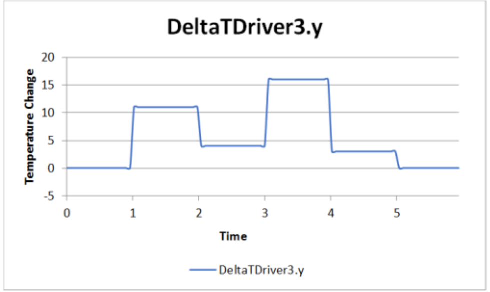
- A state transition machine diagram, or *state diagram* for short, is used in dynamic system models as well as SysML models
- A state diagram shows the conditions that causes a system to change its state
- In this example, a simple cooling system has three states, and the system will shift from *FansOff* to *HighCool* or *LowCool* depending on the temperature difference ΔT

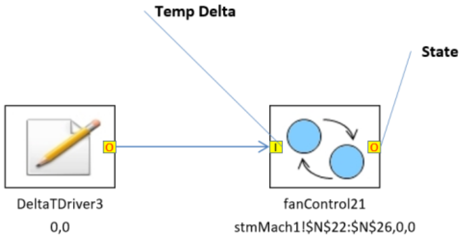


XLDyn State Diagram

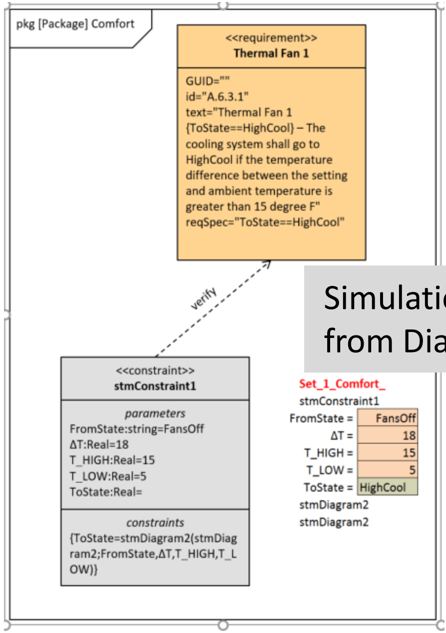
```
State FansOff
    OnEntry
    End OnEntry

    Active
        y1 = 1
        if DeltaT > T_high then goto highcool
        if DeltaT > T_Low then goto lowcool
    end Active

    OnExit
        Pressure=40
    End OnExit
end State

State LowCool
    OnEntry
    end OnEntry
    Active
      y1 = 2
        if DeltaT > T_high then goto 3
        if DeltaT < T_Low then goto 1
    end Active
end state
```

- Start with easy to write script
    - Use script to create the XL1D state machine
    - Determine states based on inputs





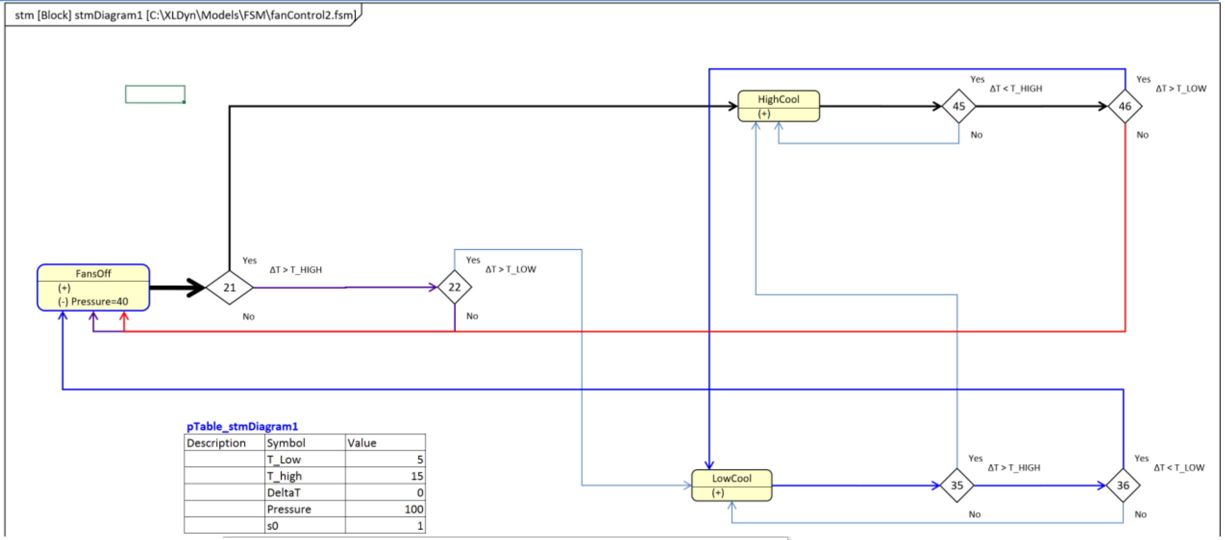
- State Machine used to verify requirement



