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System Architecture Virtual Integration (SAVI) Project : Intermodel Error Checking and Consistency Review and Demonstration

An Aerospace Vehicle Systems Institute Project (AVSI)

Presented by Greg Pollari (Rockwell Collins) and Nigel Shaw (Eurostep)

Who are we?

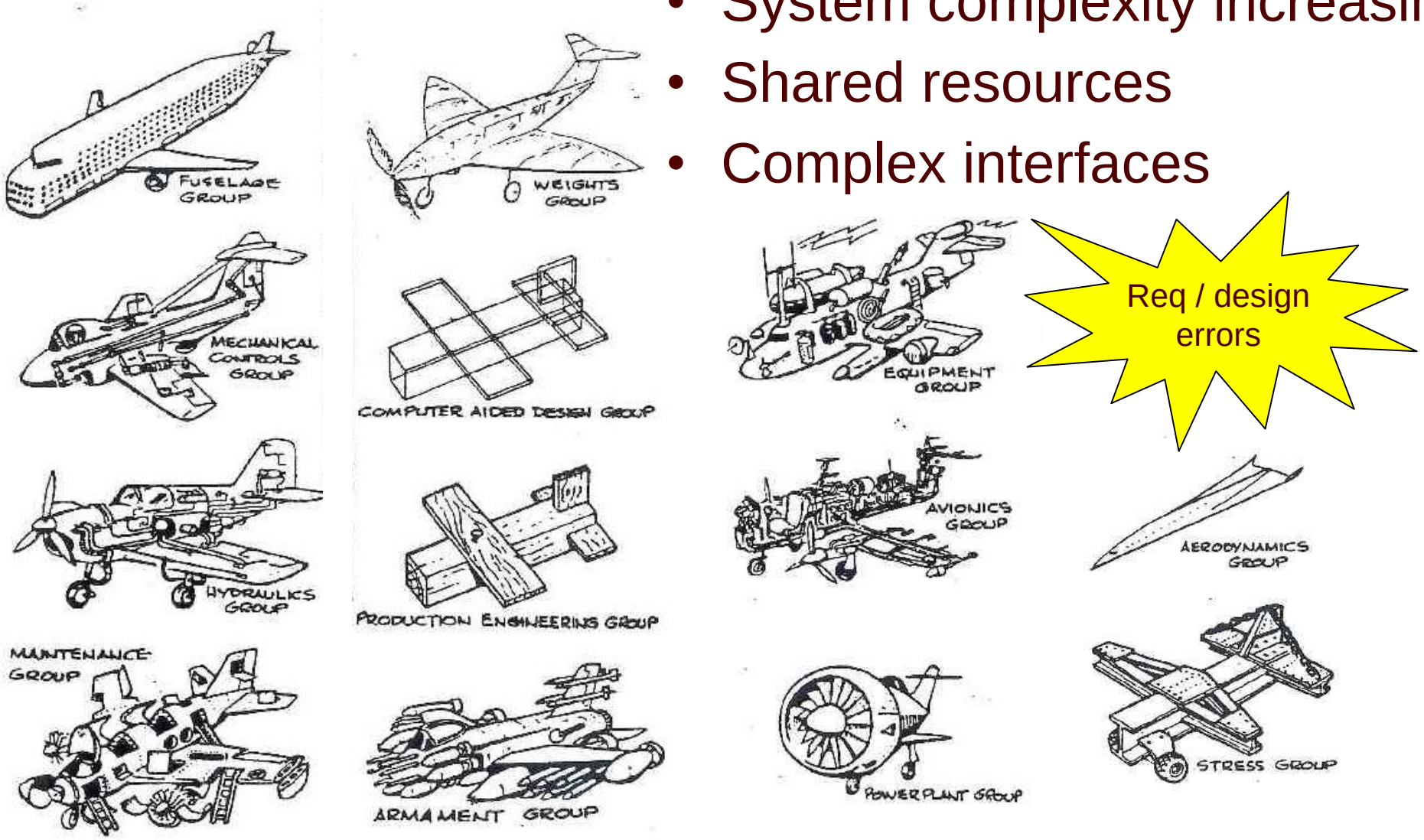
- Greg Pollari (Rockwell Collins)
  - Principal Systems & Process Engineer
  - 30 years in product design and leadership roles
  - SAVI PMC (Project Management Committee) chair
- Nigel Shaw (Eurostep)
  - Managing Director for Eurostep in UK
  - SAVI Technology Vendor Partner and subcontractor
  - 30 years standards involvement

Agenda

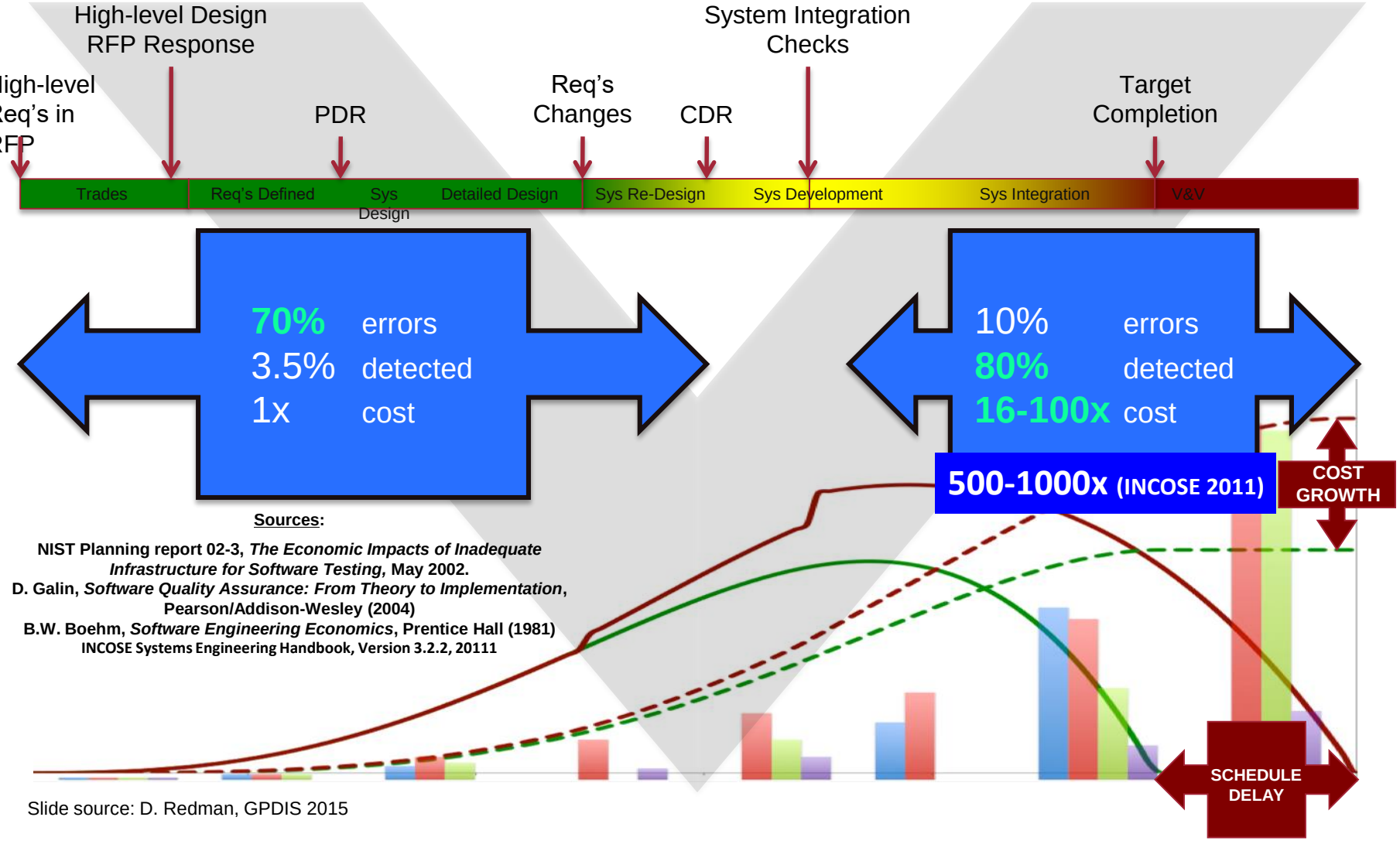
- SAVI – The problem
- SAVI – The consortium
- Two examples
- Conclusions
- Looking forward

Many systems integrated into one aircraft

- System complexity increasing
- Shared resources
- Complex interfaces



The impact of requirement/design errors is documented



Sources:

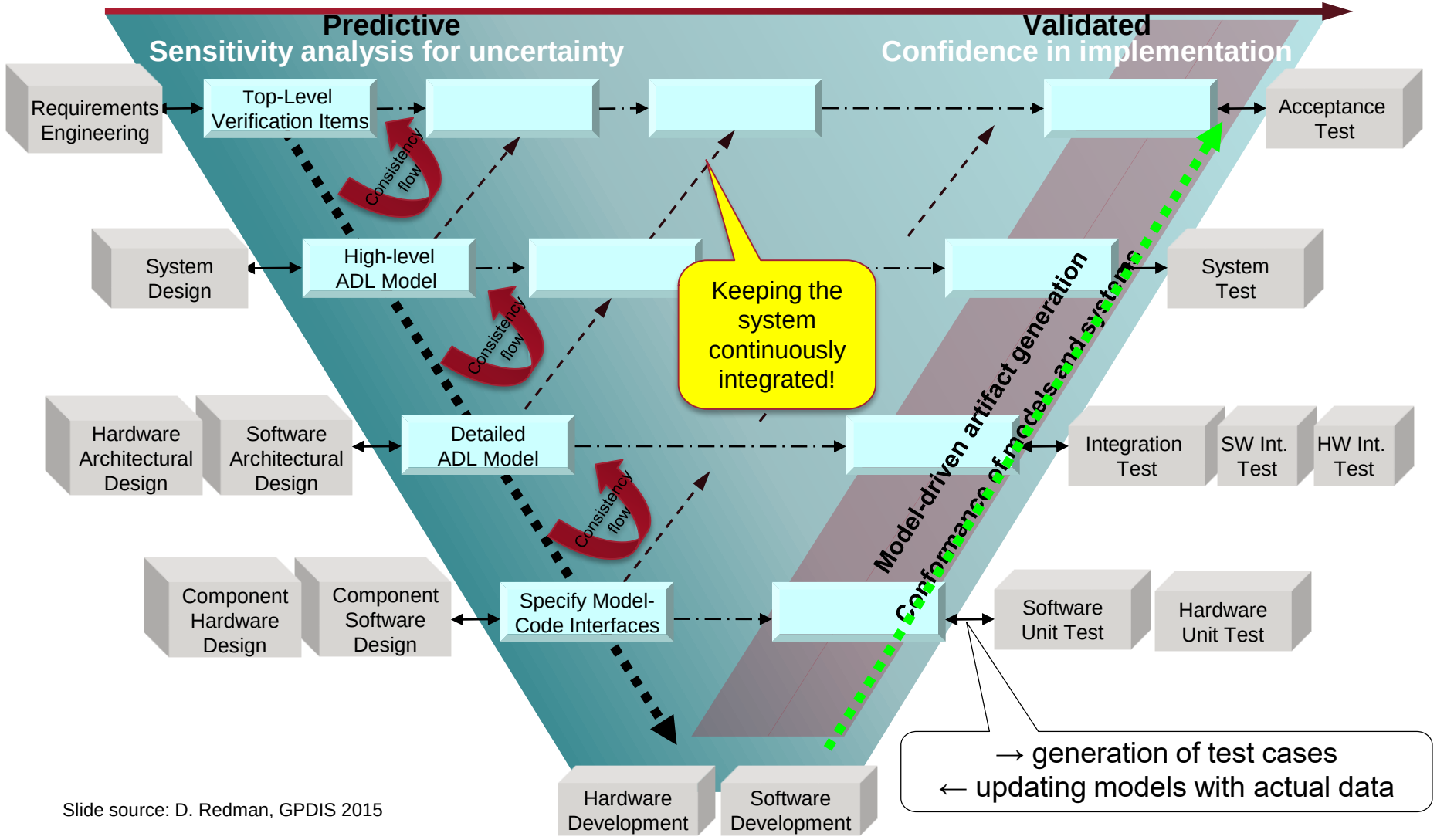
NIST Planning report 02-3, *The Economic Impacts of Inadequate Infrastructure for Software Testing*, May 2002.
D. Galin, *Software Quality Assurance: From Theory to Implementation*, Pearson/Addison-Wesley (2004)
B.W. Boehm, *Software Engineering Economics*, Prentice Hall (1981)
INCOSE Systems Engineering Handbook, Version 3.2.2, 20111

