

Augmenting Current Tools and Processes to increase the productivity of an engineering team

Bill Chown
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GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2014



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• Bill Chown

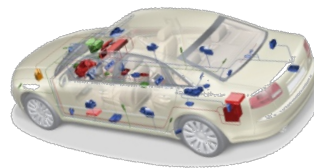
- Product Manager for the System-Level Engineering division at Mentor Graphics, responsible for OSLC-based integrated tool solutions for system design management.
- Bill has worked as an electronic designer, systems engineer and group leader in both systems and semiconductor companies before joining the EDA vendor community at its inception thirty years ago.
- He is active in several standards bodies, a board member for the Object Management Group, member of the OASIS OSLC steering committee, a Senior Member of the IEEE, and Secretary of the Cascade Chapter of INCOSE.

System Design Challenges

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Dealing with Complexity and Change

- **Ever increasing and evolving design requirements**
- **Convergence of multiple disciplines in a single system** from requirements through implementation
- **Complicated communication due to** domain-specific tools, file formats, databases, and protocols
- **Inter-divisional or even multi-company supply chains**
- **Literally millions of design artifacts** for even a moderately sized project



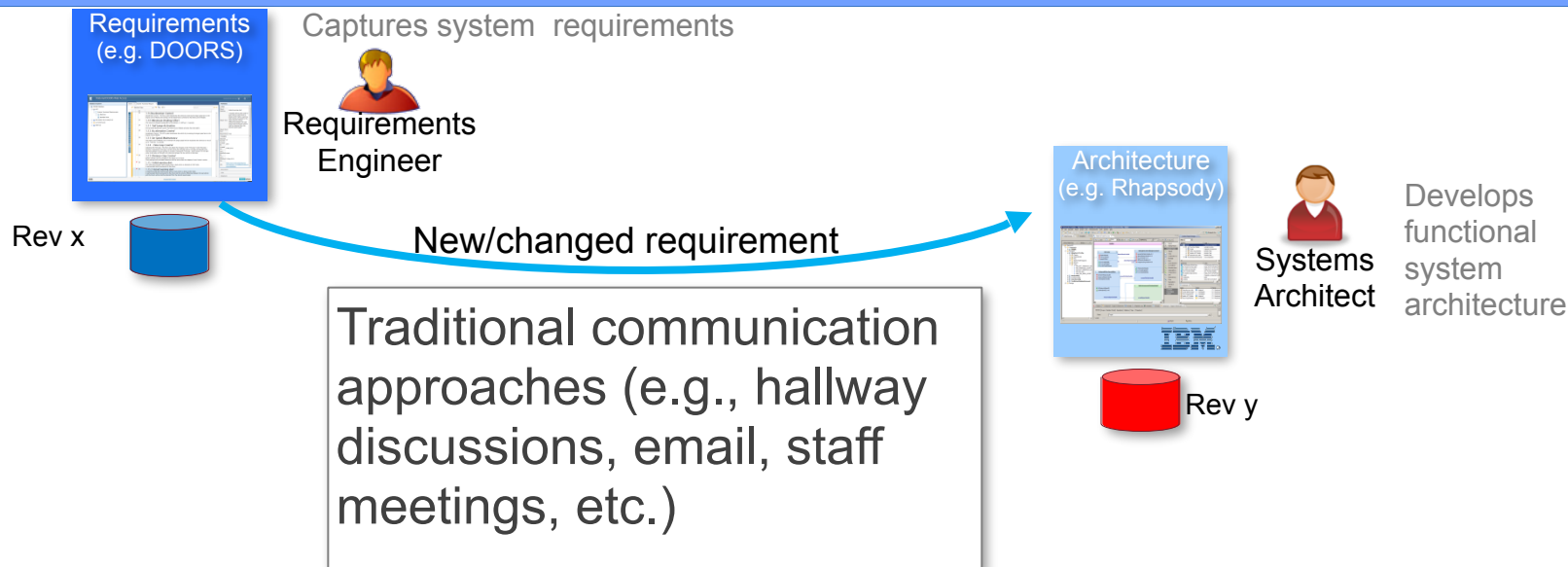
A Flow-based Use Case Example for Safety Analysis

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- **Requirements**
 - Typically in “Systems Engineering”
- **System Architecture**
 - Often not the same person[s] in “Systems”
- **Fault Injection Modeling**
 - Representative architecture and hazard simulation
- **Fault Tree Analysis**
 - Traditional logical deductive failure analysis
- **Changes that Permeate Throughout**
 - Demands comprehension of variants across domains

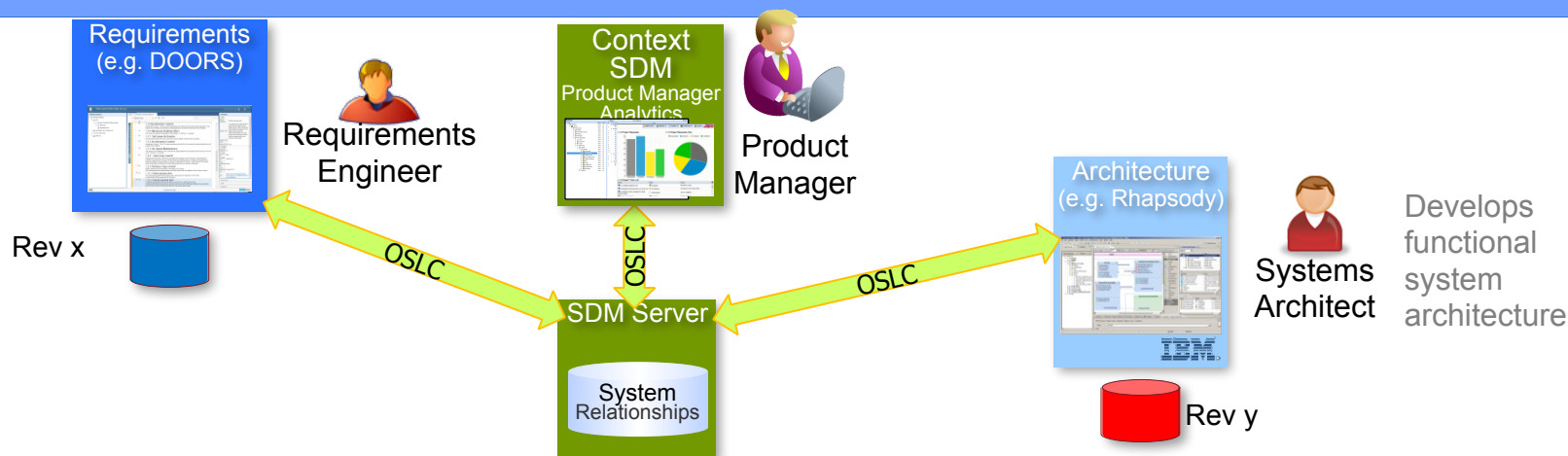
Connecting Across Disciplines

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Connecting Across Disciplines

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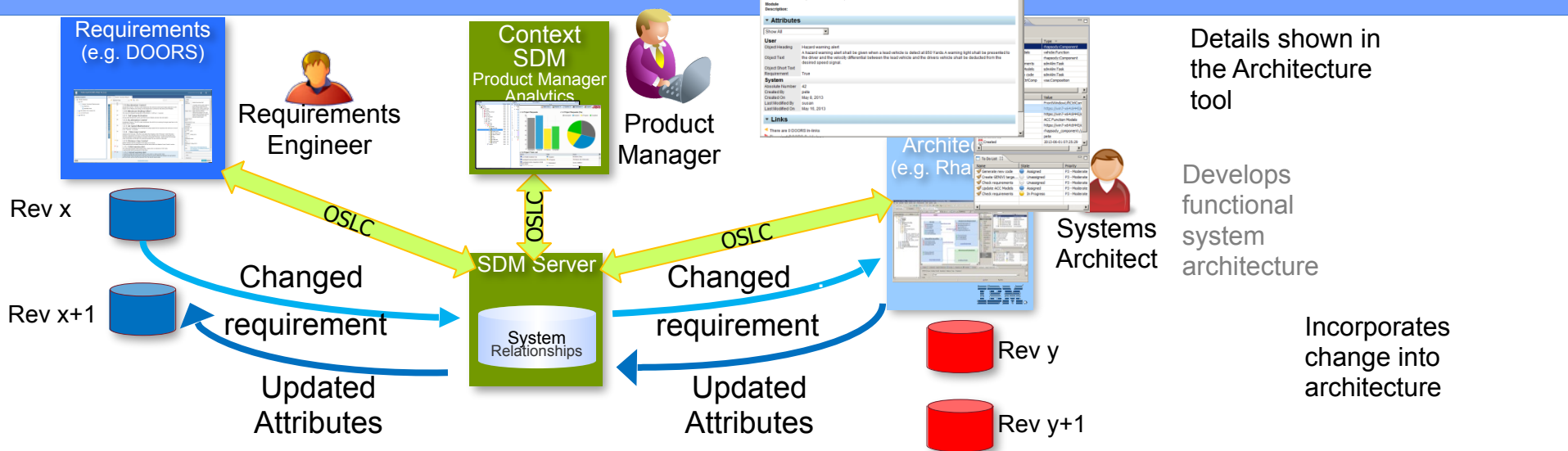


Tool-to-tool communication
can automate and integrate

The Context SDM Server
acts as a focal point,
shares relevant changes,
and builds history