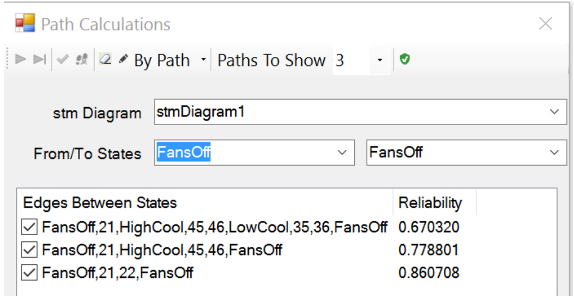
Simulation run from Diagram View

XLDyn State Diagram

- Use same script to create SysML diagram
- Find possible transition paths
- Animate transition during simulation
- Determine reliability

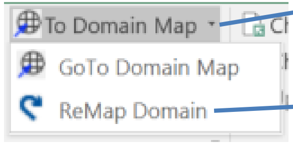


Description	Symbol	Value
	T_Low	5
	T_high	15
	DeltaT	0
	Pressure	100
	s0	1



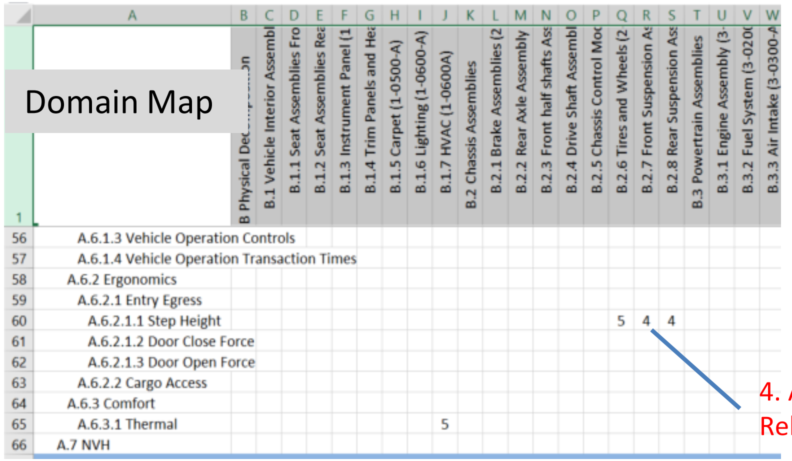
Domain Mapping

- XLDyn automatically maps the requirements to the parts using the tree structure of the model
- Add relationship strength directly to table
- Use for peer reviews and to create DFMEA