Slide source: D. Redman, GPDIS 2015

SAVI Approach

- "System Architecture Virtual Integration"
- Leverage MBSE best practices and tools
  - SAVI developed with exemplar toolset – seek to define tool characteristics, but not specific tool selection
- Reduce costs/development time through early and continuous model-based virtual integration
  - Inter-domain and inter-model consistency checks
  - Protect Intellectual Property (IP)
  - Support definition/capture of incremental evidence for system safety analysis – supporting certification approach
  - Consistency checking of constituent models participating in integration is critical element of the SAVI concept

SAVI Virtual Integration "V"ision



Slide source: D. Redman, GPDIS 2015

SAVI Participants

Full Members

- Airbus
- Boeing
- DoD
- Embraer
- GE Aviation
- Honeywell
- Rockwell Collins
- Sikorsky

Liaison Members

- FAA
- NASA
- SEI

Tool Vendor Partners

- Adventium Labs
- Ansys (Esterel Technologies)
- Eurostep Limited

Two example challenges

- The specific case: to test consistency for a printed circuit card assembly

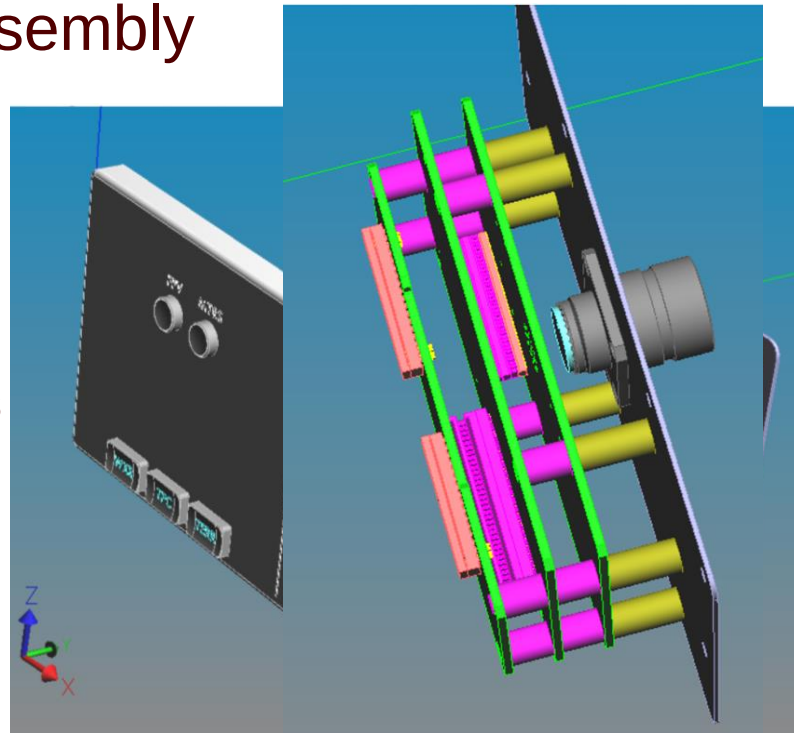
13 separate sources

Geometry:

- MCAD
- ECAD
- Excel – Connectors

Logical

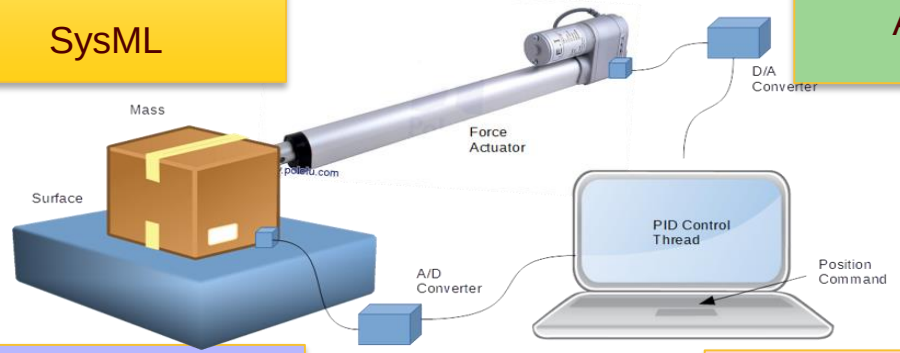
- Excel – Signals



- The generic case: to compare models of the same or related systems in different languages

SysML

AADL



Simulink®

The Sliding Mass Example System

Modelica

Both cases fit within a single Model Repository and Data Exchange/Sharing capability

Foundation process

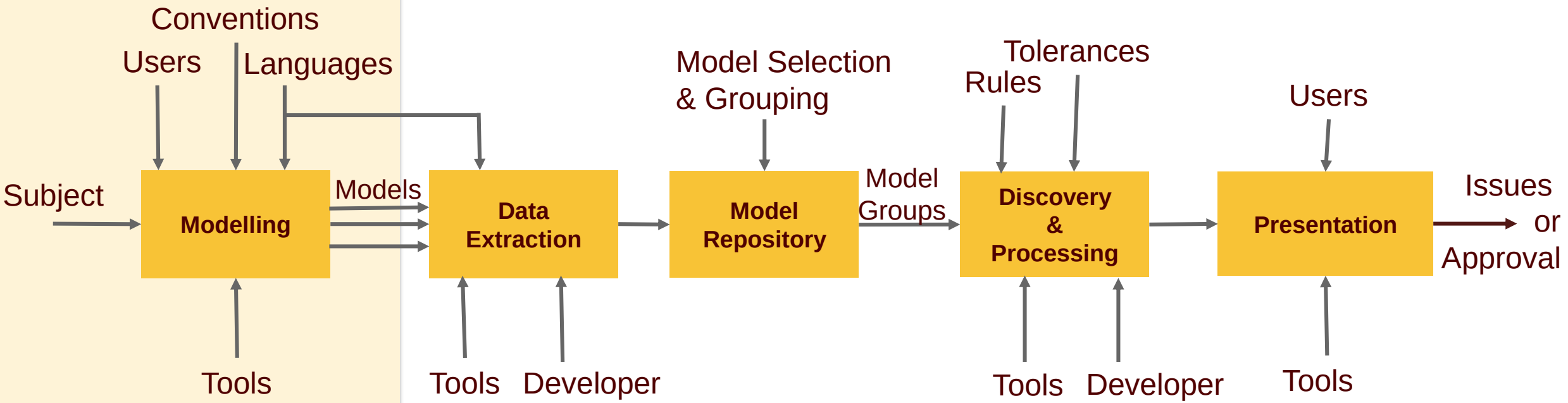
Root cause of the problem: different
- Users & Enterprises
- Languages & Tools
- Conventions
- Values
- ….

Extract content into a common view

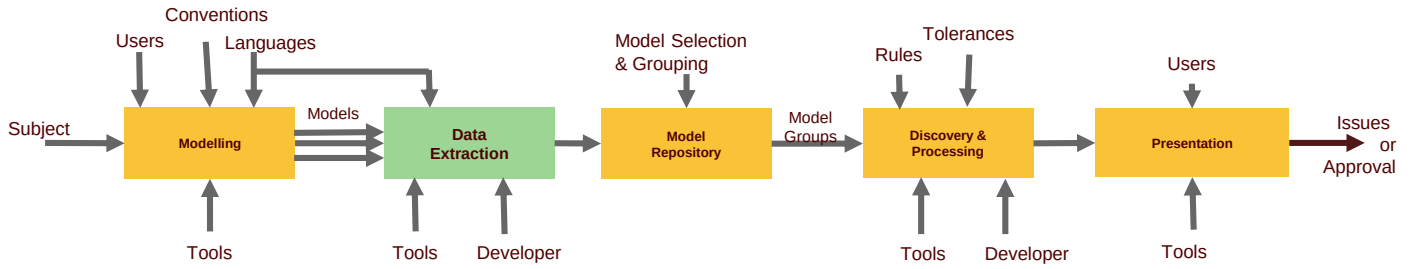
Manage model meta data and extracted content

Process extracted data and apply checks

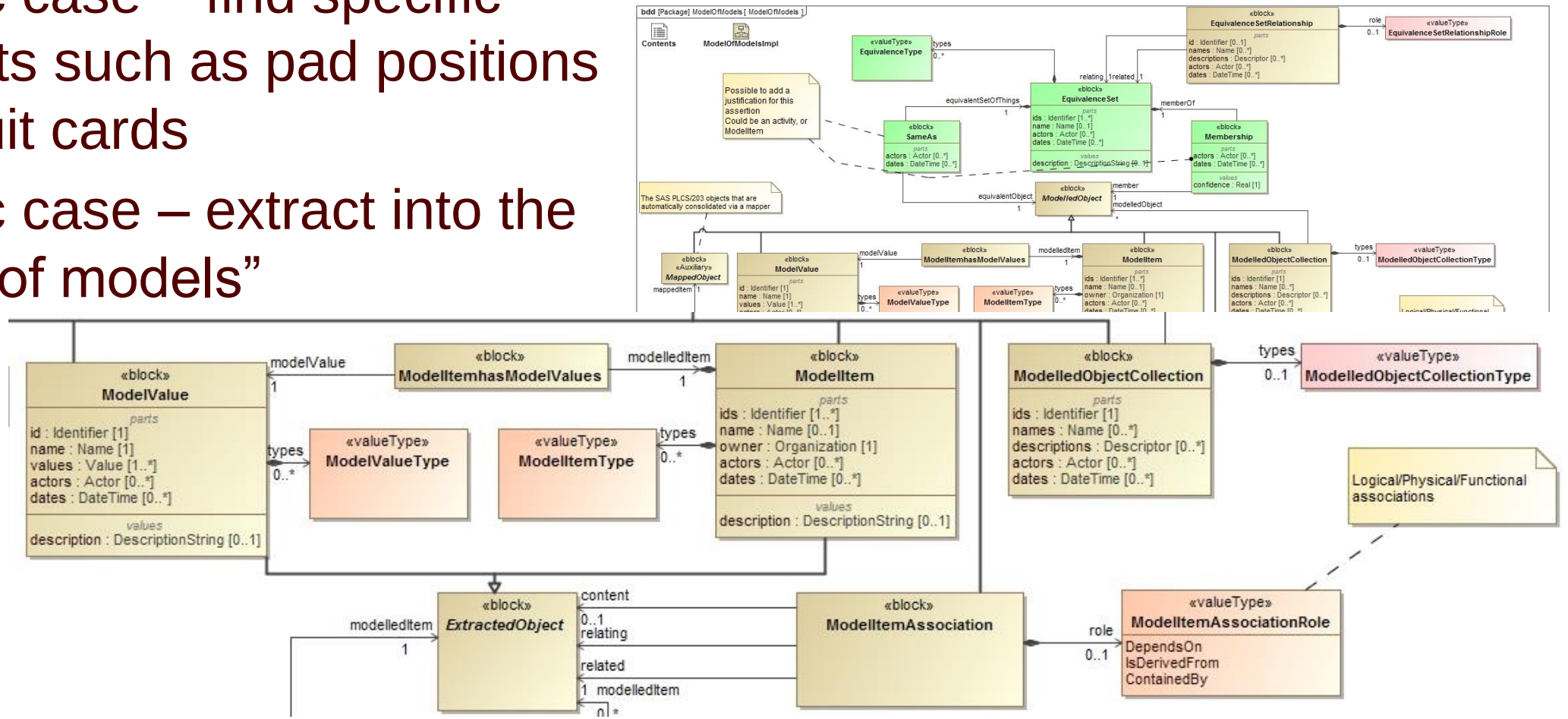
Present extracted data and check results