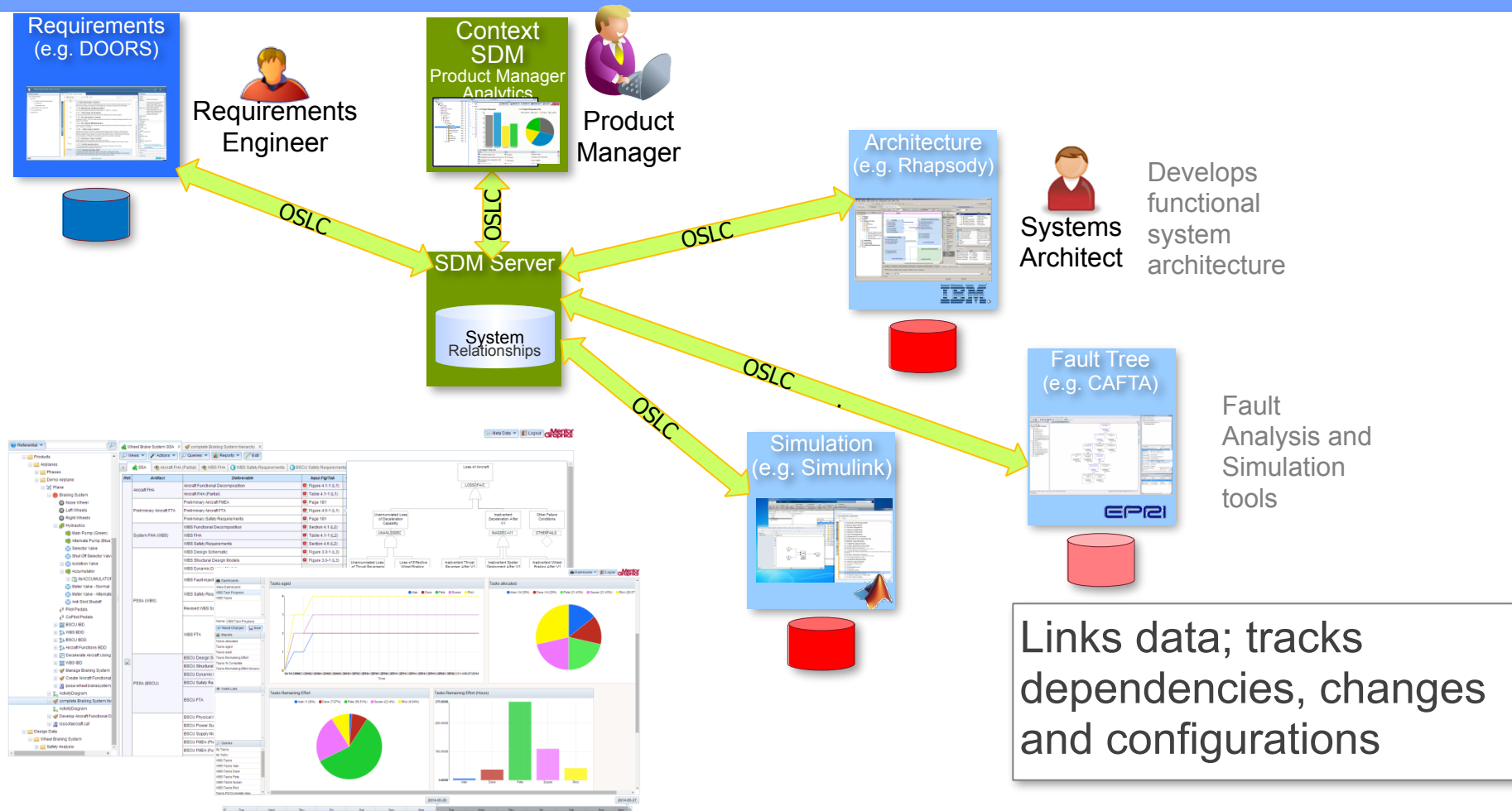
Connecting Across Disciplines

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Connecting Across Disciplines

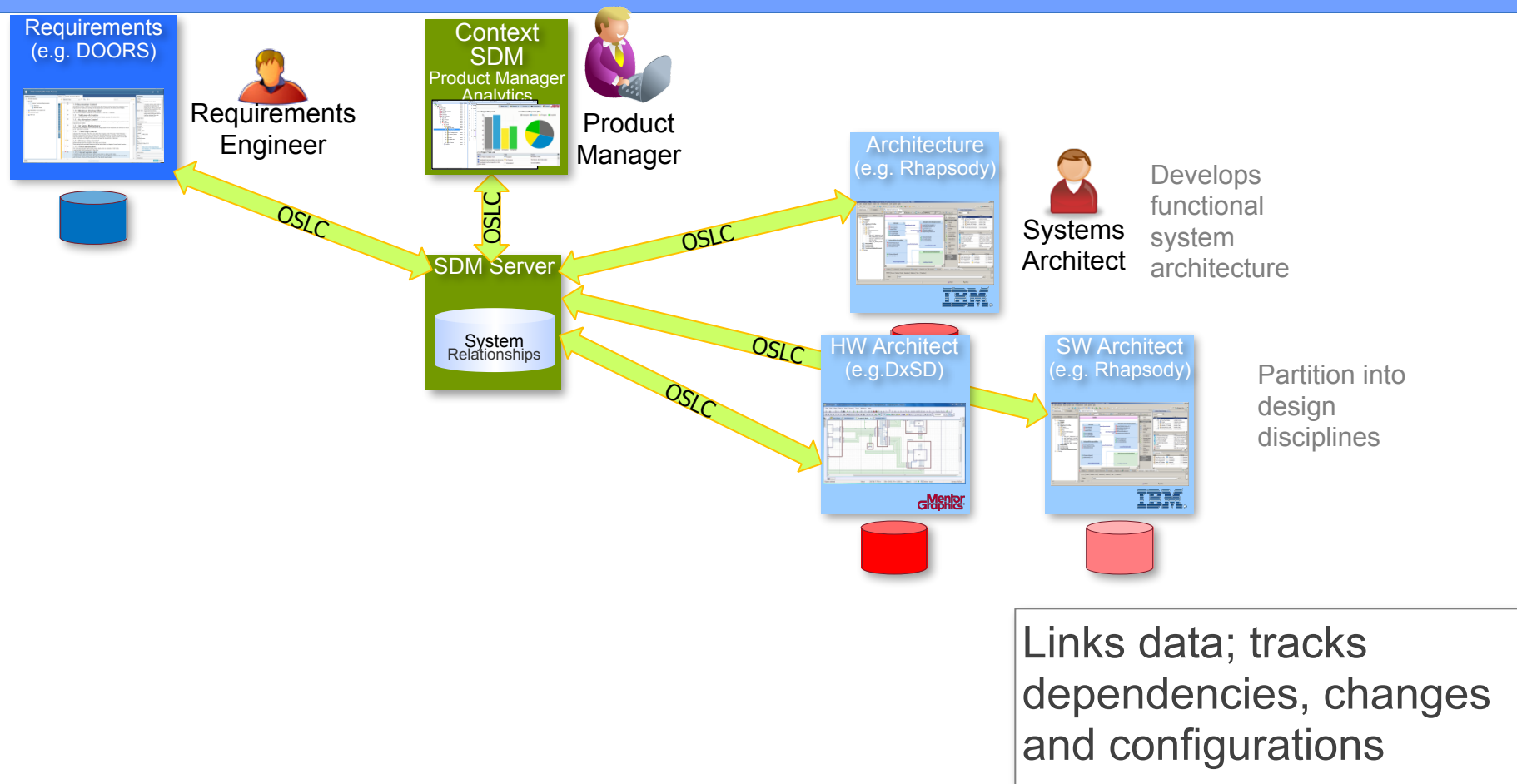
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Cross-reference information, extract analyses

Logical and Physical Architectures

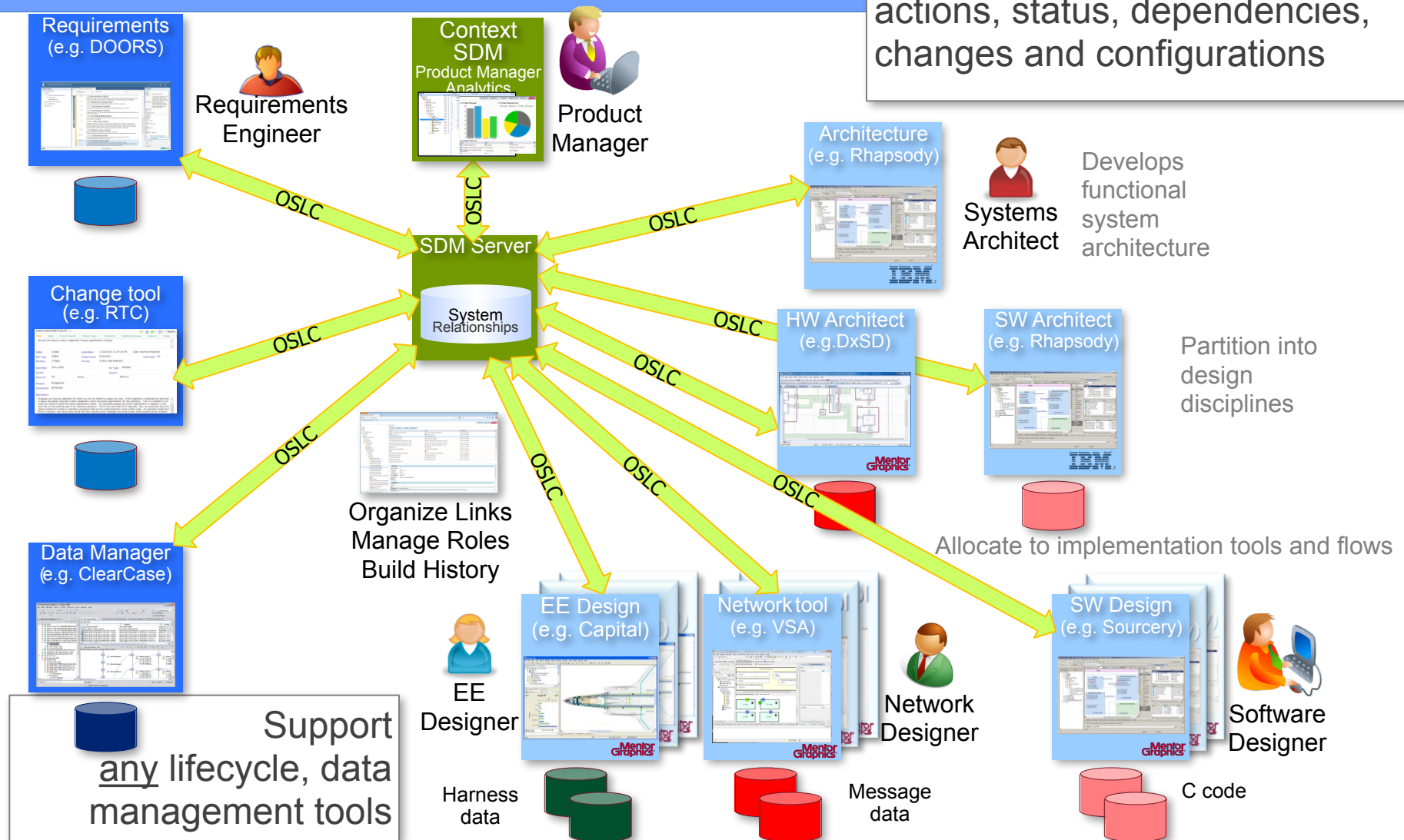
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Logical and Physical Architectures