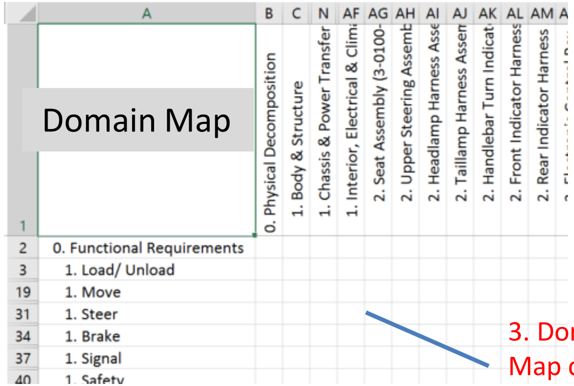


1. Click

2. Click



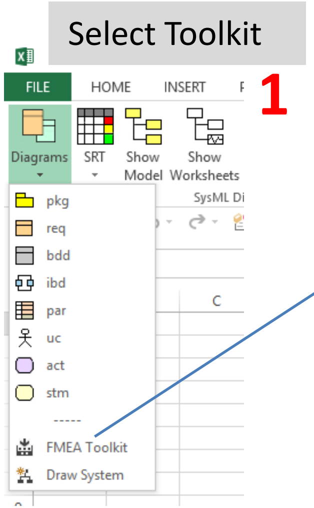
4. Add Relationships

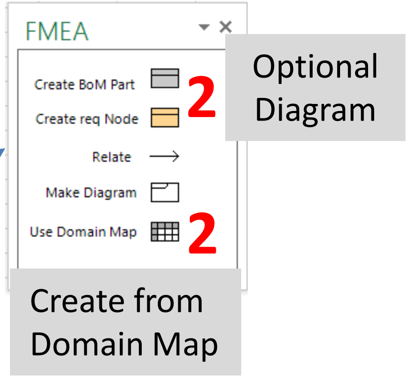


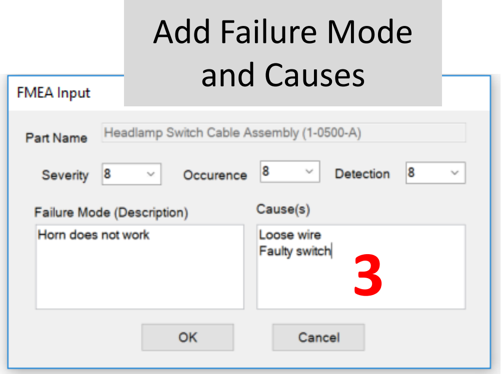
3. Domain Map created with empty cells

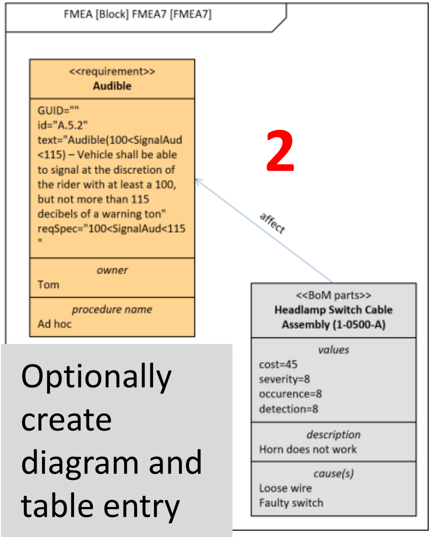
DFMEA Process

- DFMEA is a representation of:
  - What can go wrong in a part or subassembly
  - Its cause(s) and effects
  - Importance or ranked priority









	Item	Potential Failure Mode	Requirements Impacted	Potential Cause(s)	Symtoms/Detection	SEV	OCC	DET	RPN	Recommended actions	Assigned To	Target Date
5	Headlamp Switch Cable Assembly (1-0500-A)	Horn does not work	Audible(100<SignalAud<115) – Vehicle shall be able to signal at the discretion of the rider with at least a 100, but not more than 115 decibels of a warning ton	Loose wire Faulty switch		8	8	8	512			