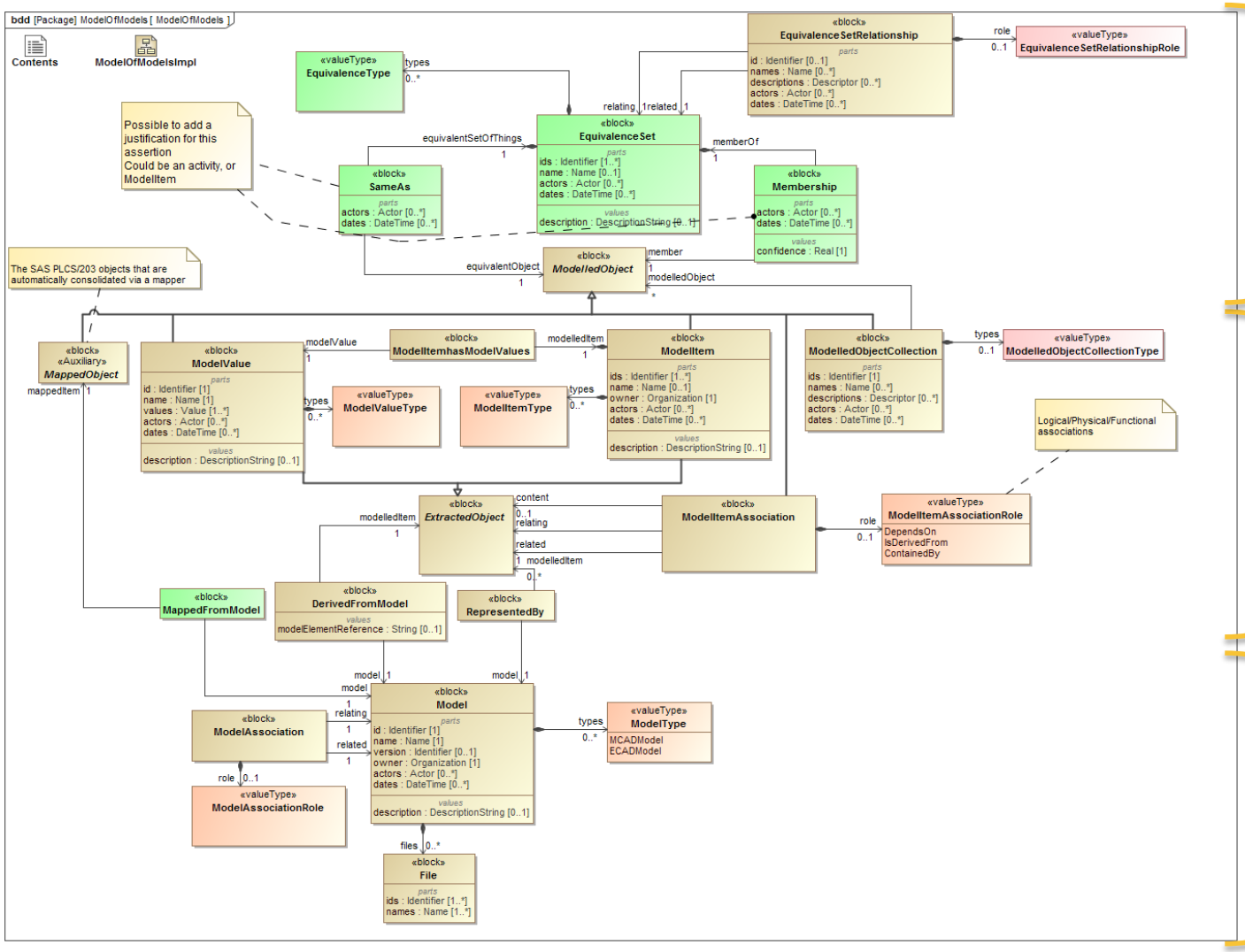
Data Extraction



- Specific case – find specific elements such as pad positions on circuit cards
- Generic case – extract into the "model of models"



Model of Models

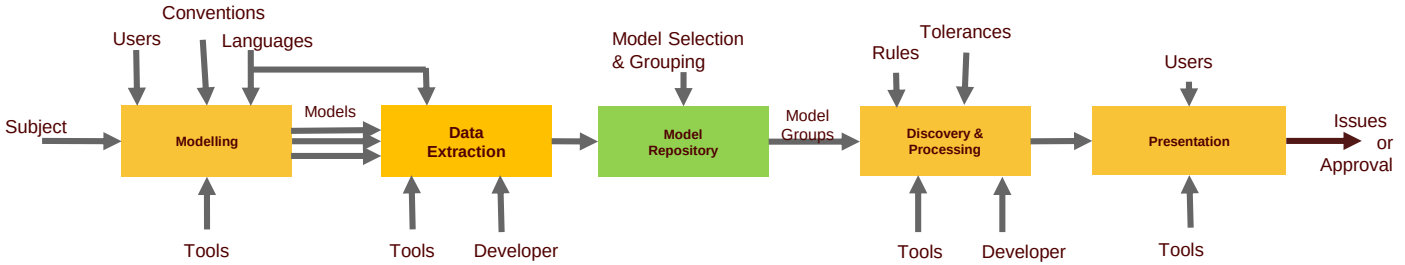


Information about equivalence between things found in the models

Information about things found in the models

Information about each model

Model Repository

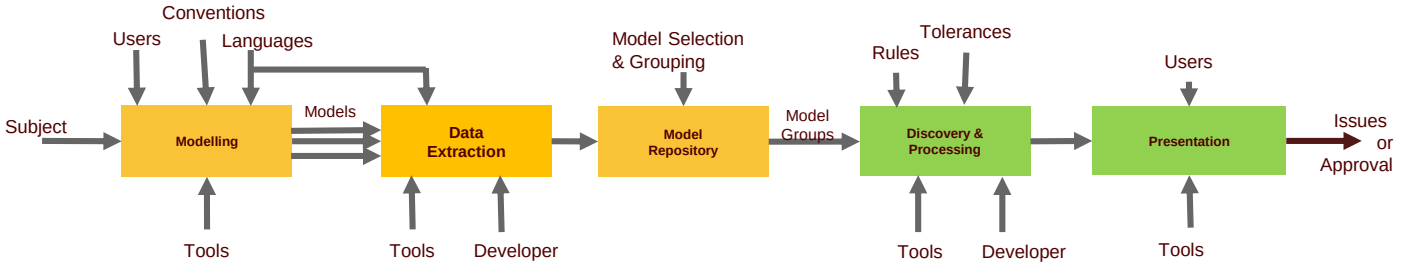


- SAVI have created a specification for a "Model Repository and Data Extraction Layer"

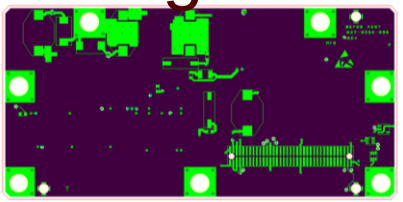
- Key issues are:
  - Enabling access to extracted data while controlling access to the source models
  - Allowing for cross enterprise sharing of models

- As an exemplar Eurostep has used ShareAspace to provide this functionality

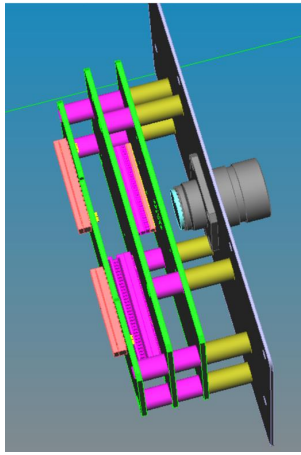
Virtual Integration



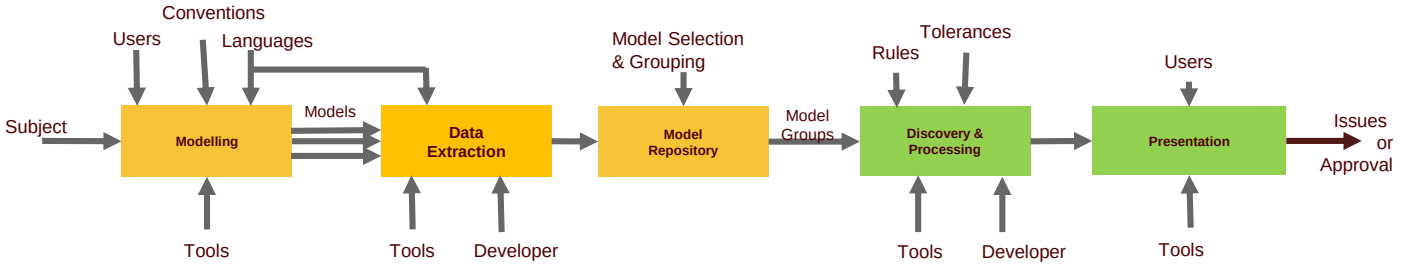
- In the specific case we can bring together data extracted from all 13 source files to create a virtual integration that supports testing geometric and logical consistency
  - Do pads and connector positions match?
  - Are the circuit board shapes consistent across ECAD and MCAD?
  - Are the signals on the boards consistent with the interconnect tables and do they match between boards?

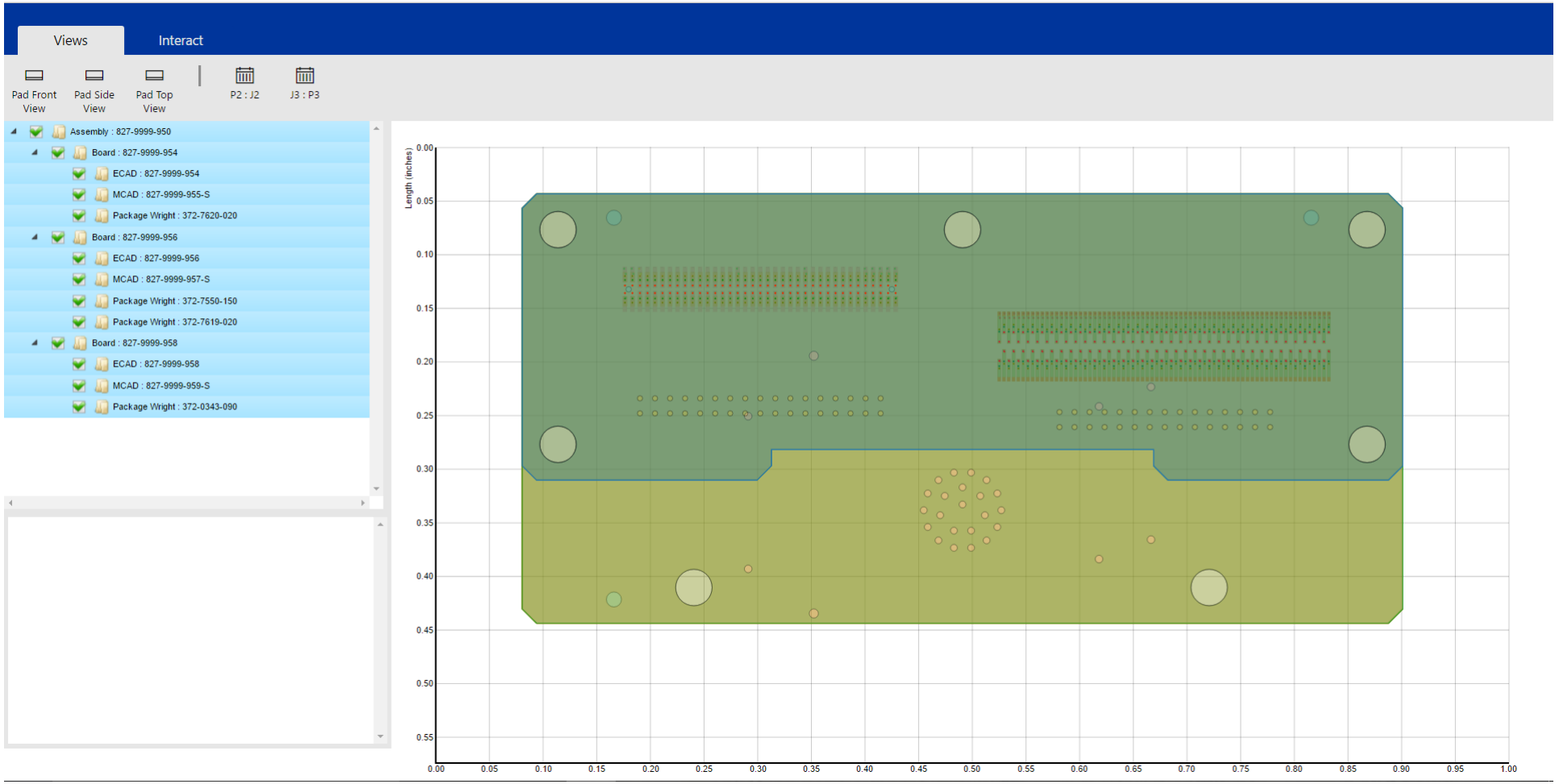


- The major challenge in this process was to be sure how the different geometric spaces relate – across MCAD, ECAD and connector definitions
  - STEP standard exports used to enable the ECAD/MCAD comparison