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Links all design tools; tracks actions, status, dependencies, changes and configurations



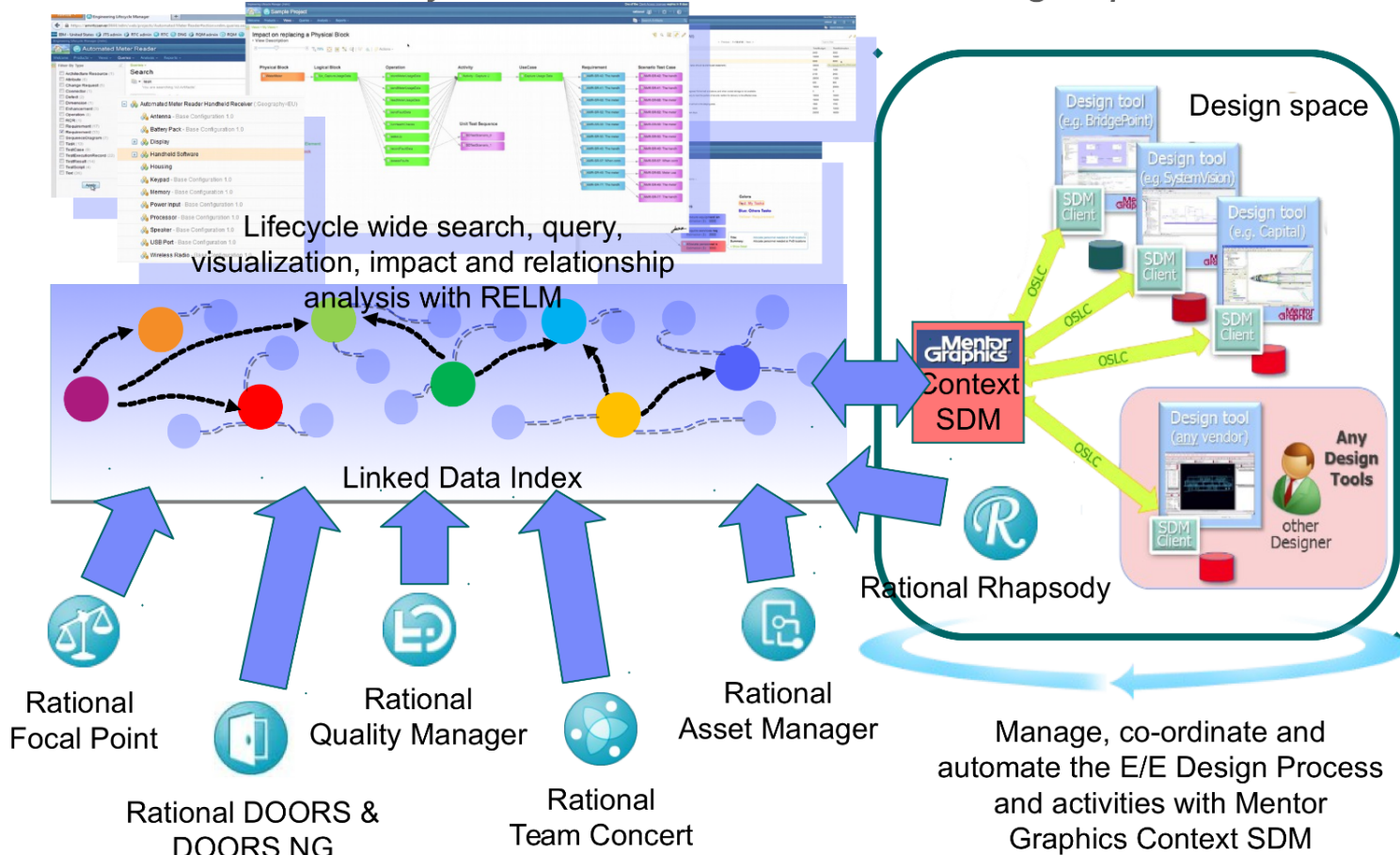
Lifecycle Management for 'Work in Progress'

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- **Managing Change**
 - Changing requirements, dependencies, configurations
- **Coordinating Disciplines**
 - Differing schedules, steps, terminology, progress
- **Finding Information**
 - Standards, processes, requirements, dependencies
- **Meeting Standards**
 - Regulatory, process, and corporate needs
- **Proving Process and Traceability**
 - Required by most standards and regulatory bodies
- **Report Status, Standards, Results...**
 - Extracting, abstracting, and organizing information
- **Hand Off to Production**
 - Version & configuration management and tracking

RELM with Mentor Graphics Context SDM

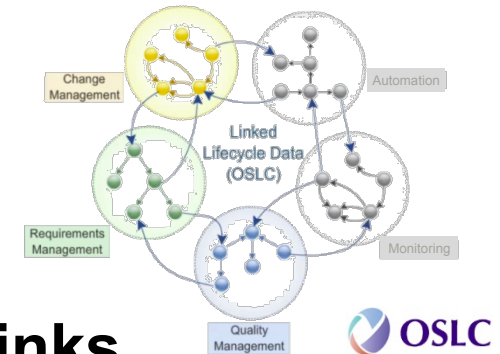
Extend RELM visibility to include the entire E/E design space



Introducing Context™ SDM

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- **Management of linked data**
- **Tool-to tool-integration**
- **Standards-based communication**
- **Context Server stores and manages the links**
 - Builds history; enables traceability and reporting
 - Original data remains with original tools and repositories
- **Context SDM plugins augment design tools**
 - Integration available for **any Mentor tool**
 - Can also support other vendors' or internal design tools
- **Web-based Product Manager accesses data and analytics**
- **OSLC standard connects to other tools**



Scenarios and Use Cases

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- **The Project Manager needs ...**
 - **Visibility** and status
- **Each Designer needs ...**
 - Access to **relevant** information
- **The Safety Analyst needs ...**
 - **Traceability** and auditability
- **The Requirements Engineer needs ...**
 - Complete and **current** data
- **The System Designer needs ...**
 - The **right product**, at the right time



Building Relationships around the Product

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The screenshot displays a web application interface for product data management. The left sidebar shows a hierarchical tree of product components, including Libraries, Orphans, Projects, Vehicle Demo, Truck, Chassis, Powertrain, Body Electronics, Functions, Comfort, Infotainment, Safety & Security, Door Locks, DoorLock Control, Wipers, Windows, and Control. The main area shows a history of changes for the 'Control' component, with a list of changes grouped by date and time. A yellow callout box points to the 'First_system' component in the history, stating 'History tracks all changes'.

sdm-user02.wv.mentorg.com

Meta Data Logout

design system boards x Design power supply x Verify power supply x flyback_sw_cm_tb x First_system x Control x

Views Actions Queries Reports

Reverse Time Only Show Differences

Start Date: End Date: Time Period: Hours

Validation Passed Validation Failed Attribute Added Attribute Modified Attribute Deleted

2013-12-11 16:00

1. Schematic2: Schematic2 (Rev. 1)
2. design system boards: design system boards (Rev. 1)
3. flyback_sw_cm_tb: flyback_sw_cm_tb (Rev. 1)

2013-12-11 17:00

1. Schematic2: Schematic2 (Rev. 1)
2. design system boards: design system boards (Rev. 1)
3. flyback_sw_cm_tb: flyback_sw_cm_tb (Rev. 1)
4. First_system: First_system (Rev. 1)

2013-12-12 11:00

1. Schematic2: Schematic2 (Rev. 1)
2. design system boards: design system boards (Rev. 1)
3. flyback_sw_cm_tb: flyback_sw_cm_tb (Rev. 1)
4. First_system: First_system (Rev. 1)
5. Design power supply: Design power supply (Rev. 1)
6. Verify power supply: Verify power supply (Rev. 1)

2013-12-12 14:00

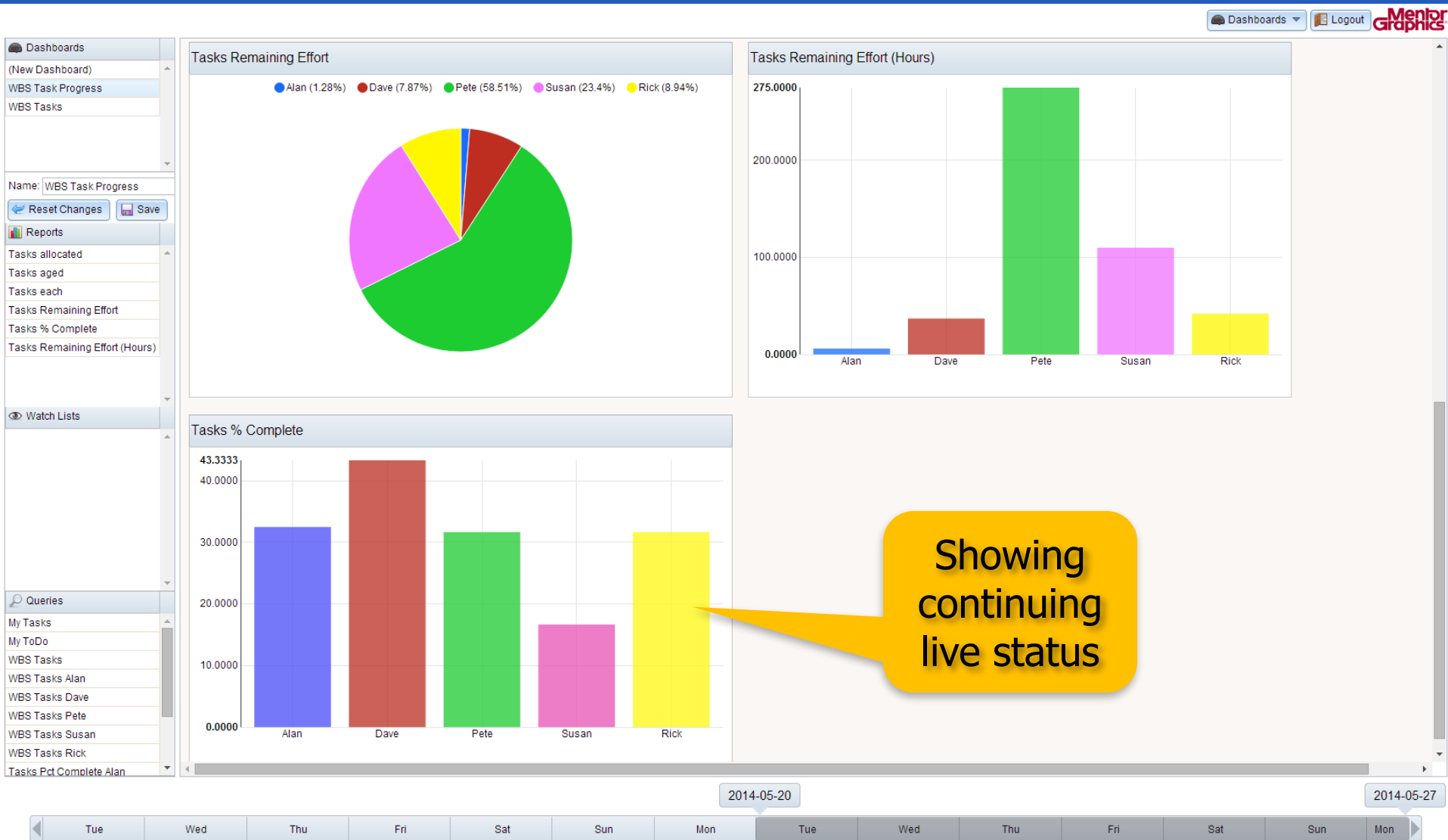
1. Schematic2: Schematic2 (Rev. 1)
2. design system boards: design system boards (Rev. 1)
3. flyback_sw_cm_tb: flyback_sw_cm_tb (Rev. 1)
4. First_system: First_system (Rev. 1)
5. Design power supply: Design power supply (Rev. 1)
6. Verify power supply: Verify power supply (Rev. 1)
7. Schematic4: Schematic4 (Rev. 1)