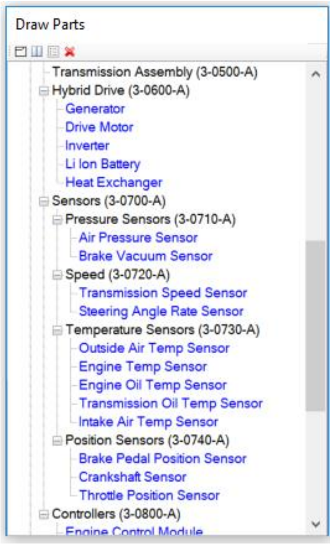
4

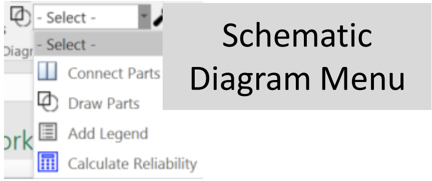
Table Entry Generated

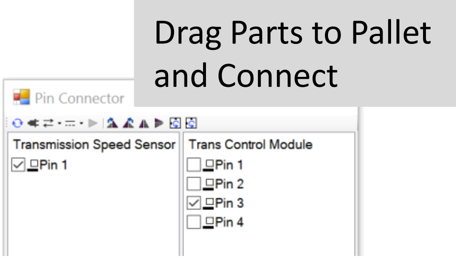
XL

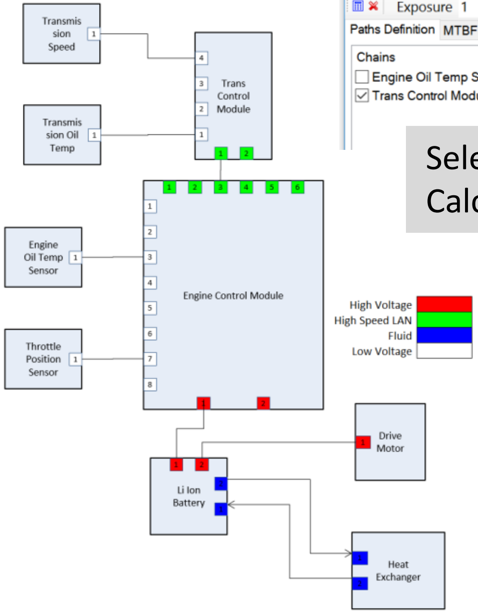
Schematic Diagrams with Reliability

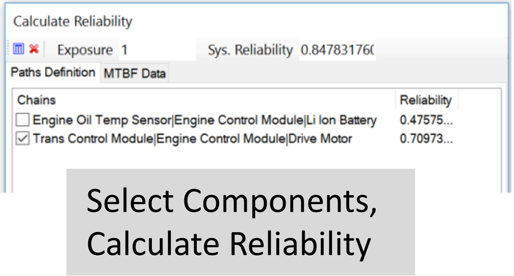
- Create schematic diagrams from part list with defined connector types
- Show connectivity and flow
- Select components then calculate reliability







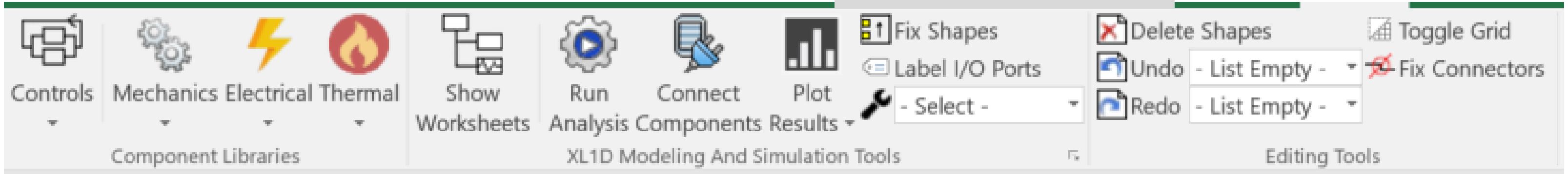




What Is XL1D?

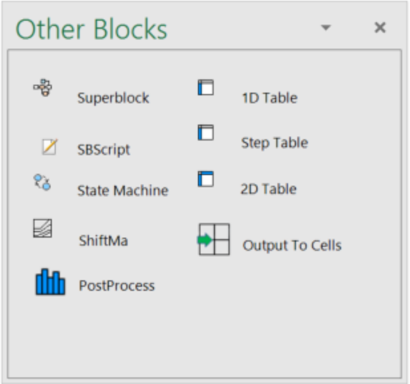
- A multi-physics lumped parameter simulation tool similar to Mathworks Simulink®
- Completely integrated with XLSE for requirements verification and parametric studies
- Includes mechanical, thermal, electrical, control systems, and reliability building blocks