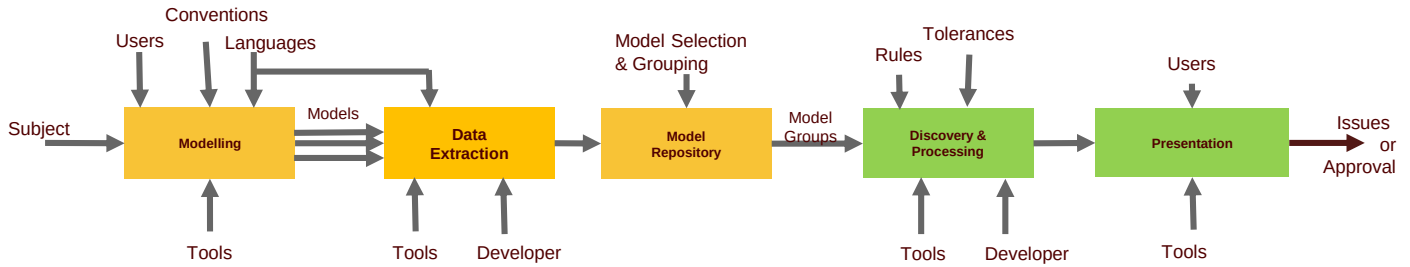


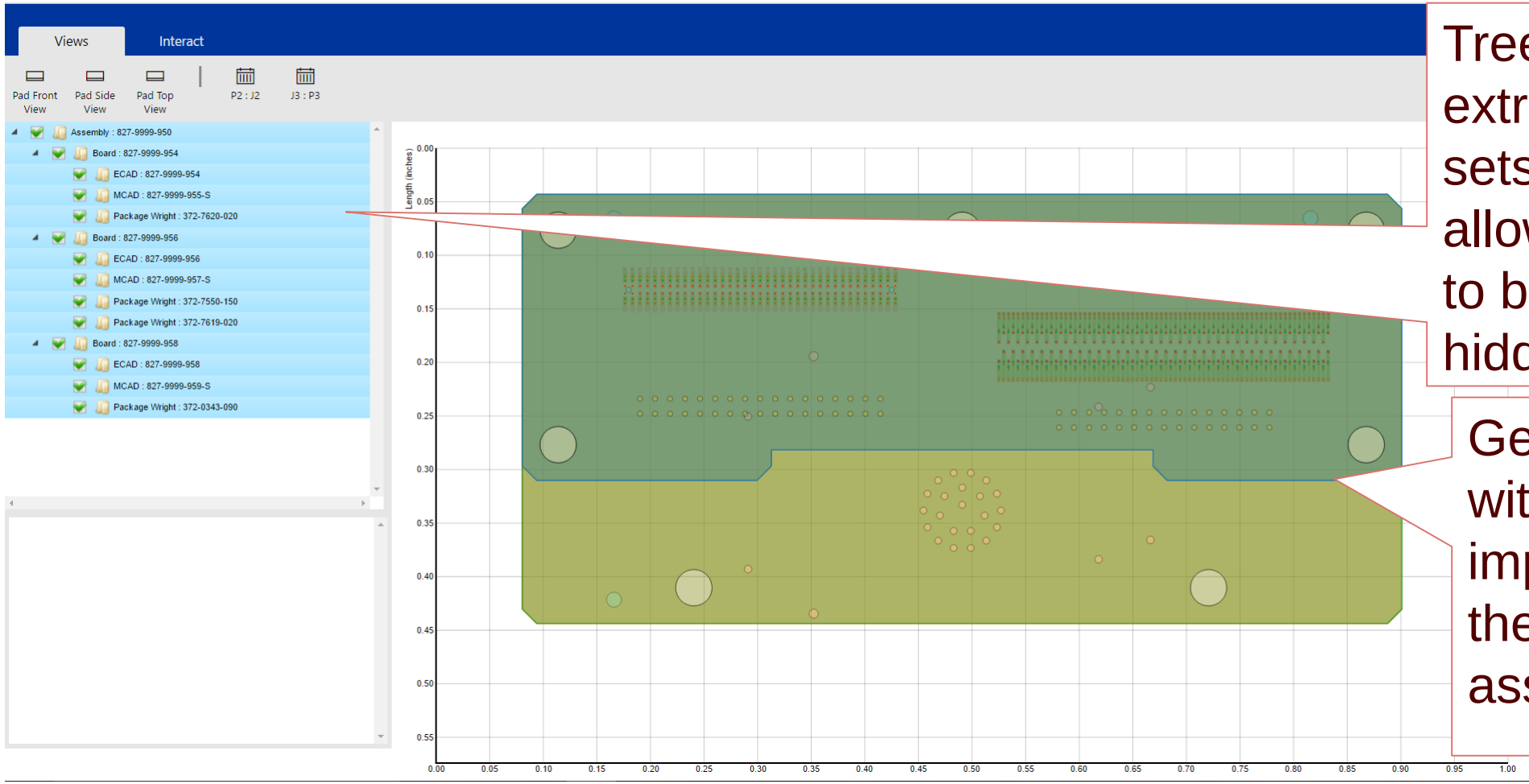
Virtual Integration





Virtual Integration

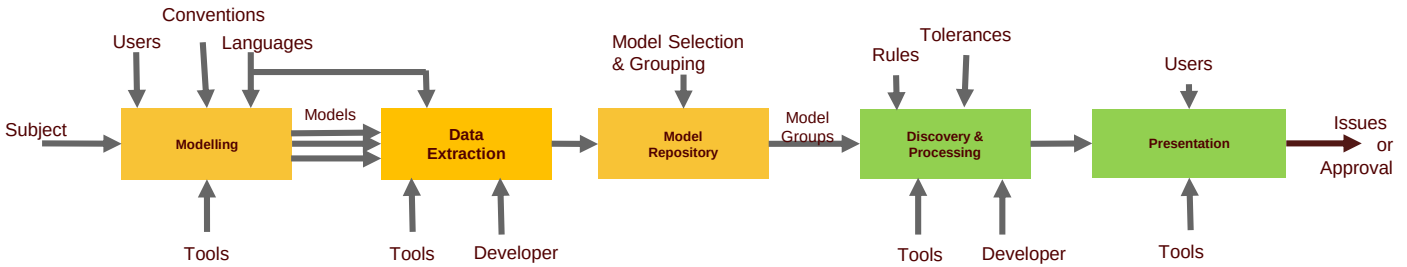


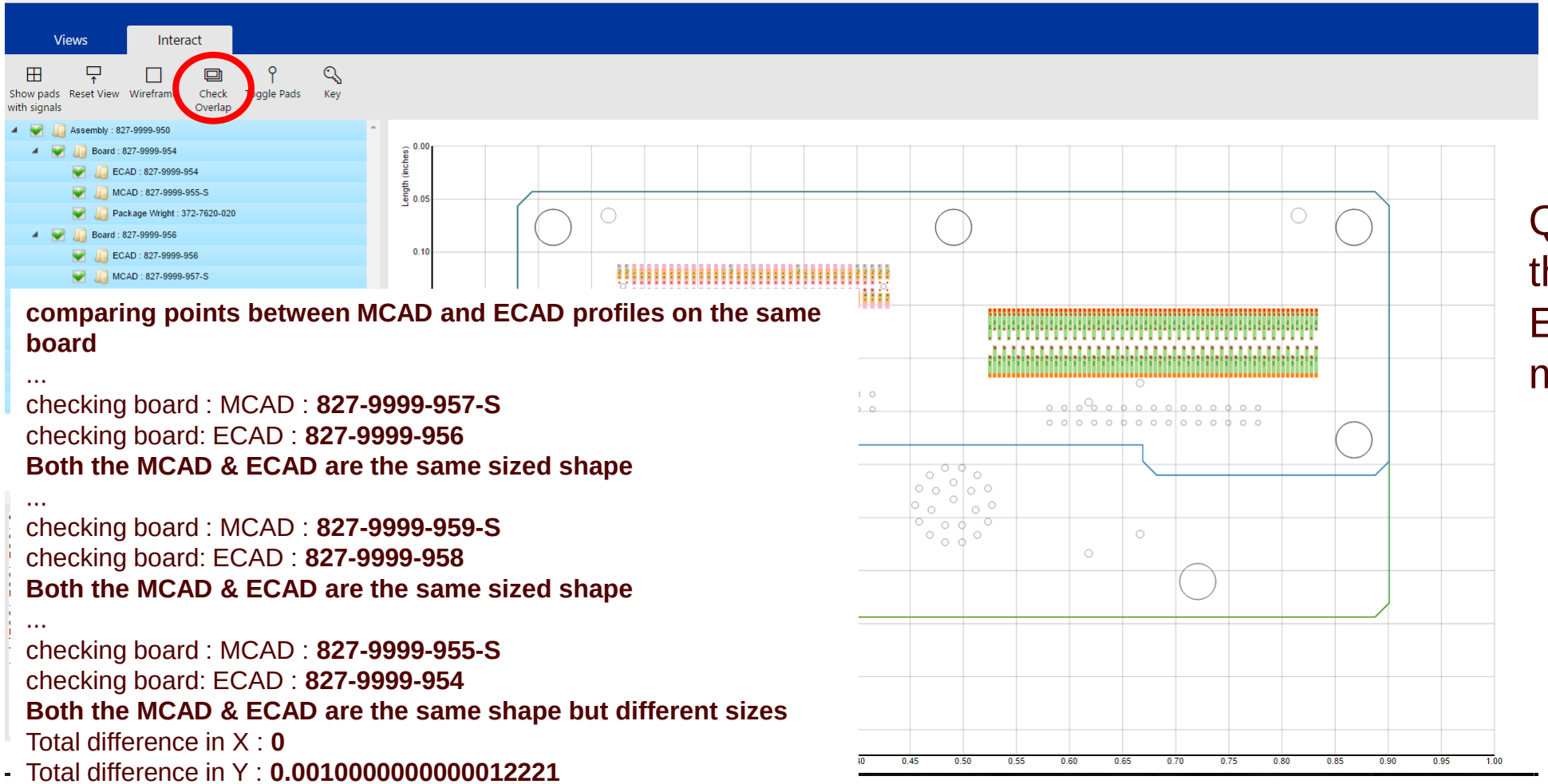


Tree view of extracted data sets allowing sources to be shown or hidden

Geometric view with all data imported into the MCAD assembly space

Consistency tests 1





comparing points between MCAD and ECAD profiles on the same board

...

checking board : MCAD : **827-9999-957-S**

checking board: ECAD : **827-9999-956**

Both the MCAD & ECAD are the same sized shape

...

checking board : MCAD : **827-9999-959-S**

checking board: ECAD : **827-9999-958**

Both the MCAD & ECAD are the same sized shape

...

checking board : MCAD : **827-9999-955-S**

checking board: ECAD : **827-9999-954**

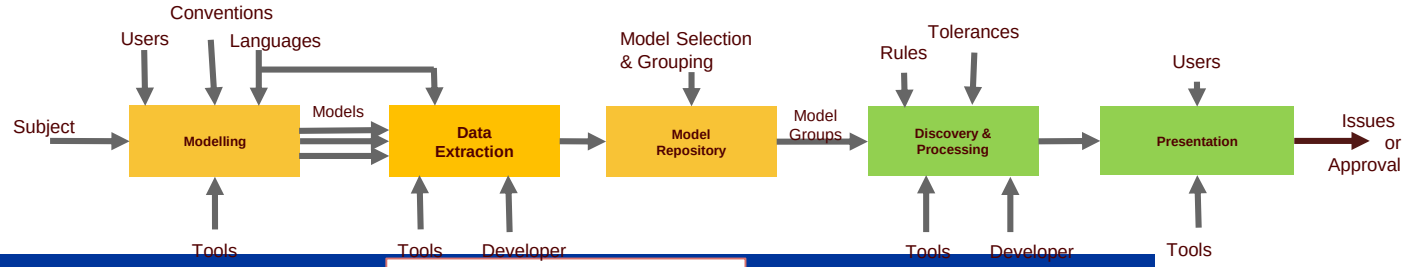
Both the MCAD & ECAD are the same shape but different sizes