2013-12-12 15:00

1. Schematic2: Schematic2 (Rev. 1)
2. design system boards: design system boards (Rev. 1)
3. flyback_sw_cm_tb: flyback_sw_cm_tb (Rev. 1)
4. First_system: First_system (Rev. 1)
5. Design power supply: Design power supply (Rev. 1)
6. Verify power supply: Verify power supply (Rev. 1)
7. Schematic4: Schematic4 (Rev. 1)
8. User Requirements (17): <https://sdm02.wv.mentorg.com:8443/dwa/rm/lur50d3587940151bf2-O-17-0000002d>

History tracks all changes

Product Manager – Tracking Resources



Design Tool Use Cases

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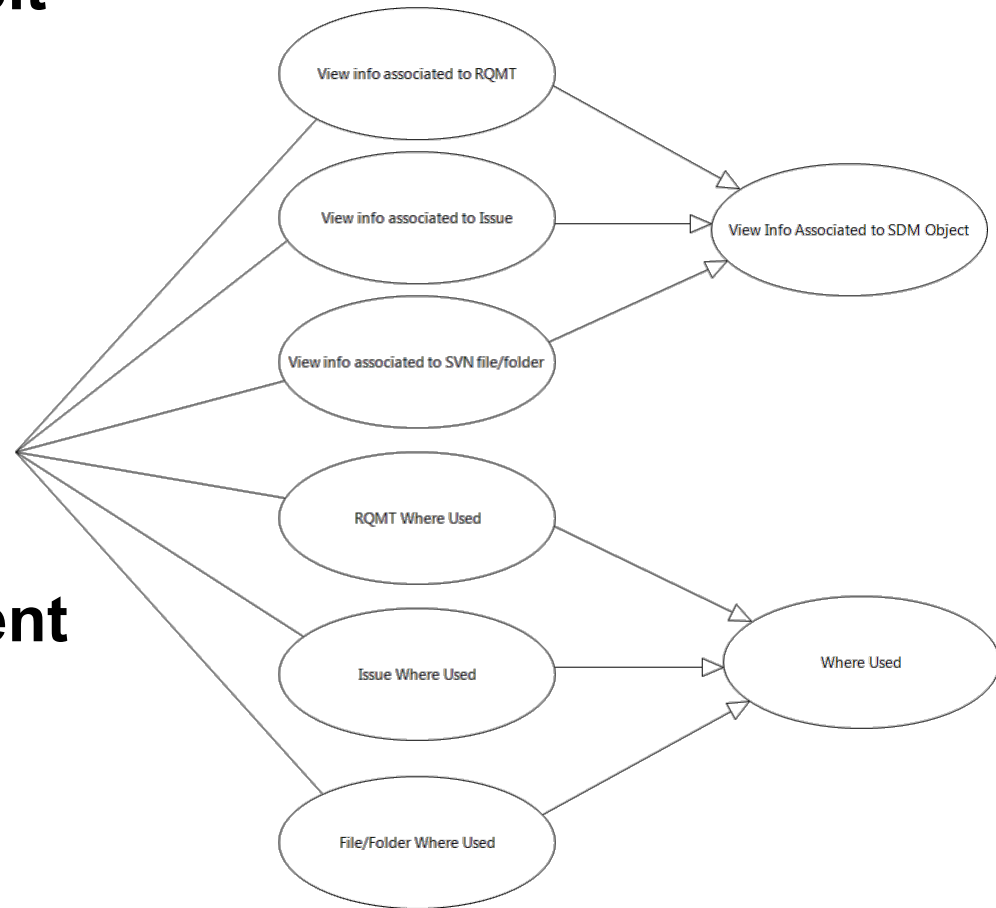
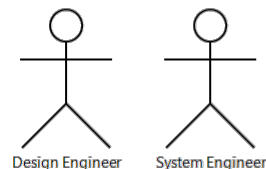
- **Remain in the familiar cockpit**

- Perform usual activities
- “Link as you think”

- **Access to all design dependencies**

- **Interactivity with System Lifecycle Management**

- **Immediate status and issue visibility**



How Does It Look? - Operation inside the Design Tools

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Design work links to Product in progress

Related items such as Requirements are a click away

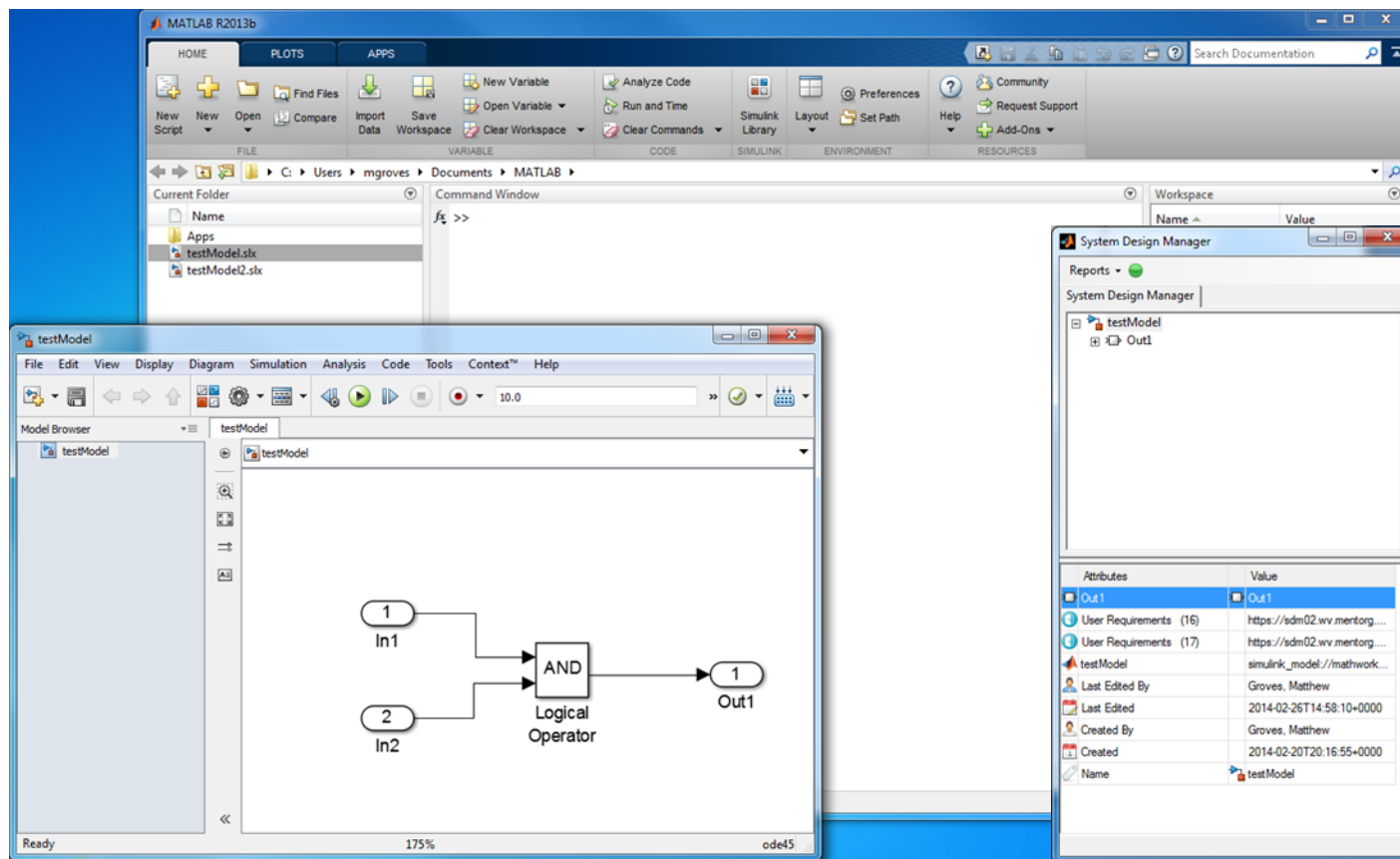
Task view shows work item status

Attributes	Value
PowerWindowECU	PowerWindowECU
PowerWindowMotorAssembly	PowerWindowMotorAssembly
Control+Block	Control+Block
Validate Window requireme...	Validate Window requireme...
Sensor+Block	Sensor+Block
Power+Block	Power+Block
17: Window Requirements	https://sdm02.wv
Schematic Validation	Schematic Validation
Update Control Schematic	Update Control Schematic
Confirm Impact of Requirem...	Confirm Impact of Requirem...
18: Window Control	https://sdm02.wv
19: All control interfaces mu...	https://sdm02.wv

Name	Owner	State
Confirm Impact of ...	Pete	Assigned
Update Control S...	Pete	In Progress
Schematic Validat...	Pete	Assigned
Validate Window ...	Pete	In Progress

Linking in Simulink

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DOORS Access (illustrated in Simulink)

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The screenshot displays the MATLAB R2013b environment with the DOORS Access window open. The window shows the 'Large Preview - User Requirements (16)' document. The 'Summary' section includes the following details:

- Object Identifier: 16
- Created On: May 21, 2013
- Created By: sdmbuild
- Last Modified On: February 24, 2014
- Last Modified By: sdmbuild
- Module Name: User Requirements
- Module Description: User Requirements

The 'Attributes' section is expanded, showing a table of attributes:

User	
Object Heading	Constraint Requirements
Object Text	
Object Short Text	

System	
Absolute Number	16
Created By	sdmbuild
Created On	May 21, 2013
Last Modified By	sdmbuild
Last Modified On	February 24, 2014

The 'Links' section indicates there are 0 DOORS In-links and 0 DOORS Out-links. The 'External Links' section shows a list of references:

- Control
- Matt
- Power+Windows+System
- <http://sdm-user01.wv.mentorg.com/Report/where-Used-Instantiated-Attribute-With-Gur?url=https%3A%2F%2Fsdm02.wv.mentorg.com%3A8443%2Fdwa%2Frm%2Furn%3Aarational%3A%3A1-5043587940151b2-Q-16-0000002d>
- <http://sdm-user02.wv.mentorg.com/Report/where-Used-Instantiated-Attribute-With-Gur?url=https%3A%2F%2Fsdm02.wv.mentorg.com%3A8443%2Fdwa%2Frm%2Furn%3Aarational%3A%3A1-5043587940151b2-Q-16-0000002d>
- testModel

The 'Workspace' window on the right shows the 'testModel' variable. The 'Design Manager' window on the right shows the 'testModel' design with 'Out1' as the output.