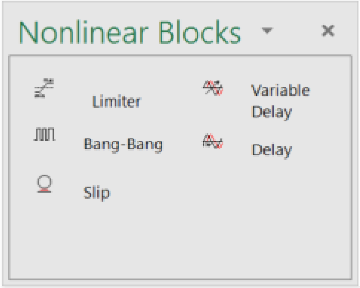
XL1D Tool Bar



XL1D Features

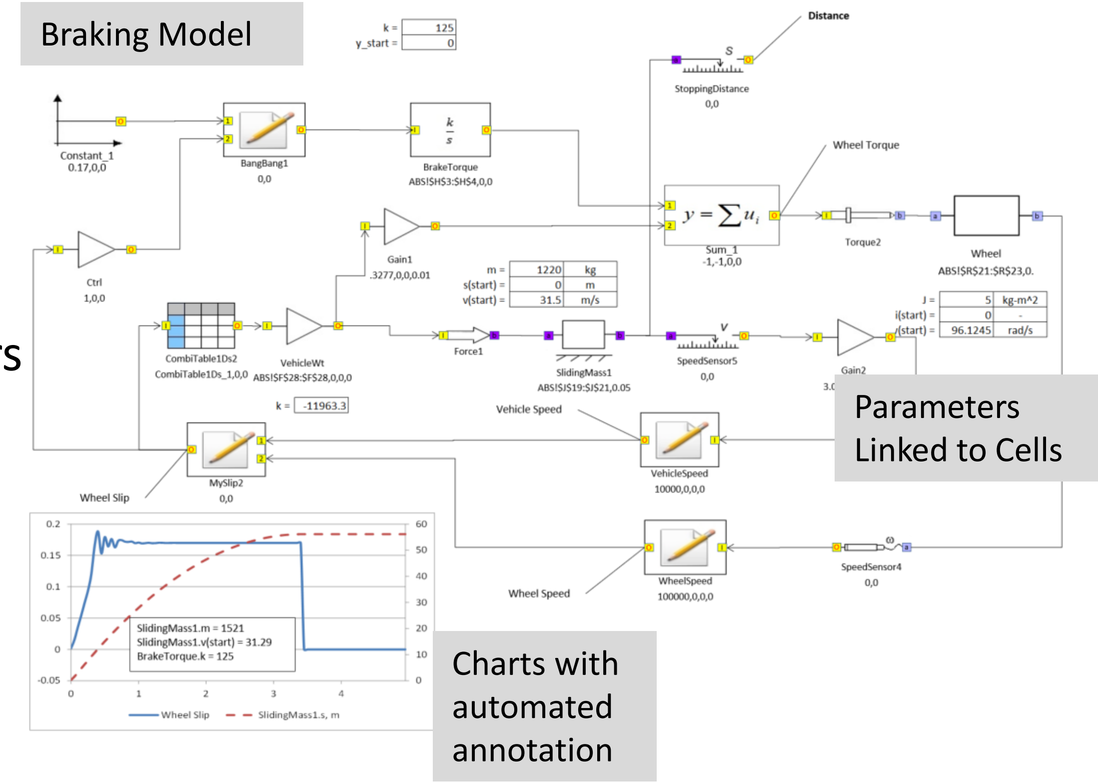
- Static, transient, and frequency domain analyses
- Supports continuous and discrete time simulation
- Powerful scripting language (without 3rd party compiler)
- Finite state machines using scripts
- Transfer Function blocks with custom labels





XL1D Features

- Automated chart creation with Excel functionality
- Built-in Units Management
- Links system parameters to Excel cells
- Run Monte Carlo to calculate performance variations, component properties have built in variation specification