Total difference in X : **0**

- Total difference in Y : **0.0010000000000012221**

Q1: How well do the MCAD and ECAD boards match up?`

Consistency tests 2

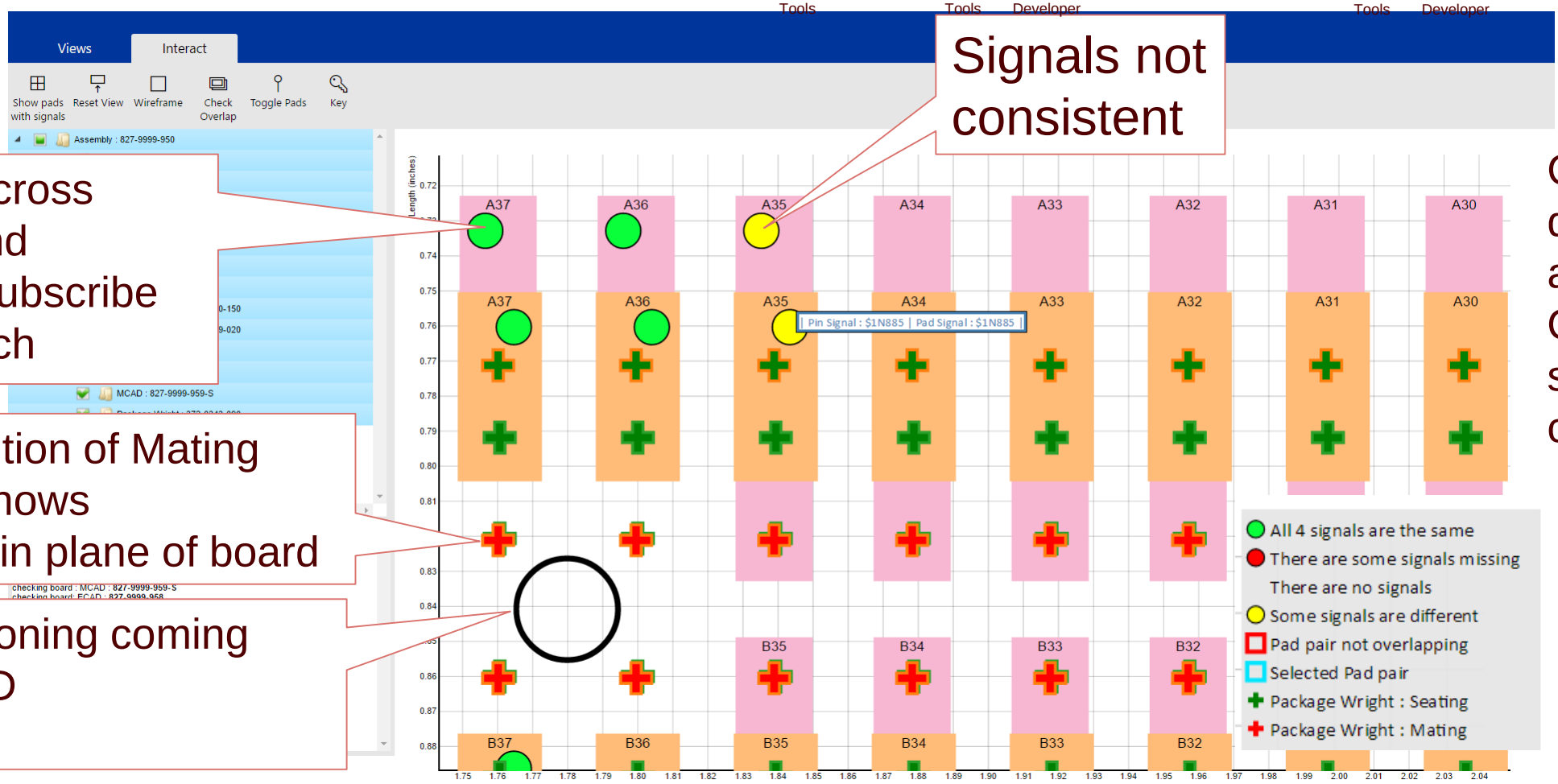


Signals not consistent

Signals across boards and Publish/Subscribe table match

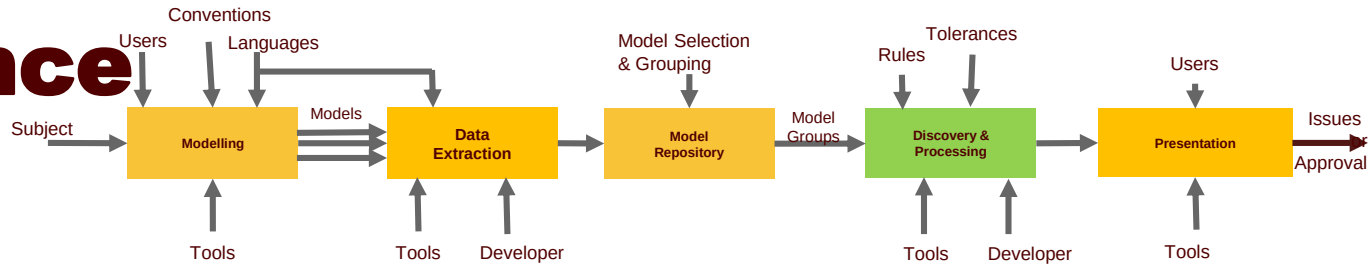
Close position of Mating Markers shows alignment in plane of board

Hole positioning coming from MCAD

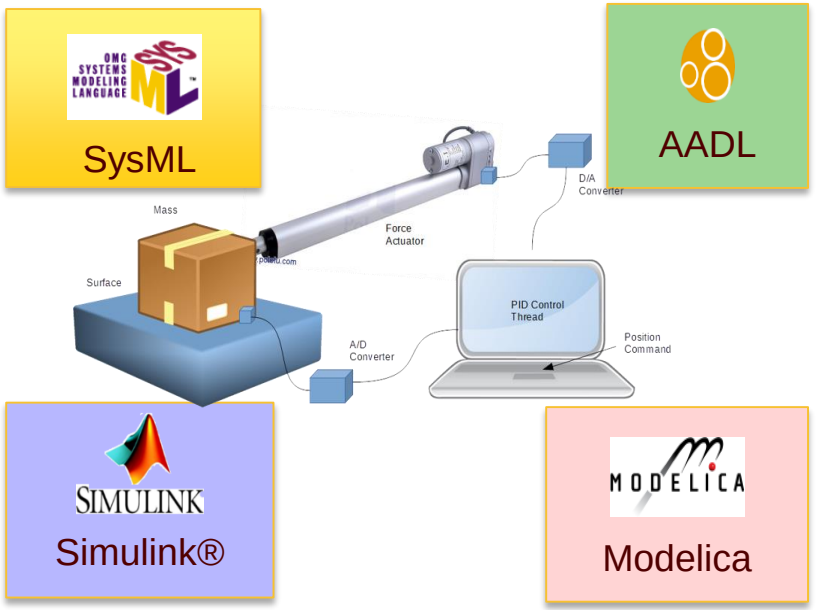


Q2: How well do connectors align?
Q3: Are the signals consistent?

Discovery of equivalence

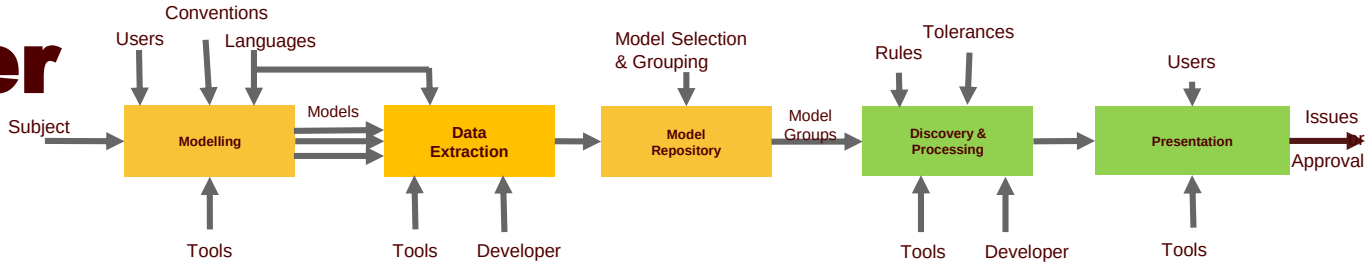


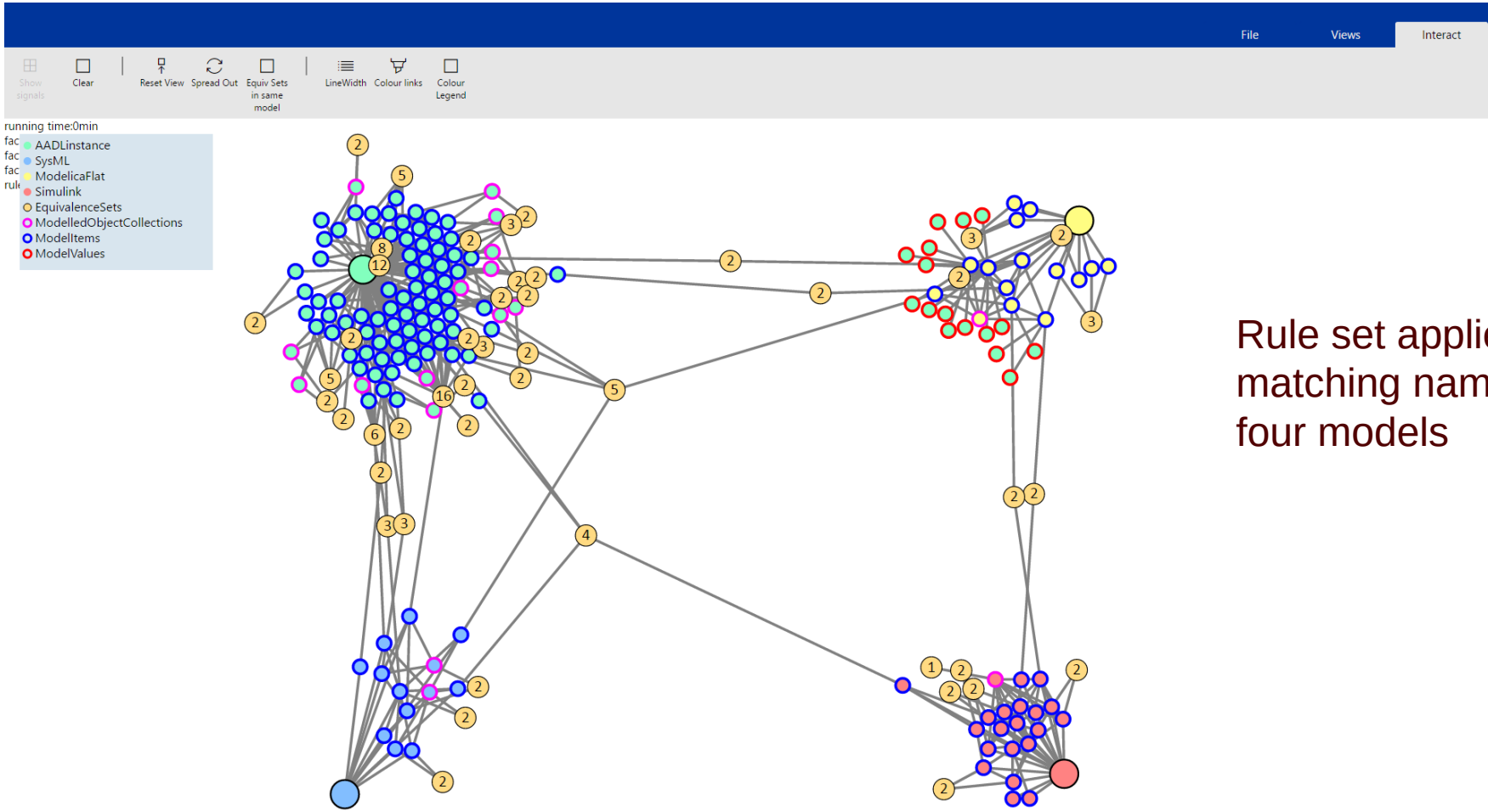
- In the generic case, need to identify where “things” should be consistent, then test if they are consistent
- Have all models in a single form, i.e. the “model of models”
- Enables
  - Application of a rule engine to find equivalences
  - The user to identify equivalences and look for consistency
    - Edit results from the rule engine
    - Identify patterns that should match across models
  - Apply rules to determine consistency