Functional Models in Rhapsody, with Context SDM

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System Design Manager

Related	Type
Target	rhapsody:Component
ACC Function Models	vehicle:Function
Target	rhapsody:Component
Check requirements	sdmAlm:Task
Update ACC Models	sdmAlm:Task
Generate new code	sdmAlm:Task
FrontWindowLiftCtrlComp	vsa:Composition

Attributes	Value
FrontWindowLiftCtrlComp	FrontWindowLiftCtrlComp
42: Hazard warning alert	https://win7-x64:8443/
44: Initial warning alert	https://win7-x64:8443/
ACC Function Models	ACC Function Models
45: Distance Gap Control	https://win7-x64:8443/
Target	rhapsody_component://
Created By	pete
Created	2013-06-01 07:25:29

Name	State	Priority
Generate new code	Assigned	P3 - Moderate
Create GENIVI target...	Unassigned	P3 - Moderate
Check requirements	Unassigned	P3 - Moderate
Update ACC Models	Assigned	P3 - Moderate
Check requirements	In Progress	P3 - Moderate

ALM Operation inside the Design Tools

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Builder

itsCruise

- desiredSpeed:double
- memorySpeed
- speedOffset
- evCruiseEnable
- evCruiseDisable
- evSetCoastRelease

itsEngineControl:EngineControl

- sensedVehSpd:double=0.0
- desiredSpeed:double=0.0
- thrust:double=0.0
- difference:double=0.0
- integrate:long double=0.0
- chSensedVehSpd()
- evCruiseEnabled()
- evCruiseDisabled()

itsSpeedFilter:SpeedFilter

- sensedVehSpd:double
- measuredSpeed:double
- vehicleSpeed:double
- chMeasuredSpeed()
- updateSpeed():void

itsEnvironment:FrictionModel

- actualSpeed:double

System Design Manager

Related	Type
Target	rhapsody:Component
ACC Function Models	vehicle:Function
Target	rhapsody:Component
Check requirements	sdmAlm:Task
Update ACC Models	sdmAlm:Task
Generate new code	sdmAlm:Task
FrontWindowLiftCtrlComp	vsa:Composition

Attributes	Value
Generate new code	Generate new code
Update ACC Models	Update ACC Models
Check requirements	Check requirements
Target	Target
Created By	pete
Created	2013-05-31 08:13:24
Last Edited By	pete
Last Edited	2013-05-31 08:13:24

To Do List

Name	State	Priority
Generate new code	Assigned	P3 - Moderate
Create GENI	Start Task	- Moderate
Check require		- Moderate
Update ACC		- Moderate
Check require		- Moderate

Generate new code

- Start Task
- Generate new code Attributes
- Rename Generate new code
- Copy URI
- Preview
- Remove Selected

This designer commences a new task

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CAFTA Fault Tree Integration

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Cafta - pssa-wheelbrakesystem3.caf

File Edit Properties View Project Tools Context™ Window Help

Project Workspace

Project S18 WBS Project.psa

- Fault Trees
 - brakingloss.caf
 - brakingloss1.caf
 - bscufault1.caf
 - lossofaircraft.caf
 - pssa-wheelbrakesystem1.caf
 - pssa-wheelbrakesystem2.caf
 - pssa-wheelbrakesystem3.caf
- Databases
 - brakingloss.rr
 - brakingloss1.rr
 - bscufault1.rr
 - lossofaircraft.rr
 - pssa-wheelbrakesystem1.rr
 - pssa-wheelbrakesystem2.rr
 - pssa-wheelbrakesystem3.rr
- Documents
 - s18 wbs project.rr

pssa-wheelbrakesystem3.caf

Name: Compile Preliminary Aircraft FTA
Id: 6841

Title	Value
Task ID	6841
State	In Progress
Owner	Susan
Type	General
Priority	P1 - Urgent
Name	Compile Preliminary Aircraft FTA
Created	2014-04-18T18:07:15+0000
Created By	Pete
Last Edited	2014-04-19T18:36:28+0000
Last Edited By	Susan
Date Due	2014-04-18
Estimated Effort	50

UNANLSSWB : 4.960E-07 : Unannounced Loss of all Wheel Braking

Find Results

Database: K:\FaultTrees\PSSA-WheelBrakeSystem3.rr\CAP\NUM

System Design Manager

Reports • Actions •

System Design Manager

pssa-wheelbrakesystem3.caf

Attributes Value

Attributes	Value
Braking System	Braking System
pssa-wheelbrakesys...	cafta_faultTree://epr...
Created By	Susan
Created	2014-04-22T14:34:...
By	Susan
	2014-04-22T14:31:...
	pssa-wheelbrakesys...

Task ID 6841

State In Progress

Owner Susan

Type General

Priority P1 - Urgent

Name Compile Preliminary Aircraft FTA

Created 2014-04-18T18:07:15+0000

Created By Pete

Last Edited 2014-04-19T18:36:28+0000

Last Edited By Susan

Date Due 2014-04-18

Estimated Effort 50

State In Progress

Date Due 2014-04-18

Priority P1 - Urgent

Document Compile Preliminary Aircraft FTA

Review WB... Unassigned 2014-04-21 P3 -

CAFTA Fault Tree Integration

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Cafta - pssa-wheelbrakesystem3.caf

File Edit Properties View Project Tools Context™ Window Help

Project Workspace

Project S18 WBS Project.psa

- Fault Trees
 - brakingloss.caf
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 - lossofaircraft.caf
 - pssa-wheelbrakesystem1.caf
 - pssa-wheelbrakesystem2.caf
 - pssa-wheelbrakesystem3.caf
- Databases
 - brakingloss.rr
 - brakingloss1.rr
 - bscufault1.rr
 - lossofaircraft.rr
 - pssa-wheelbrakesystem1.rr
 - pssa-wheelbrakesystem2.rr
 - pssa-wheelbrakesystem3.rr
- Documents

pssa-wheelbrakesystem3.caf

Summary

Object Identifier: 266
Created On: April 14, 2014
Created By: sdmbuild
Last Modified On: April 17, 2014
Last Modified By: sdmbuild
Module Name: AIR6110 Requirements
Module Description: AIR6110 Requirements extracted

Attributes

Show All

User

Object Heading	Value
S18-BSCU-R-0003	
Object Text	The probability of "Loss of a single BSCU" shall be less than 5.75E-3 per flight BSCUS18-WBS-R-6105
Object Short Text	The probability of "Loss of a single BSCU" shall be less than 5.75E-3 per flight
Paragraph Style	<Object Text.body text>

Database: K:\FaultTrees\PSSA-WheelBrakeSystem3.rr\CAP\NUM

UNANLSSWB : 4.960E-07 : Unannounced Loss of all Wheel Braking

Find Results

System Design Manager

Reports • Actions •

System Design Manager

- pssa-wheelbrakesystem3.caf
 - Braking System

Attributes

Attribute	Value
brakingloss.caf	pssa-wheelbrakesystem3.caf
probability of "Loss of a single BSCU"	https://sdm02.wv.n
Requirements (265)	https://sdm02.wv.n
Unit shall have metering ...	https://sdm02.wv.n
Brake System shall be co...	https://sdm02.wv.n
Brake System shall provi...	https://sdm02.wv.n
Brake System shall includ...	https://sdm02.wv.n
shall have hydraulically...	https://sdm02.wv.n
shall have autobrake fun...	https://sdm02.wv.n
shall have a means to d...	https://sdm02.wv.n
Aircraft Functional Deco...	Create Aircraft Fur
Braking System	Manage Braking S

Name	State	Date Due	Prior
Compile Prel...	In Progress	2014-04-18	P1
Document R...	Unassigned	[Empty]	P3
Review WB...	Unassigned	2014-04-21	P3

CAFTA Fault Tree Integration

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Cafta - pssa-wheelbrakesystem3.caf

File Edit Properties View Project Tools Context™ Window Help

Project Workspace

Project S18 WBS Project.psa

- Fault Trees
 - brakingloss.caf
 - brakingloss1.caf
 - bscufault1.caf
 - lossofaircraft.caf
 - pssa-wheelbrakesystem1.caf
 - pssa-wheelbrakesystem2.caf
 - pssa-wheelbrakesystem3.caf
- Databases
 - brakingloss.rr
 - brakingloss1.rr
 - bscufault1.rr
 - lossofaircraft.rr
 - pssa-wheelbrakesystem1.rr
 - pssa-wheelbrakesystem2.rr
 - pssa-wheelbrakesystem3.rr
- Documents

pssa-wheelbrakesystem3.caf

Database: K:\FaultTrees\PSSA-WheelBrakeSystem3.rr\CAP\NUM

System Design Manager

Reports • Actions •

System Design Manager

- pssa-wheelbrakesystem3.caf
 - Braking System

Attributes

Attributes	Value
pssa-wheelbrakesystem3.caf	pssa-wheelbrakesystem3.caf
The probability of 1 loss of a sin	https://sdm12.wy...

Where Am I Referenced?