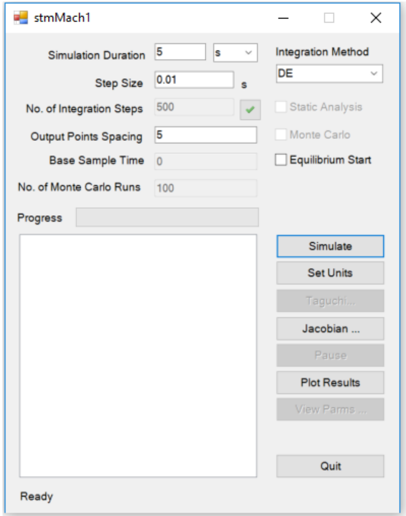


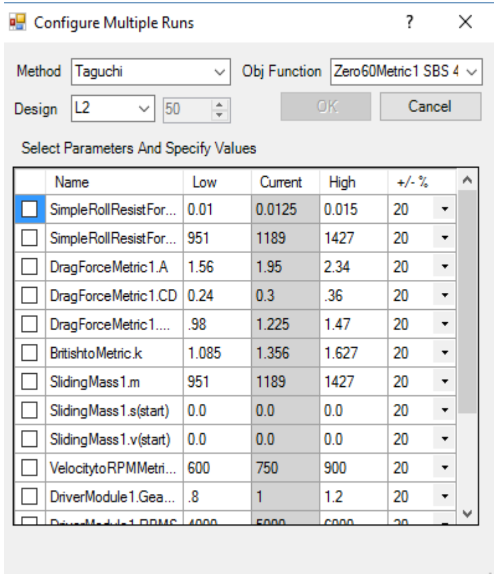
CombiTable1Ds_1

Slip	Mu
0	0
0.05	0.4
0.1	0.8
0.15	0.97
0.2	1
0.25	0.98
0.3	0.96
0.35	0.94
0.4	0.92
0.45	0.9
0.5	0.88
0.55	0.855
0.6	0.83
0.65	0.81
0.7	0.79
0.75	0.77
0.8	0.75
0.85	0.73
0.9	0.72
0.95	0.71
1	0.7

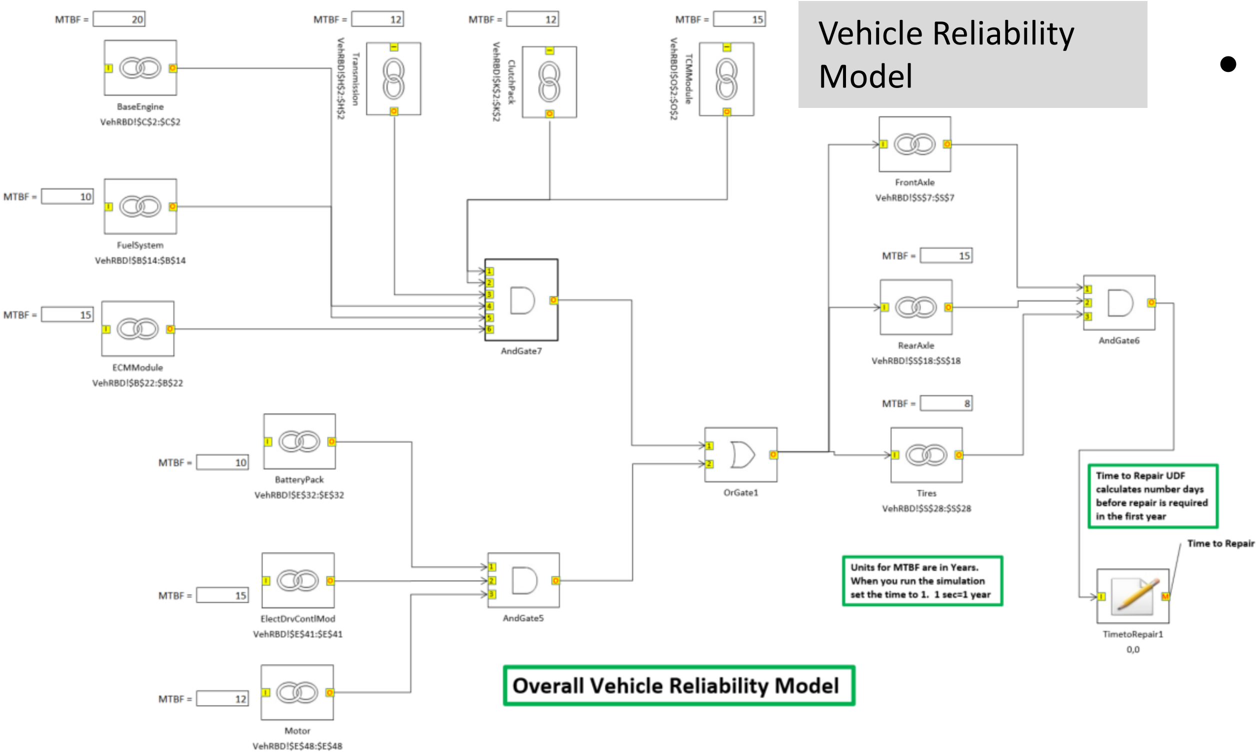
XL1D Features

- Easily configures DoE studies
- Automatically connects components across worksheets (superblocks)
- Completely integrated with XLSE for requirements verification and parametric studies