- Use fuzzy comparison due to differences in names and conventions

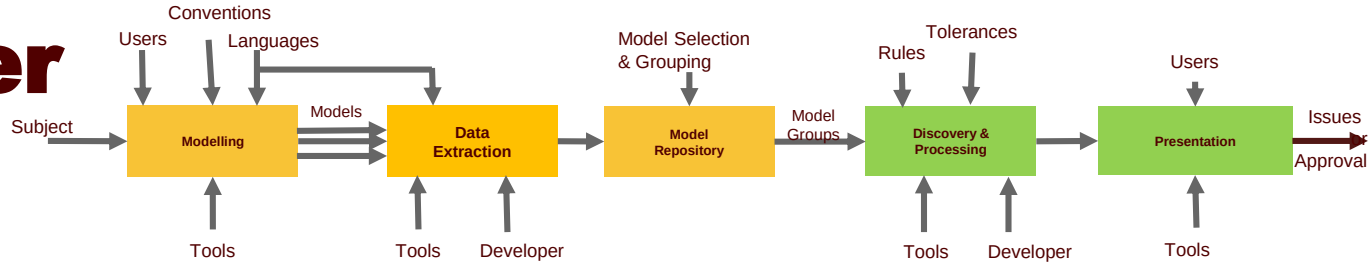
Model of Models viewer

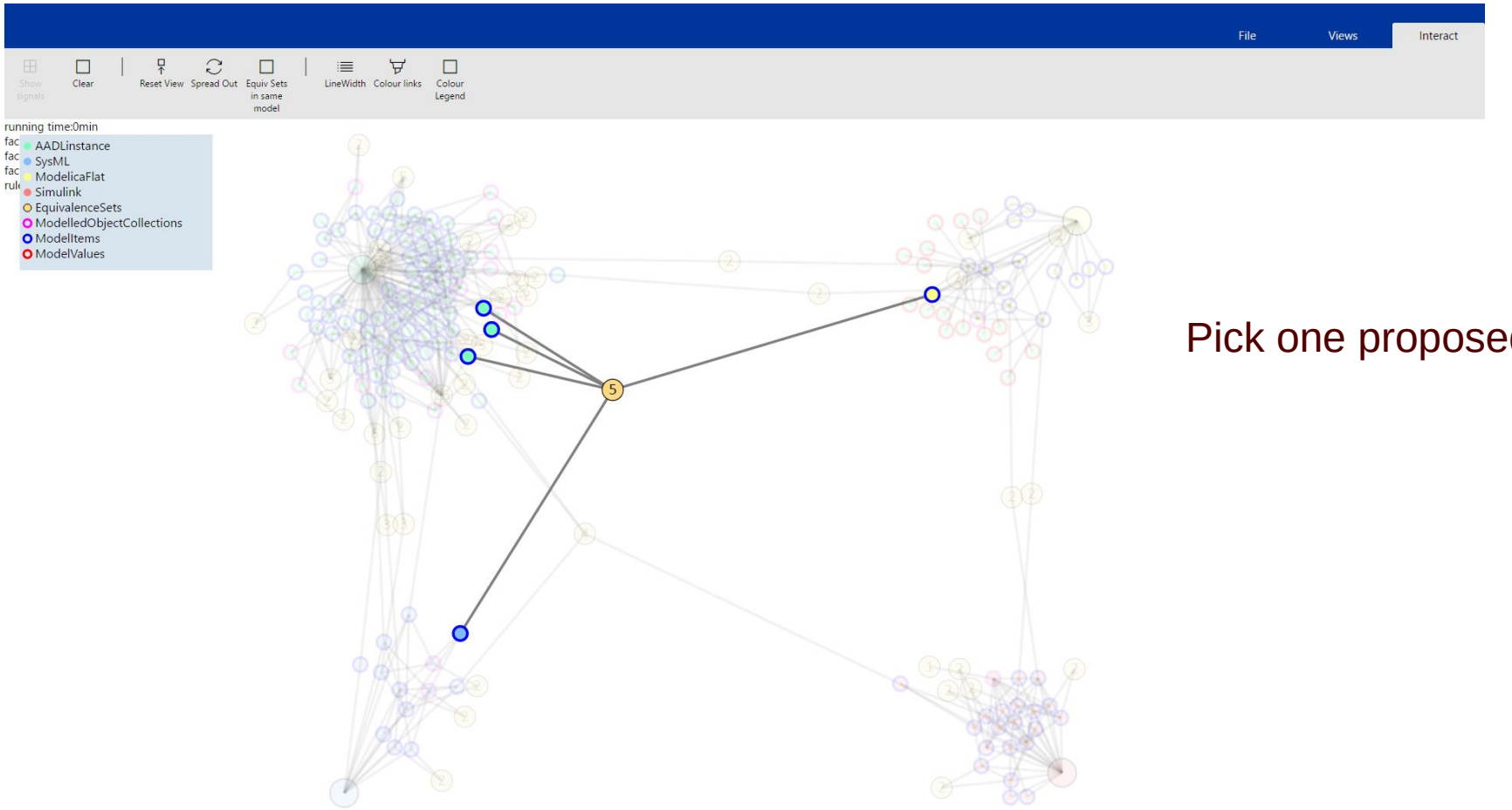




Rule set applied to identify matching names across the four models

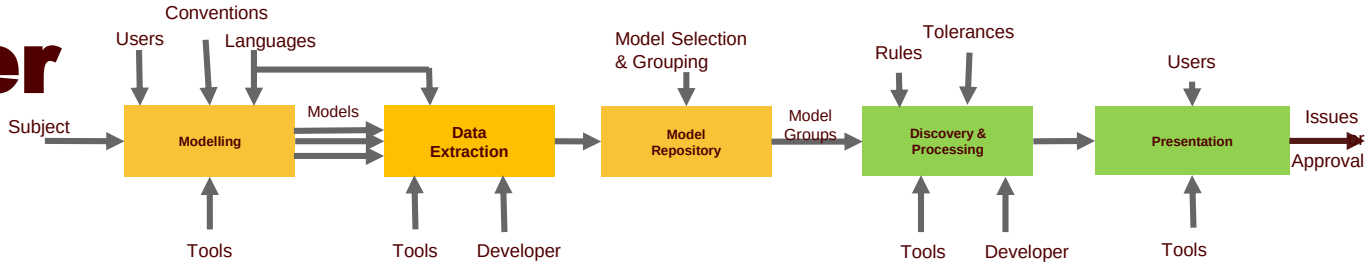
Model of Models viewer

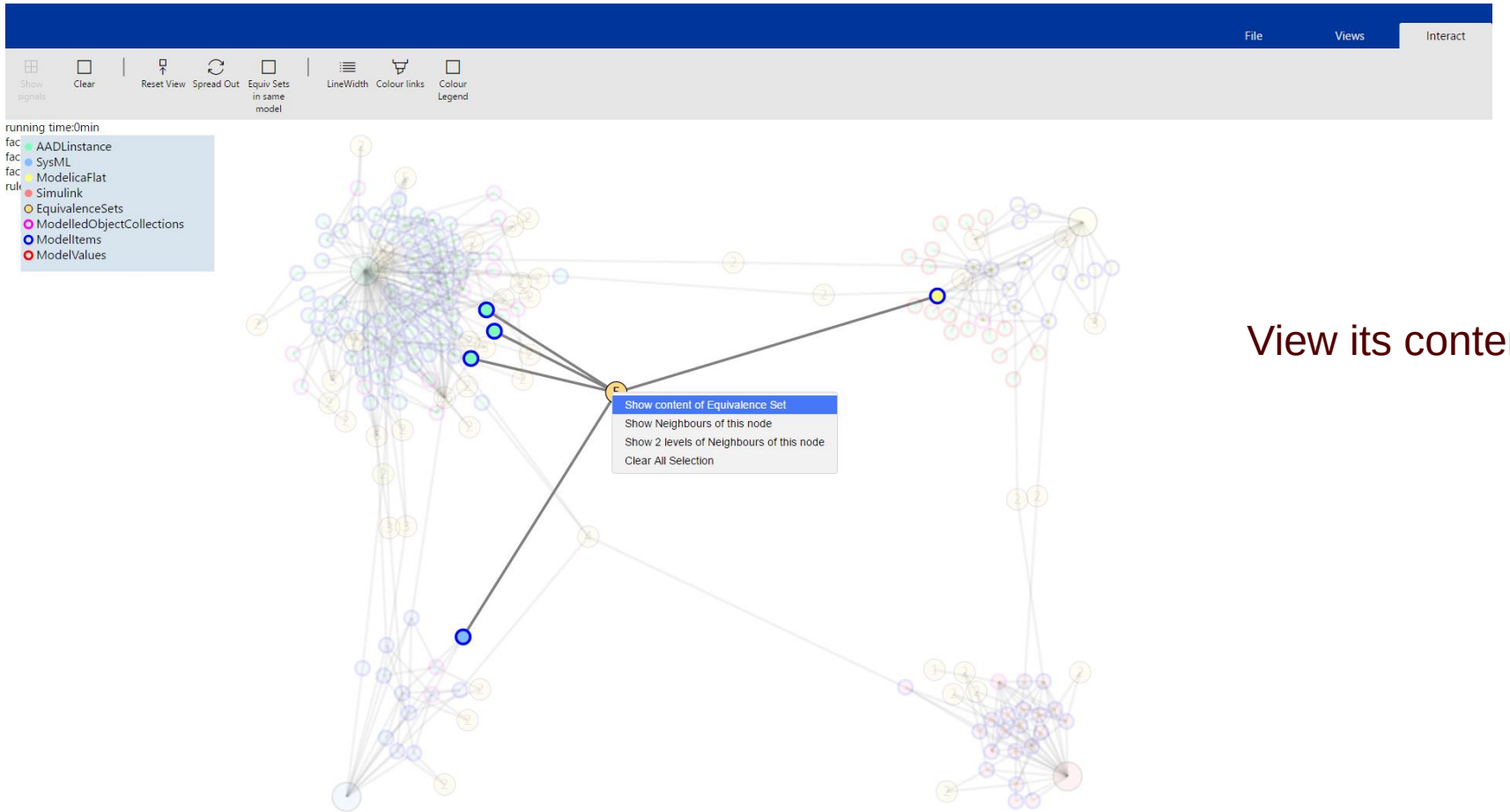




Pick one proposed set to examine

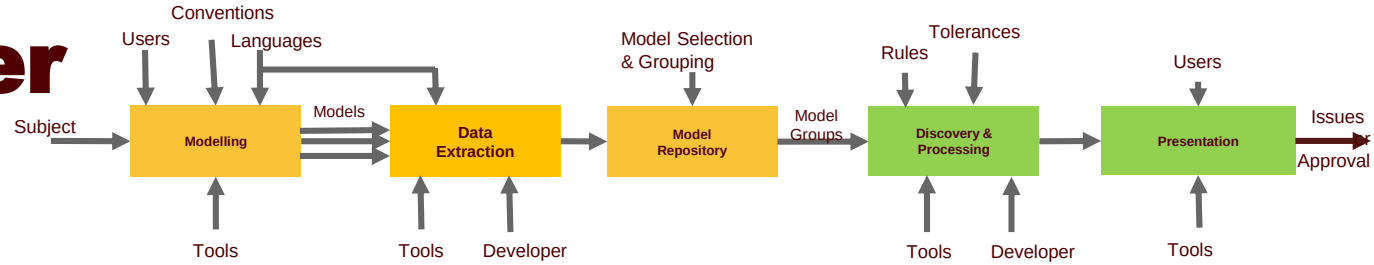
Model of Models viewer

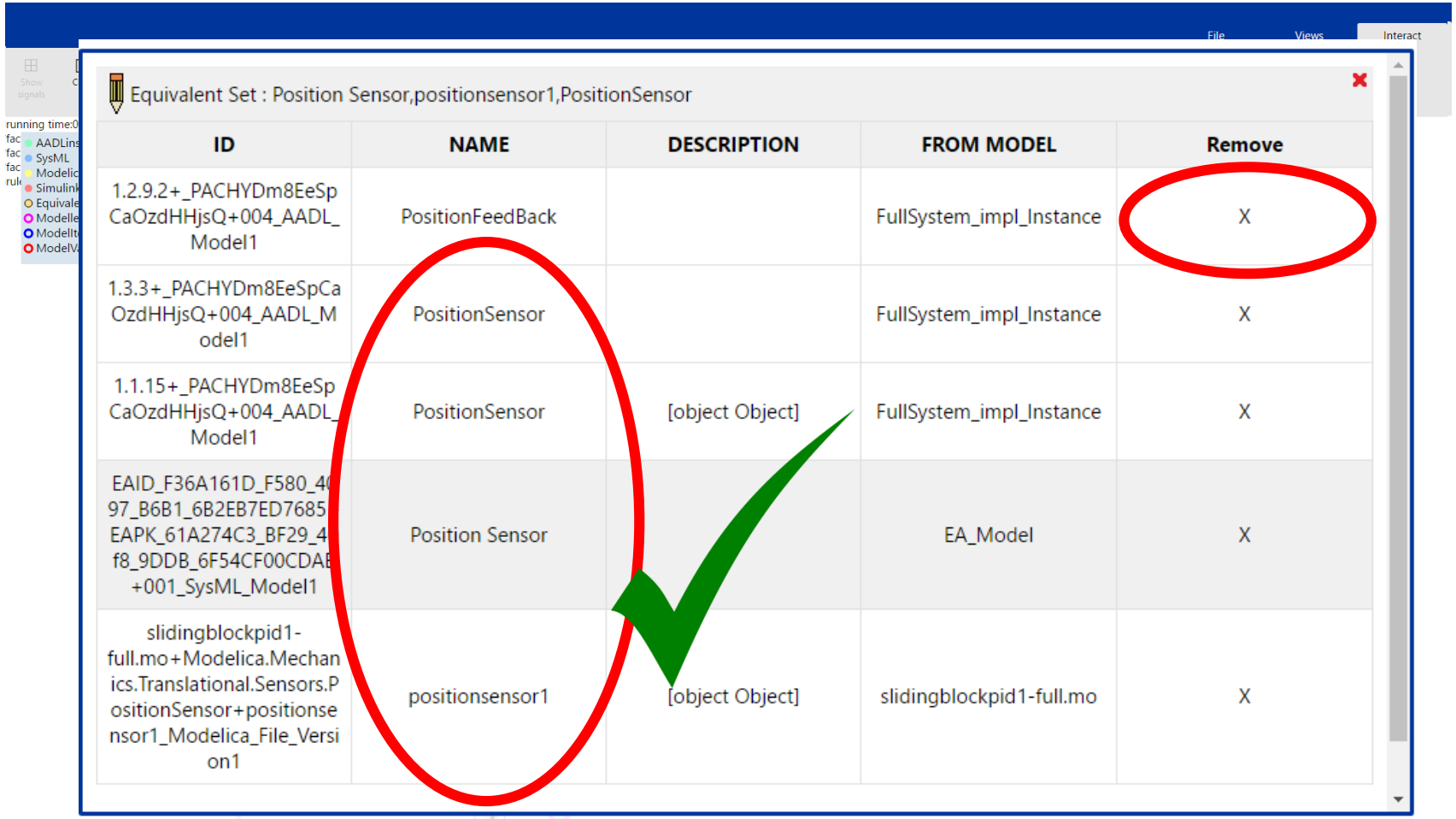




View its content

Model of Models viewer





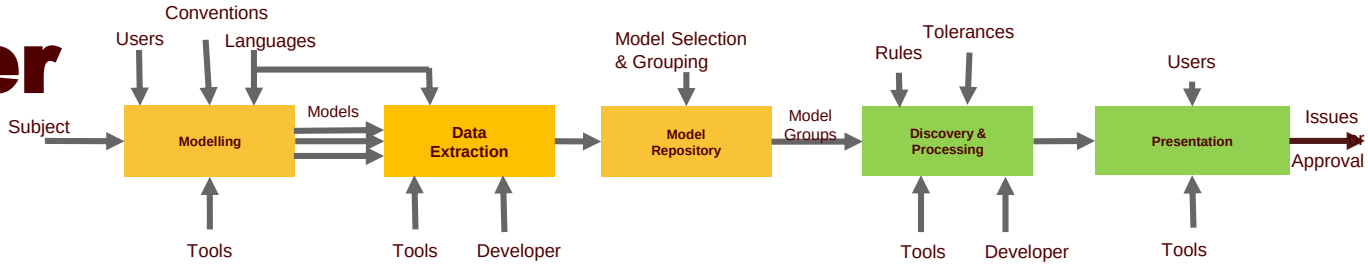
Equivalent Set : Position Sensor,positionsensor1,PositionSensor