Open DOORS Requirement

Edit Attribute

Edit Attribute In New Tab

Delete Attribute

Attach to Event BSCU1FAILS

Attach to pssa-wheelbrakesystem3.caf

Copy Value

Preview

Manage Braking System

Manage Braking S

My Tasks

Name	State	Date Due	Prior
Compile Prel...	In Progress	2014-04-18	P1
Document R...	Unassigned	[Empty]	P3
Review WB...	Unassigned	2014-04-21	P3

BSCU1FAILS: 5.750E-03 : BSCU 1 Failure Causes Loss of Braking Commands

Find Results

Tabular Analysis

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Meta Data Logout **Mentor Graphics**

Referential

- Products
 - Airplanes
 - Phases
 - Demo Airplane
 - Plane
 - Braking System
 - Nose Wheel
 - Left Wheels
 - Right Wheels
 - Hydraulics
 - Main Pump (Green)
 - Alternate Pump (Blue)
 - Selector Valve
 - Shut Off Selector Valve
 - Isolation Valve
 - Accumulator
 - itsACCUMULATOR
 - Meter Valve - Normal
 - Meter Valve - Alternate
 - Anti Skid Shutoff
 - Pilot Pedals
 - CoPilot Pedals
 - BSCU IBD
 - WBS BDD
 - BSCU BDD
 - Aircraft Functions BDD
 - Decelerate Aircraft Using
 - WBS IBD
 - Manage Braking System
 - Create Aircraft Functional
 - psa-wheelbrakesystem
 - ActivityDiagram
 - complete Braking System hi
 - ActivityDiagram
 - Develop Aircraft Functional D
 - lossofaircraft.caf
- Design Data
 - Wheel Braking System
 - Safety Analysis

Wheel Brake System SSA x complete Braking System hierarchy x

Views Actions Queries Reports Edit

SSA Aircraft FHA (Partial) WBS FHA WBS Safety Requirements BSCU Safety Requirements

Ref.	Artifact	Deliverable	Input Fig/Tab	
Aircraft FHA	Aircraft Functional Decomposition	Figure 4.1-1 (L1)		
	Aircraft FHA (Partial)	Table 4.1-1 (L1)		
	Preliminary Aircraft FMEA	Page 181		
Preliminary Aircraft FTA	Preliminary Aircraft FTA	Figure 4.6-1 (L1)		
	Preliminary Safety Requirements	Page 181		
System FHA (WBS)	WBS Functional Decomposition	Section 4.1 (L2)		
	WBS FHA	Table 4.1-1 (L2)		
	WBS Safety Requirements	Section 4.6 (L2)		
PSSA (WBS)	WBS Design Schematic	Figure 3.0-1 (L3)		
	WBS Structural Design Models	Figure 3.0-1 (L3)		
	WBS Dynamic Design Models			
	WBS Fault-Injection Testing			
	WBS Safety Requirements & Design Decisions	Section 4.1.1 (L3) Table 4.1.1-1 (L3)		
	Revised WBS Safety Requirements & Design Decisions	Section 4.1.2 (L3) Table 4.1.2-1 (L3)		
	WBS FTA	Figure 4.2.1-1 (L3) Figure 4.2.1-2 (L3) Figure 4.2.1-3 (L3)		
	PSSA (BSCU)	BSCU Design Schematic	Figure 3.0-1 (L4)	
	BSCU Structural Design Models			
	BSCU Dynamic Design Models			
BSCU Safety Requirements & Design Decisions	Table 4.1.1-1 (L4)			
BSCU FTA	BSCU FTA	Figure 4.2.1-1 (L4) Figure 4.2.1-2 (L4)		
	BSCU Physical Implementation	Figure 3.0-1 (L5)		
	BSCU Power Supply Diagram	Figure 3.0-2 (L5)		
	BSCU Supply Monitor	Figure 3.0-3 (L5)		
	BSCU FMEA (Piece Parts)	Table 4.2-2 (L5)		
	BSCU FMEA (Functional)	Table 4.1-1 (L5)		

1st Level

Aircraft Functions

- Control Thrust
- Control Flight Path
- Determine Orientation
- Determine Position and Heading
- Control Aircraft on the Ground
- Control Cabin Environment

2nd Level

- Determine Air/Ground Transition
- Decelerate Aircraft on the Ground
- Control Aircraft Direction on the Ground

(Aircraft FHA) Aircraft Functions

Artifact	Deliverable	Input Fig/Tab	Output Fig/Tab	Tool
WBS FTA	WBS FTA		Fault Tree	CAFTA
PSSA (BSCU)	BSCU Design Schematic	Figure 3.0-1 (L4)	Schematic	SystemVision
BSCU Structural Design Models	BSCU Structural Design Models		SysML BDD/IBD	Rhapsody
BSCU Dynamic Design Models	BSCU Dynamic Design Models		SysML ACT/SEQ/SM	Rhapsody
BSCU Safety Requirements & Design Decisions	BSCU Safety Requirements & Design Decisions		Requirements	DOORS
BSCU FTA	BSCU FTA		Fault Tree	CAFTA
BSCU Physical Implementation	BSCU Physical Implementation		Schematic	SystemVision
BSCU Power Supply Diagram	BSCU Power Supply Diagram		Schematic	SystemVision
BSCU Supply Monitor	BSCU Supply Monitor		Schematic	SystemVision
BSCU FMEA (Piece Parts)	BSCU FMEA (Piece Parts)		FMEA Table	SDM
BSCU FMEA (Functional)	BSCU FMEA (Functional)		FMEA Table	SDM

Tabular Analysis

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[Meta Data](#)
[Logout](#)

Referential

- Products
 - Airplanes
 - Phases
 - Demo Airplane
 - Plane
 - Braking System
 - Nose Wheel
 - Left Wheels
 - Right Wheels
 - Hydraulics
 - Main Pump (Green)
 - Alternate Pump (Blue)
 - Selector Valve
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 - Meter Valve - Normal
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 - Pilot Pedals
 - CoPilot Pedals
 - BSCU IBD
 - WBS BDD
 - BSCU BDD
 - Aircraft Functions BDD
 - Decelerate Aircraft Using
 - WBS IBD
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 - Create Aircraft Functional
 - pssa-wheelbrakesystem
 - ActivityDiagram
 - complete Braking System hierarchy
 - ActivityDiagram
 - Develop Aircraft Functional D
 - lossofaircraft.caf
 - Design Data
 - Wheel Braking System
 - Safety Analysis

Wheel Brake System SSA
complete Braking System hierarchy

Views
Actions
Queries
Reports
Edit

SSA
Aircraft FHA (Partial)
WBS FHA
WBS Safety Requirements
BSCU Safety Requirements


Ref.	Artifact	Deliverable	Input Fig/Tab
	Aircraft FHA	Aircraft Functional Decomposition	Figure 4.1-1 (L1)
		Aircraft FHA (Partial)	Table 4.1-1 (L1)
	Preliminary Aircraft FTA	Preliminary Aircraft FMEA	Page 181
		Preliminary Aircraft FTA	Figure 4.6-1 (L1)
System FHA (WBS)	WBS Functional Decomposition	Section 4.1 (L2)	
	WBS FHA	Table 4.1-1 (L2)	
	WBS Safety Requirements	Section 4.6 (L2)	
	WBS Design Schematic	Figure 3.0-1 (L3)	
	WBS Structural Design Models	Figure 3.0-1 (L3)	
	WBS Dynamic Design Models		
PSSA (WBS)	WBS Fault-Injection Testing		
	WBS Safety Requirements & Design Decisions	Section 4.1.1 (L3) Table 4.1.1-1 (L3)	
	Revised WBS Safety Requirements & Design Decisions	Section 4.1.2 (L3) Table 4.1.2-1 (L3)	
	WBS FTA	Figure 4.2.1-1 (L3)	
		Figure 4.2.1-2 (L3)	
		Figure 4.2.1-3 (L3)	
PSSA (BSCU)	BSCU Design Schematic	Figure 3.0-1 (L4)	
	BSCU Structural Design Models		
	BSCU Dynamic Design Models		
	BSCU Safety Requirements & Design Decisions	Table 4.1.1-1 (L4)	
	BSCU FTA	Figure 4.2.1-1 (L4)	
		Figure 4.2.1-2 (L4)	
	BSCU Physical Implementation	Figure 3.0-1 (L5)	
	BSCU Power Supply Diagram	Figure 3.0-2 (L5)	
	BSCU Supply Monitor	Figure 3.0-3 (L5)	
	BSCU FMEA (Piece Parts)	Table 4.2-2 (L5)	
	BSCU FMEA (Functional)	Table 4.1-1 (L5)	

Aircraft FHA (Partial - addresses only "Deceleration Aircraft on the Ground")

Failure Condition	Phase	Classification	Tool
Loss of Deceleration Capability			
a. Unannounced loss of deceleration capability	Landing /RTO	Catastrophic	Rhapsody
b. Annunciated loss of deceleration capability	Landing	Hazardous	SDM
c. Unannounced loss of deceleration capability	Taxi	Major	CAFTA
d. Annunciated loss of deceleration capability	Taxi	No Safety Effect	DOORS
Inadvertent Deceleration after V1	Takeoff	Catastrophic	Rhapsody
Partial loss of Deceleration Capability			
a. Unannounced partial loss of deceleration capability	Landing /RTO	Hazardous	SDM
b. Annunciated partial loss of deceleration capability	Landing	Major	DOORS
c. Unannounced partial loss of deceleration capability	Taxi	Minor	SystemVision
d. Annunciated partial loss of deceleration capability	Taxi	No Safety Effect	Rhapsody
Loss of automatic stopping capability			
a. Unannounced loss of automatic stopping capability	Landing /RTO	Major	SDA (ATLAB)
b. Annunciated loss of automatic stopping capability	Landing /RTO	No Safety Effect	DOORS
Asymmetric Deceleration			
a. Unannounced asymmetric deceleration	Landing /RTO	Major	
b. Annunciated asymmetric deceleration	Landing	Minor	CAFTA
c. Asymmetric deceleration	Taxi	No Safety Effect	

Tabular Analysis

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Referential

Products

Airplanes

Phases

Demo Airplane

Plane

Braking System

Nose Wheel

Left Wheels

Right Wheels

Hydraulics

Main Pump (Green)

Alternate Pump (Blue)