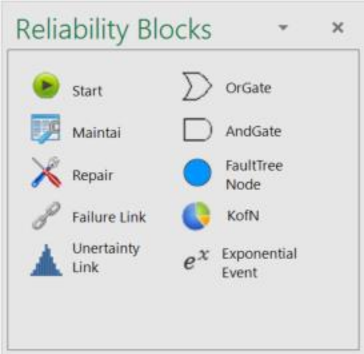




XL1D Features



- Fault Tree and Reliability Block Diagrams



Summary

- Balance designs at the system, subsystem and component level
- Import requirements from and export updates to enterprise systems
- All requirements and verifiers managed in a single application
- XLDyn's SysML diagrams are actionable
- Easy access "project status view" including on mobile devices
- XLDyn's ease of use and integration makes MBSE a way to do your work, not document what you did
- XLDyn requires minimal training so *ALL* engineers can use it

Backup Slides

Summary: XLDyn Users

Enterprise Data

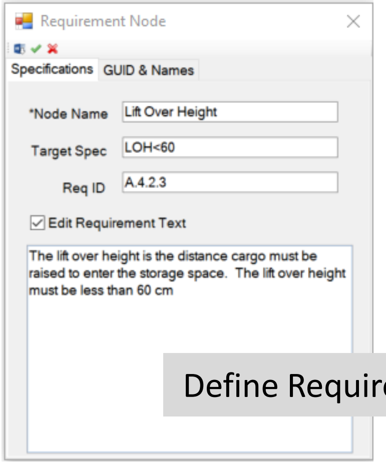
XLDyn Closes the Gap

Simulation And Test

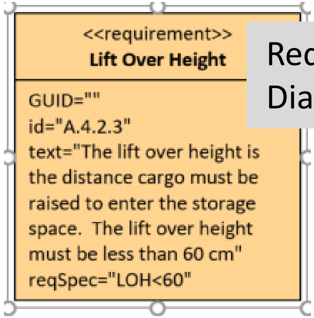
- All Industries and Design Levels:
  - Product Development Engineers
  - Simulation and Test Engineers
  - Systems Engineers
  - Engineering Program Managers
  - Executives and Managers

Adding Requirements and Parts

- Requirements and BoM parts are added directly to diagrams and synchronized in all views and added to the SRD



Define Requirement



Requirement Diagram

A.4.2 **Cargo** – Cargo capacity is comprised of both weight and volume measures

A.4.2.1 **Cargo Volume** {CargoVol>1.0} – Available volume for passenger cargo shall be at least 1 square meter

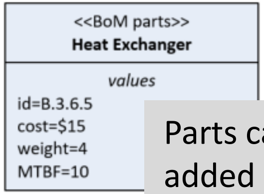
A.4.2.2 **Cargo Weight** {CargoWt>50} – Cargo compartments must be able to carry at least 50 kg

A.4.2.3 **Lift Over Height**{LOH<60} - The lift over height is the distance cargo must be raised to enter the storage space. The lift over height must be less than 60 cm

Added to System Requirement Document (SRD)

A.4.2	Cargo	Cargo – Cargo capacity is comprised of both weight and volume measures			
A.4.2.1	Cargo Volume	Cargo Volume {CargoVol>1.0} – Availa	ad hoc	CargoVol>1.(	1.100
A.4.2.2	Cargo Weight	Cargo Weight {CargoWt>50} – Cargo compartment		CargoWt>50	
A.4.2.3	Lift Over Height	The lift over height is the distance ca	Ad hoc	LOH<60	

Added to System Requirement Table (SRT)



Parts can be added also