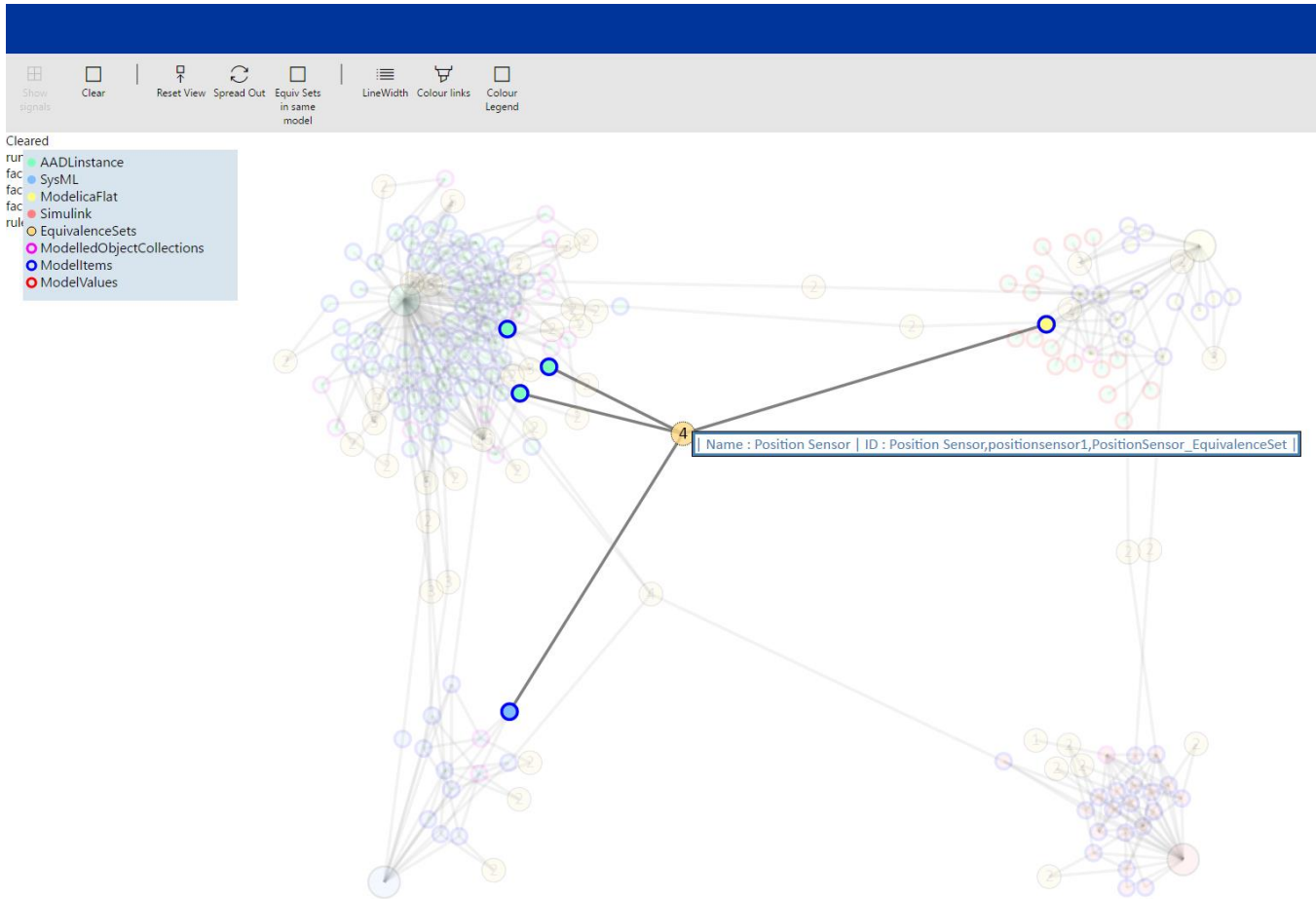
ID	NAME	DESCRIPTION	FROM MODEL	Remove
1.2.9.2+_PACHYDm8EeSpCaOzdHHjsQ+004_AADL_Model1	PositionFeedBack		FullSystem_impl_Instance	X
1.3.3+_PACHYDm8EeSpCaOzdHHjsQ+004_AADL_Model1	PositionSensor		FullSystem_impl_Instance	X
1.1.15+_PACHYDm8EeSpCaOzdHHjsQ+004_AADL_Model1	PositionSensor	[object Object]	FullSystem_impl_Instance	X
EAID_F36A161D_F580_40 97_B6B1_6B2EB7ED7685 EAPK_61A274C3_BF29_4 f8_9DDB_6F54CF00CDAE +001_SysML_Model1	Position Sensor		EA_Model	X
slidingblockpid1-full.mo+Modelica.Mechanics.Translational.Sensors.PositionSensor+positionsensor1_Modelica_File_Version1	positionsensor1	[object Object]	slidingblockpid1-full.mo	X

Edit content of the discovered equivalent set

Fuzzy matching has identified four occurrences of three different names used across models
Plus one false match

Model of Models viewer

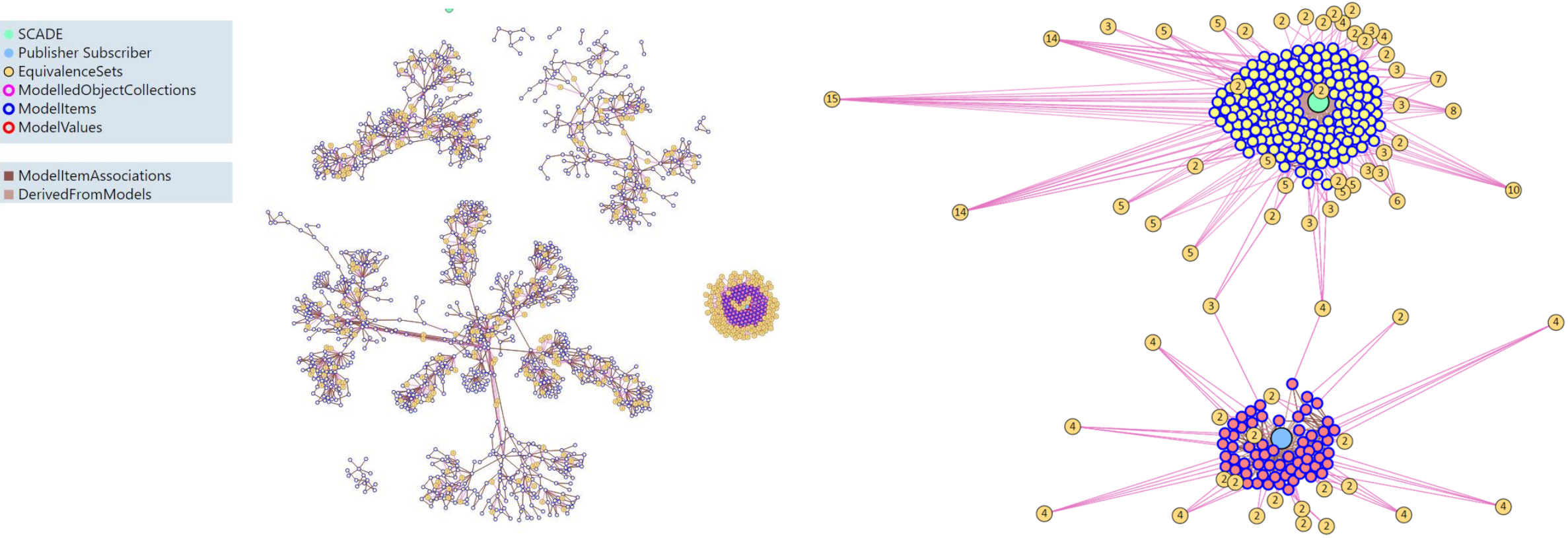




Set now only contains good matches

Now can check associated properties, structures, etc.

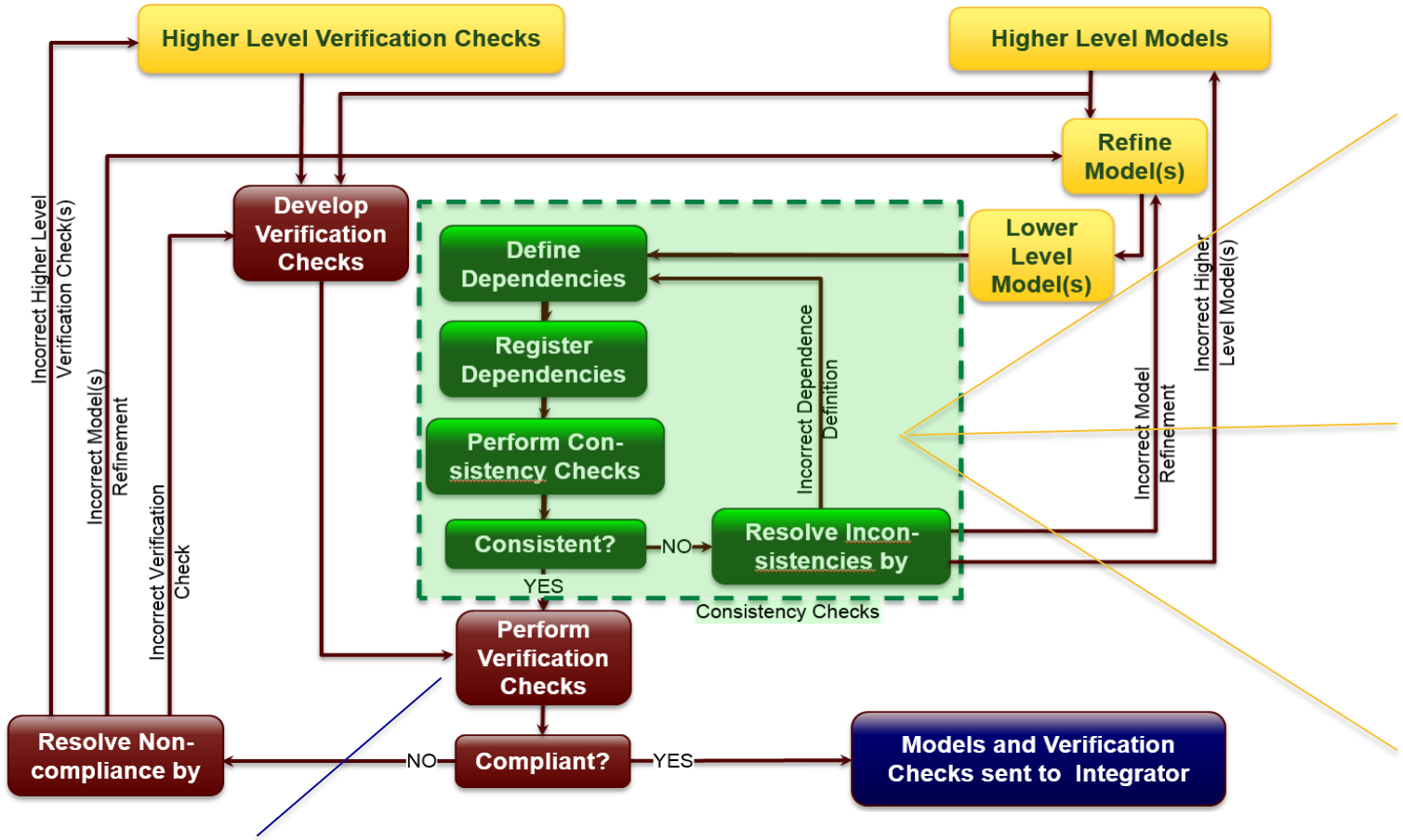
Production scale models



These are the same two pairs of models with different relationships and rules applied.