Selector Valve

Shut Off Selector Valve

Isolation Valve

Accumulator

itsACCUMULATOR

Meter Valve - Normal

Meter Valve - Alternate

Anti Skid Shutoff

Pilot Pedals

CoPilot Pedals

BSCU IBD

WBS BDD

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Aircraft Functions BDD

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complete Braking System hi

ActivityDiagram

Develop Aircraft Functional D

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Design Data

Wheel Braking System

Safety Analysis

Wheel Brake System SSA

complete Braking System hierarchy

Views

Actions

Queries

Reports

Edit

SSA

Aircraft FHA (Partial)

WBS FHA

WBS Safety Requirements

BSCU Safety Requirements

Ref.	Artifact	Deliverable	Input Fig/Tab
	Aircraft FHA	Aircraft Functional Decomposition	Figure 4.1-1 (L1)
		Aircraft FHA (Partial)	Table 4.1-1 (L1)
	Preliminary Aircraft FTA	Preliminary Aircraft FMEA	Page 181
	Preliminary Aircraft FTA	Preliminary Aircraft FTA	Figure 4.6-1 (L1)
		Preliminary Safety Requirements	Page 181
	System FHA (WBS)	WBS Functional Decomposition	Section 4.1 (L2)
	System FHA (WBS)	WBS FHA	Table 4.1-1 (L2)
		WBS Safety Requirements	Section 4.6 (L2)
		WBS Design Schematic	Figure 3.0-1 (L3)
		WBS Structural Design Models	Figure 3.0-1 (L3)
		WBS Dynamic Design Models	
		WBS Fault-Injection Testing	
	PSSA (WBS)	WBS Safety Requirements & Design Decisions	Section 4.1.1 (L3)
		Table 4.1.1-1 (L3)	
		Revised WBS Safety Requirements & Design Decisions	Section 4.1.2 (L3)
			Table 4.1.2-1 (L3)
	WBS FTA		Figure 4.2.1-1 (L3)
			Figure 4.2.1-2 (L3)
			Figure 4.2.1-3 (L3)
	PSSA (BSCU)	BSCU Design Schematic	Figure 3.0-1 (L4)
		BSCU Structural Design Models	
		BSCU Dynamic Design Models	
	PSSA (BSCU)	BSCU Safety Requirements & Design Decisions	Table 4.1.1-1 (L4)
			Figure 4.2.1-1 (L4)
		BSCU FTA	Figure 4.2.1-2 (L4)
		BSCU Physical Implementation	Figure 3.0-1 (L5)
		BSCU Power Supply Diagram	Figure 3.0-2 (L5)
		BSCU Supply Monitor	Figure 3.0-3 (L5)
		BSCU FMEA (Piece Parts)	Table 4.2-2 (L5)
		BSCU FMEA (Functional)	Table 4.1-1 (L5)

4.1.6 Aircraft FHA Outputs

(Editor Note: The aircraft level FHA and associated fault tree give a preliminary set of failure conditions and associated requirements to consider at the system level. These failure conditions and requirements will be validated and updated during the system level FHA.)

Based on the FHA safety objectives, architectural decisions were made during the conceptual design phase. These architectural decisions are the basis for the preliminary aircraft fault tree shown in Figure 4.6-1.

The requirement of 1E-9 per flight hour for "Unannounced loss of deceleration capability" results from the failure condition classification of catastrophic. This requirement is equivalent to a requirement of 5E-9 per flight, since the average flight length is 5 hours.

The requirements of 5E-7 per flight for "Unannounced loss of all speed brakes on contaminated runway" and for "Unannounced loss of all wheel brakes" result from the classification of these failure conditions as Hazardous (this classification is equivalent to 1E-7 per flight hour). These classifications are based on knowledge and experience with these system failures conditions. These requirements result in a requirement probability of 1E-6 per flight (i.e., 2x5E-7 per flight hr.) at the next higher level of "Unannounced loss of effective wheel braking".

As shown in Figure 4.6-1, the allocation of the above requirements allows the budget for "Unannounced loss of thrust reversers" to be set at 5E-3 per flight. This is 5E-9 divided by 1E-6.

Figure 4.6-1 also shows a fault tree leg associated with inadvertent deceleration after V1. Three aircraft systems can exhibit failure conditions that cause an inadvertent deceleration after V1. Each of the failure conditions is classified as Catastrophic and must meet 1E-9 per flight hour or 5E-9 per flight.

However, since they are only catastrophic during a specific phase of flight operation, their "per hour" requirements need to be factored. The factor is the average flight length of 5 hours divided by the at risk time (15 seconds would be a conservative estimate of the time from V1 to rotation).

Hence, the hourly failure rate requirement for each is $1E-9/\text{ft hr} \times 5 \text{ ft hrs/ft} \times 1 \text{ ft}/0.25 \text{ min} \times 60 \text{ min}/1 \text{ hr} = 1.2E-6/\text{hr}$

The probability requirements after converting them to failure rate requirements would read as follows:

- 1) Inadvertent Thrust Reverse after V1 1.2E-6 per hour
- 2) Inadvertent spoiler deployment after V1 1.2E-6 per hour

Tabular Analysis

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Meta Data Logout **Mentor Graphics**

Referential

- Products
 - Airplanes
 - Phases
 - Demo Airplane
 - Plane
 - Braking System
 - Nose Wheel
 - Left Wheels
 - Right Wheels
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 - Alternate Pump (Blue)
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 - ActivityDiagram
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- Design Data
 - Wheel Braking System
 - Safety Analysis

Wheel Brake System SSA | complete Braking System hierarchy

Views Actions Queries Reports Edit

SSA Aircraft FHA (Partial) WBS FHA WBS Safety Requirements BSCU Safety Requirements

Ref.	Artifact	Deliverable	Input Fig/Tab
Aircraft FHA	Aircraft Functional Decomposition	Figure 4.1-1 (L1)	
	Aircraft FHA (Partial)	Table 4.1-1 (L1)	
	Preliminary Aircraft FMEA	Page 181	
Preliminary Aircraft FTA	Preliminary Aircraft FTA	Figure 4.6-1 (L1)	
	Preliminary Safety Requirements	Page 181	
System FHA (WBS)	WBS Functional Decomposition	Section 4.1 (L2)	
	WBS FHA	Table 4.1-1 (L2)	
	WBS Safety Requirements	Section 4.6 (L2)	
PSSA (WBS)	WBS Design Schematic	Figure 3.0-1 (L3)	
	WBS Structural Design Models	Figure 3.0-1 (L3)	
	WBS Dynamic Design Models		
	WBS Fault-Injection Testing		
	WBS Safety Requirements & Design Decisions	Section 4.1.1 (L3) Table 4.1.1-1 (L3)	
	Revised WBS Safety Requirements & Design Decisions	Section 4.1.2 (L3) Table 4.1.2-1 (L3)	
	WBS FTA	Figure 4.2.1-1 (L3) Figure 4.2.1-2 (L3) Figure 4.2.1-3 (L3)	
	BSCU Design Schematic	Figure 3.0-1 (L4)	
	BSCU Structural Design Models		
	BSCU Dynamic Design Models		
PSSA (BSCU)	BSCU Safety Requirements & Design Decisions	Table 4.1.1-1 (L4)	
	BSCU FTA	Figure 4.2.1-1 (L4) Figure 4.2.1-2 (L4)	
	BSCU Physical Implementation	Figure 3.0-1 (L5)	
	BSCU Power Supply Diagram	Figure 3.0-2 (L5)	
	BSCU Supply Monitor	Figure 3.0-3 (L5)	
	BSCU FMEA (Piece Parts)	Table 4.2-2 (L5)	
	BSCU FMEA (Functional)	Table 4.1-1 (L5)	

Loss of Aircraft

LOSSOFA/C

Unannounced Loss of Deceleration Capability (UNANLSDEC)

Inadvertent Deceleration After V1 (INADDEC+V1)

Other Failure Conditions (OTHERFAILS)

Unannounced Loss of Thrust Reversers (UNANLSST/R)

Loss of Effective Wheel Braking (UNLSSEFFWB)

Inadvertent Thrust Reverser After V1 (INADT/R+V1)

Inadvertent Spoiler Deployment After V1 (INADSP+V1)

Inadvertent Wheel Braking After V1 (INADWB1)

Unannounced Loss of All Speedbrakes on Contaminated Runway (UNLSSSPDBR)


Unannounced Loss of All Wheel Braking (UNANLSSWB)

(Aircraft FHA) Preliminary Aircraft Fault Tree

Artifact	Deliverable	Input Fig/Tab	Tool
BSCU Structural Design Models	BSCU Structural Design Models		SysML BDD/IBD
BSCU Dynamic Design Models	BSCU Dynamic Design Models		SysML ACT/SEQ/SM
BSCU Safety Requirements & Design Decisions	BSCU Safety Requirements & Design Decisions		Requirements
BSCU FTA	BSCU FTA		Fault Tree
BSCU Physical Implementation	BSCU Physical Implementation		Schematic
BSCU Power Supply Diagram	BSCU Power Supply Diagram		Schematic
BSCU Supply Monitor	BSCU Supply Monitor		Schematic
BSCU FMEA (Piece Parts)	BSCU FMEA (Piece Parts)		FMEA Table
BSCU FMEA (Functional)	BSCU FMEA (Functional)		FMEA Table