Conclusions

- The aim is to allow discovery of consistency issues much earlier than physical test
  - In the general case this is a challenging problem
    - Making progress on establishing both process and mechanisms
  - The approach is feasible for specific domains
    - Through the use of standard formats, can resolve the spatial relationships and so perform virtual integration and check consistency of integration
- SAVI is working on:
  - A Virtual Integration Process
  - Methods for considering emergent model behaviour as well as static tests
  - Specific capabilities such as safety and security across models



Models capture our understanding of system and its components

Separate models express decomposition and viewpoints

How do we assure that our individual views and composed (virtual) perspectives are looking at one system?

Only by assuring ourselves that our models are consistent can we have confidence that subsequent analyses and their results can be trusted!

Looking forward

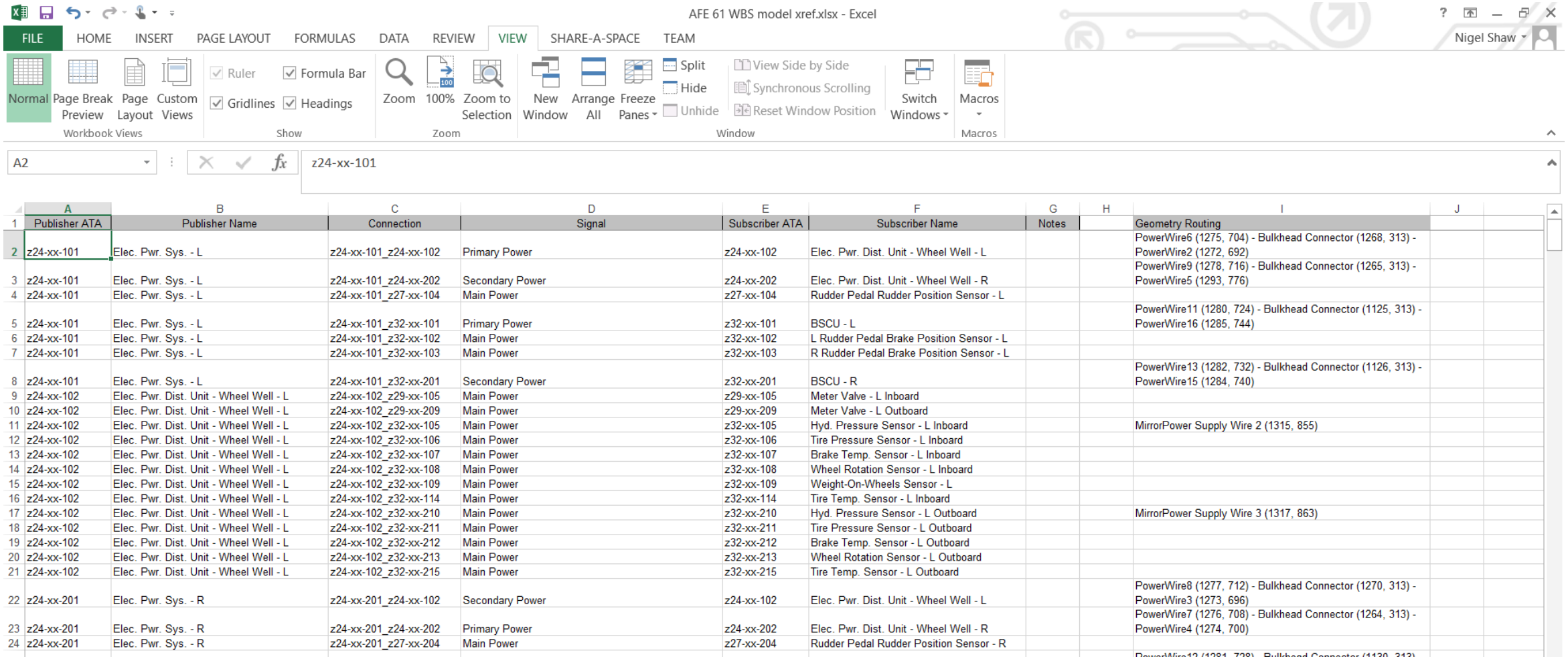
- As Model Based Systems Engineering becomes the normal way of business, it will be even more important to minimise the risk due to inconsistency between models, both within and across enterprises

- This problem is not going to go away!

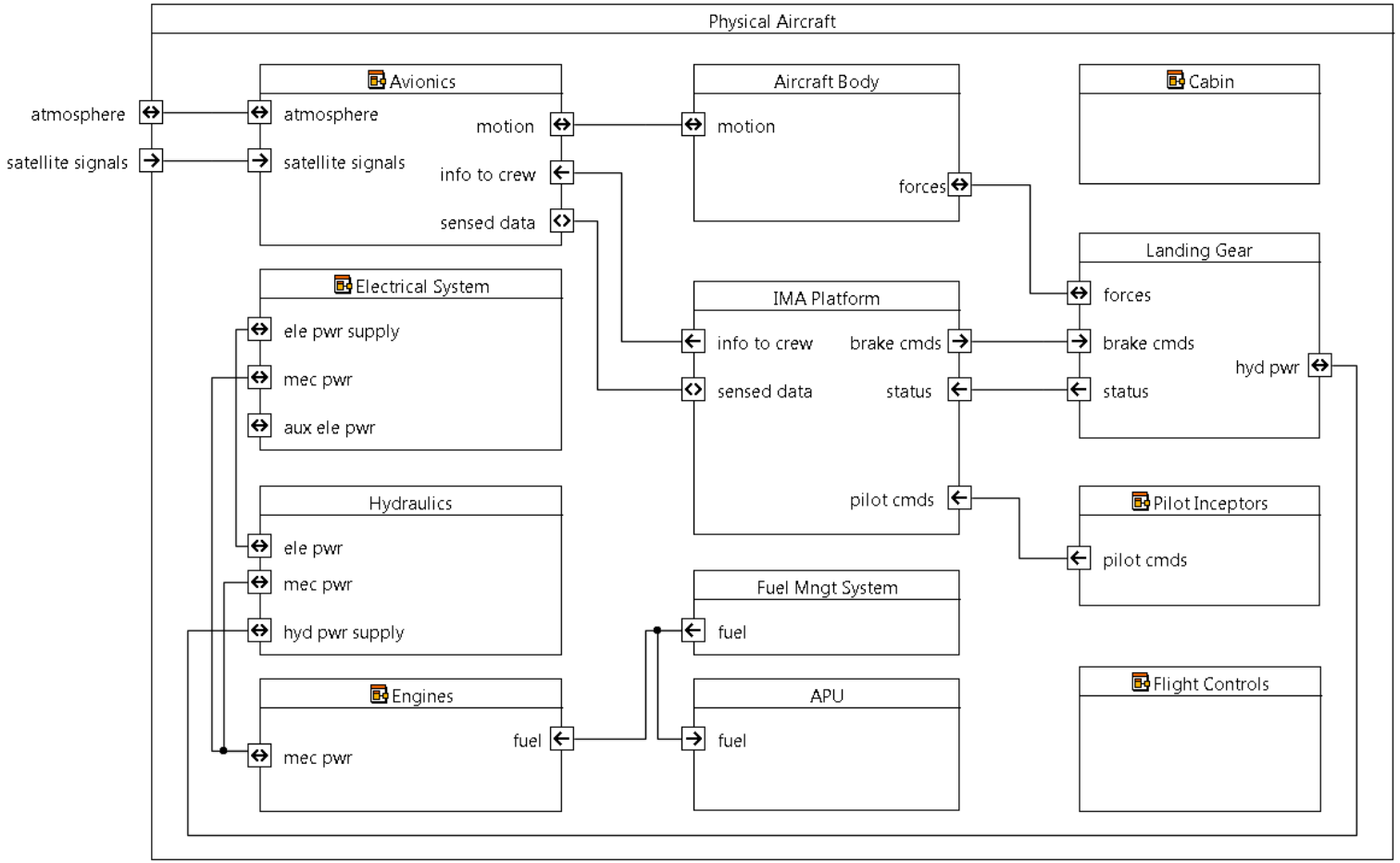
Website: savi.avsi.aero

Back up slides

Publish subscribe



	A	B	C	D	E	F	G	H	I	J
1	Publisher ATA	Publisher Name	Connection	Signal	Subscriber ATA	Subscriber Name	Notes		Geometry Routing	
2	z24-xx-101	Elec. Pwr. Sys. - L	z24-xx-101_z24-xx-102	Primary Power	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L			PowerWire6 (1275, 704) - Bulkhead Connector (1268, 313) - PowerWire2 (1272, 692)	
3	z24-xx-101	Elec. Pwr. Sys. - L	z24-xx-101_z24-xx-202	Secondary Power	z24-xx-202	Elec. Pwr. Dist. Unit - Wheel Well - R			PowerWire9 (1278, 716) - Bulkhead Connector (1265, 313) - PowerWire5 (1293, 776)	
4	z24-xx-101	Elec. Pwr. Sys. - L	z24-xx-101_z27-xx-104	Main Power	z27-xx-104	Rudder Pedal Rudder Position Sensor - L				
5	z24-xx-101	Elec. Pwr. Sys. - L	z24-xx-101_z32-xx-101	Primary Power	z32-xx-101	BSCU - L			PowerWire11 (1280, 724) - Bulkhead Connector (1125, 313) - PowerWire16 (1285, 744)	
6	z24-xx-101	Elec. Pwr. Sys. - L	z24-xx-101_z32-xx-102	Main Power	z32-xx-102	L Rudder Pedal Brake Position Sensor - L				
7	z24-xx-101	Elec. Pwr. Sys. - L	z24-xx-101_z32-xx-103	Main Power	z32-xx-103	R Rudder Pedal Brake Position Sensor - L				
8	z24-xx-101	Elec. Pwr. Sys. - L	z24-xx-101_z32-xx-201	Secondary Power	z32-xx-201	BSCU - R			PowerWire13 (1282, 732) - Bulkhead Connector (1126, 313) - PowerWire15 (1284, 740)	
9	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z29-xx-105	Main Power	z29-xx-105	Meter Valve - L Inboard				
10	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z29-xx-209	Main Power	z29-xx-209	Meter Valve - L Outboard				
11	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-105	Main Power	z32-xx-105	Hyd. Pressure Sensor - L Inboard			MirrorPower Supply Wire 2 (1315, 855)	
12	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-106	Main Power	z32-xx-106	Tire Pressure Sensor - L Inboard				
13	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-107	Main Power	z32-xx-107	Brake Temp. Sensor - L Inboard				
14	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-108	Main Power	z32-xx-108	Wheel Rotation Sensor - L Inboard				
15	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-109	Main Power	z32-xx-109	Weight-On-Wheels Sensor - L				
16	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-114	Main Power	z32-xx-114	Tire Temp. Sensor - L Inboard				
17	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-210	Main Power	z32-xx-210	Hyd. Pressure Sensor - L Outboard			MirrorPower Supply Wire 3 (1317, 863)	
18	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-211	Main Power	z32-xx-211	Tire Pressure Sensor - L Outboard				
19	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-212	Main Power	z32-xx-212	Brake Temp. Sensor - L Outboard				
20	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-213	Main Power	z32-xx-213	Wheel Rotation Sensor - L Outboard				
21	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L	z24-xx-102_z32-xx-215	Main Power	z32-xx-215	Tire Temp. Sensor - L Outboard				
22	z24-xx-201	Elec. Pwr. Sys. - R	z24-xx-201_z24-xx-102	Secondary Power	z24-xx-102	Elec. Pwr. Dist. Unit - Wheel Well - L			PowerWire8 (1277, 712) - Bulkhead Connector (1270, 313) - PowerWire3 (1273, 696)	
23	z24-xx-201	Elec. Pwr. Sys. - R	z24-xx-201_z24-xx-202	Primary Power	z24-xx-202	Elec. Pwr. Dist. Unit - Wheel Well - R			PowerWire7 (1276, 708) - Bulkhead Connector (1264, 313) - PowerWire4 (1274, 700)	
24	z24-xx-201	Elec. Pwr. Sys. - R	z24-xx-201_z27-xx-204	Main Power	z27-xx-204	Rudder Pedal Rudder Position Sensor - R				


Physical Aircraft
Avionics
atmosphere
satellite signals
motion
info to crew
sensed data
Aircraft Body
motion
forces
Cabin
Landing Gear
forces
brake cmds
status
hyd pwr
Electrical System
ele pwr supply
mec pwr
aux ele pwr
IMA Platform
info to crew
sensed data
brake cmds
status
pilot cmds
Hydraulics
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