Tabular Analysis

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Wheel Brake System SSA x complete Braking System hierarchy x							
Views Actions Queries Reports Edit							
SSA Aircraft FHA (Partial) WBS FHA WBS Safety Requirements BSCU Safety Requirements & Design Decisions Preliminary Safety Requirements BSCU FMEA (Functional) Revised WBS S							
Ref.	Artifact	Deliverable	Input Fig/Tab	Complete	Output	Deliv. Type	Tool
	Aircraft FHA	Aircraft Functional Decomposition	Figure 4.1-1 (L1)		Aircraft Functional Decomposition	SysML BDD	Rhapsody
		Aircraft FHA (Partial)	Table 4.1-1 (L1)	55%	Aircraft FHA (Partial)	FHA Table	SDM
	Preliminary Aircraft FTA	Preliminary Aircraft FMEA	Page 181		Preliminary Aircraft FMEA	FMEA Table	SDM
		Preliminary Aircraft FTA	Figure 4.6-1 (L1)		Preliminary Aircraft FTA	Fault Tree	CAFTA
	System FHA (WBS)	Preliminary Safety Requirements	Page 181		Preliminary Safety Requirements	Requirements	DOORS
		WBS Functional Decomposition	Section 4.1 (L2)		WBS Functional Decomposition	SysML ACT	Rhapsody
		WBS FHA	Table 4.1-1 (L2)		WBS FHA	FHA Table	SDM
		WBS Safety Requirements	Section 4.6 (L2)		WBS Safety Requirements	Requirements	DOORS
	PSSA (WBS)	WBS Design Schematic	Figure 3.0-1 (L3)		WBS Design Schematic	Schematic	SystemVision
		WBS Structural Design Models	Figure 3.0-1 (L3)		WBS Structural Design Models	SysML BDD/IBD	Rhapsody
		WBS Dynamic Design Models			WBS Dynamic Design Models	SysML ACT/SEQ/SM	Rhapsody
		WBS Fault-Injection Testing			WBS Fault-Injection Testing	Fault Injection Model	SDA (MATLAB)
		WBS Safety Requirements & Design Decisions	Section 4.1.1 (L3) Table 4.1.1-1 (L3)		WBS Safety Requirements & Design Decisions	Requirements	DOORS
		Revised WBS Safety Requirements & Design Decisions	Section 4.1.2 (L3) Table 4.1.2-1 (L3)		Revised WBS Safety Requirements & Design Decisions	Requirements	DOORS
		WBS FTA	Figure 4.2.1-1 (L3) Figure 4.2.1-2 (L3) Figure 4.2.1-3 (L3)		WBS FTA	Fault Tree	CAFTA
		BSCU Design Schematic	Figure 3.0-1 (L4)		BSCU Design Schematic	Schematic	SystemVision
		BSCU Structural Design Models			BSCU Structural Design Models	SysML BDD/IBD	Rhapsody
		BSCU Dynamic Design Models			BSCU Dynamic Design Models	SysML ACT/SEQ/SM	Rhapsody
	PSSA (BSCU)	BSCU Safety Requirements & Design Decisions	Table 4.1.1-1 (L4)		BSCU Safety Requirements & Design Decisions	Requirements	DOORS
		BSCU FTA	Figure 4.2.1-1 (L4) Figure 4.2.1-2 (L4)		BSCU FTA	Fault Tree	CAFTA
		BSCU Physical Implementation	Figure 3.0-1 (L5)		BSCU Physical Implementation	Schematic	SystemVision
		BSCU Power Supply Diagram	Figure 3.0-2 (L5)		BSCU Power Supply Diagram	Schematic	SystemVision
		BSCU Supply Monitor	Figure 3.0-3 (L5)		BSCU Supply Monitor	Schematic	SystemVision
		BSCU FMEA (Piece Parts)	Table 4.2-2 (L5)		BSCU FMEA (Piece Parts)	FMEA Table	SDM
		BSCU FMEA (Functional)	Table 4.1-1 (L5)		BSCU FMEA (Functional)	FMEA Table	SDM

Integral PDF Viewer Adds Interactivity

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The screenshot displays the Integral PDF Viewer interface. The top bar shows the document name 'document.pdf' and the page number '184 of 331'. The sidebar on the right, titled 'System Design Manager', lists a hierarchy of documents including 'Section 4.1 (L2)', 'PDF Document', and various figures and tables. The main content area displays the text of the document, which is a technical specification for SAE ARP4761. The text is organized into sections: 'NOTE: System FHA', '4.0 RESULTS OF THE WHEEL BRAKE SYSTEM FUNCTIONAL', '4.1 Identified Wheel Brake System Functions', '4.2 Identified Failure Conditions', and '4.2.1 Functional Failure Conditions'. The text describes the wheel brake system functions and failure conditions, including a note about the purpose of the example and a table of failure conditions.

SAE ARP4761

NOTE: System FHA

4.0 RESULTS OF THE WHEEL BRAKE SYSTEM FUNCTIONAL

4.1 Identified Wheel Brake System Functions

The wheel brake system performs the following functions.

- a. Decelerate the wheels on the ground
 - (1) Manual activation
 - (2) Automatic activation
 - (3) Antiskid
- b. Decelerate the wheels on gear retraction
- c. Differential braking for directional control
- d. Prevent aircraft from moving when parked

(Editor's Note: For the purpose of this example, the "Decelerate the wheels on the ground" function is analyzed. The function is identified in column (1) of Table 4.1-1.)

4.2 Identified Failure Conditions

For the function "Decelerate the wheels on the ground", the following set of failure conditions and assumptions for the assessment were determined.

4.2.1 Functional Failure Conditions

- a. Total Loss of Wheel Braking
- b. Partial Symmetrical Loss of Wheel Braking
- c. Asymmetrical Loss of Wheel Braking
- d. Inadvertent Application of Wheel Braking

4.2.2 Environmental and Emergency Configurations and Conditions

- a. Runway Conditions (Wet, icy, etc.)
- b. Runway Length
- c. Tail/Cross Wind
- d. Engine Out
- e. Hydraulic System Loss
- f. Electrical System Loss

4.2.3 Phases - (ground phases)

4.1.6 Aircraft FHA Outputs

(Editor Note: The aircraft level FHA and associated fault tree give a preliminary set of failure conditions and associated requirements to consider at the system level. These failure conditions and requirements will be validated and updated during the system level FHA.)

Based on the FHA safety objectives, architectural decisions were made during the conceptual design phase. These architectural decisions are the basis for the preliminary aircraft fault tree shown in Figure 4.6-1.

The requirement of 1E-9 per flight hour for "Unannounced loss of deceleration capability" results from the failure condition classification of catastrophic. This requirement is equivalent to a requirement of 5E-9 per flight, since the average flight length is 5 hours.

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As shown in Figure 4.6-1, the allocation of the above requirements allows the budget for "Unannounced loss of thrust reversers" to be set at 5E-3 per flight. This is 5E-9 divided by 1E-6.

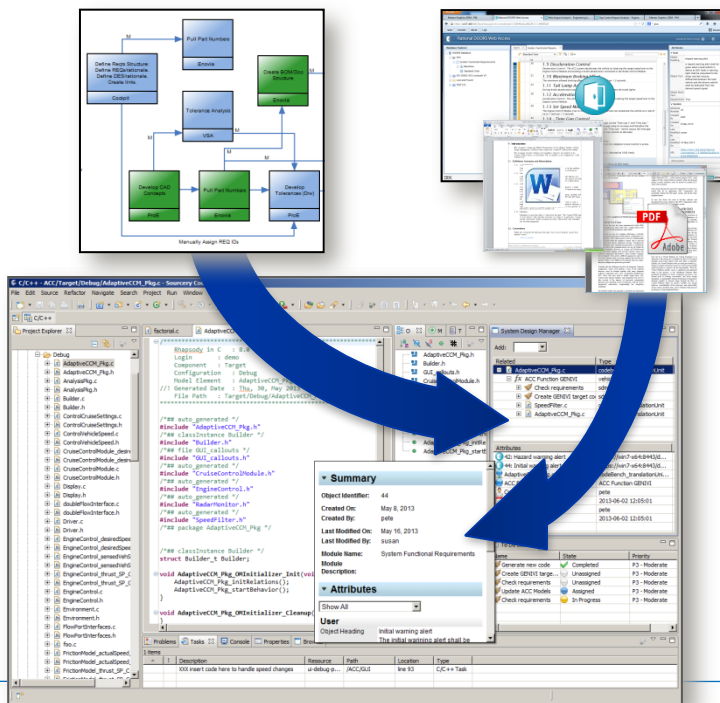
Figure 4.6-1 also shows a fault tree leg associated with inadvertent deceleration after V1. Three aircraft systems can exhibit failure conditions that cause an inadvertent deceleration after V1. Each of the failure conditions is classified as Catastrophic and must meet 1E-9 per flight hour or 5E-9 per flight.

However, since they are only catastrophic during a specific phase of flight

Context Supports the Users' Daily Tasks

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- No walking to the bookshelf (or heaven forbid - the library) to find the spec, going to the next status meeting to raise the red flag, and then coming back to the design to try to remember where she was

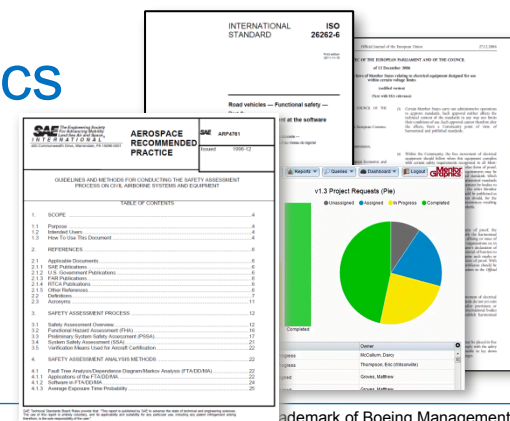
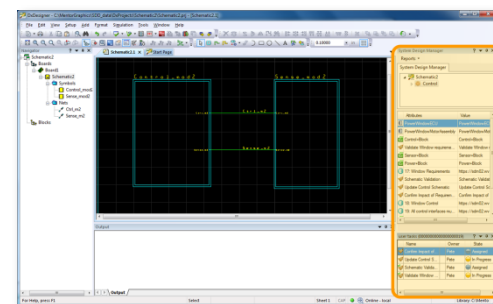
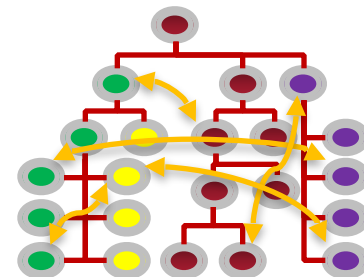


- This really works to make the designer's daily tasks easier, and supports better product management
- It plugs in to what they do today, into the tools they use today, without requiring methodology change

Context SDM – Three Key Capabilities

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- **Manage relationships** between tools throughout design disciplines
 - Coordinate changes, dependencies, and impacts
 - Integrate with current tools and flows
- **Bring information and interaction** to the users where it can be applied directly
 - Sourced from any original repositories
 - Interact with appropriate design tools
 - Maximize usability and efficiency
- **Enable** product management, tracing, **analytics** and **reporting**
 - View or export dynamic data views
 - Standards compliance support



Augmenting Current Tools and Processes

to increase the productivity of an engineering team

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Interoperability

• Summary

- “Integration through Data Exchange”
- “Design representations and requirements synchronized”
- Interactive system design management in users’ familiar tools
- Standards-based connection to any* necessary tools

• Future Directions

- Integral templated process support for ARP, etc.
- Increased automation of repetitive steps
- A path towards effective Model Driven Safety Analysis

• For More Information

- See us at our Vendor Expo this afternoon – Table 4
- bill_chown@mentor.com

“any tools”: some are easier than others!

Thank You!

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