

MBSE

Multi-Model, Multi-Domain Interoperability

Greg Pollari – Rockwell Collins
Nigel Shaw - Eurostep

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My name is Greg Pollari

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- **Rockwell Collins**
- **Principal Systems & Process Engineer**
- **Degrees in Physics, Electrical & Computer Engineering, Business Administration**
- **SAVI (Systems Architecture Virtual Integration) project lead**
- **Organizations (past and present)**
 - **GPDIS MBSE track co-lead**
 - **INCOSE**
 - **MoSSEC**
 - **Purdue PLM Center**
 - **PDES Inc.**
 - **NDIA Systems Engineering Modeling & Simulation Committee**

My name is Nigel Shaw

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- Managing Director of Eurostep Limited since 1995
- Previously with British Aerospace, Leeds University
- Degrees in Geophysics and Computation
- Involved in STEP since 1986
- Chair of ProSTEP Round Table. 1995-1998
- Technical Lead for PLCS Inc. 1999-2005
- Eurostep PM for CRESCENDO, CONGA and TOICA
- Eurostep PM for our work with SAVI
- Standards geek, believer and analyst
- Interoperability challenger



SAVI – The Starting Point

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- **SAVI (Systems Architecture Virtual Integration)**
 - AVSI (Aerospace Vehicle Systems Institute) project
- **SAVI early and continuous model-based virtual integration**
 - Leverages distributed **inter-domain, inter-model consistency checks**
 - **Protects IP** (Intellectual Property)
 - Maintains configuration management
 - Captures incremental **evidence for safety analysis and certification**
 - Addresses security analysis
 - **Reduces cost** and development time
- **SAVI Foundation**
 - SAVI Model Repository (MR)
 - SAVI Data Extraction Layer (DEL)
 - SAVI Virtual Integration Process (VIP)

Rockwell
Collins



United
Technologies

Honeywell

Software Engineering Institute



SAVI
System Architecture Virtual Integration

AIRBUS



BOEING



EMBRAER

Tool Vendor Partners:
Adventium Labs, Esterel Technologies, Eurostep

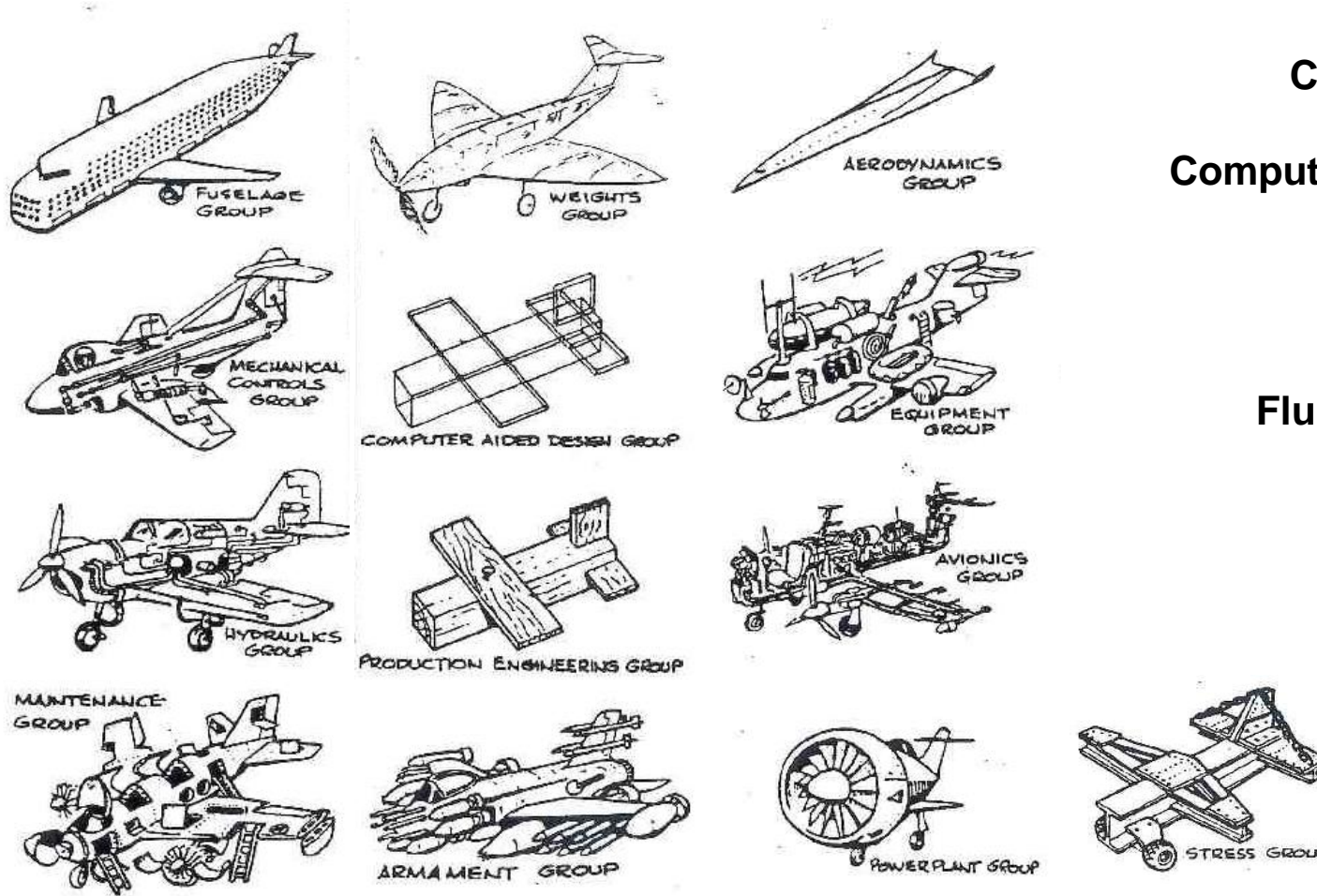
SAVI – The Problem

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- **Model Based Engineering is the way modern products and systems are built**
 - System complexity increasing
 - Shared resources
 - Complex interfaces
- **Now likely to join models together into bigger simulations**
 - Need consistent models
- **Independent models of the same system can be inconsistent**

Many groups, each with their own methods, tools and models

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Drawings based on: C. W. Miller, c1948, "Dream Airplanes" Design Engineer, Vega Aircraft Corp

Acoustics
Buckling and Collapse
CAD Integrated Analysis
Composites
Computational Fluid Dynamics
Contact and Impact
Crashworthiness
Durability and Fatigue
Electromagnetics
Fluid Structure Interaction
Forming
Fracture and Failure
Impact
Multibody Dynamics
Noise and Vibration
Optimization
Process Automation
Sealing
Shock and Vibration
Thermal

Selection of analysis types from one vendor!

Many models = Increased Risk of Inconsistency

SAVI identified inconsistency types:

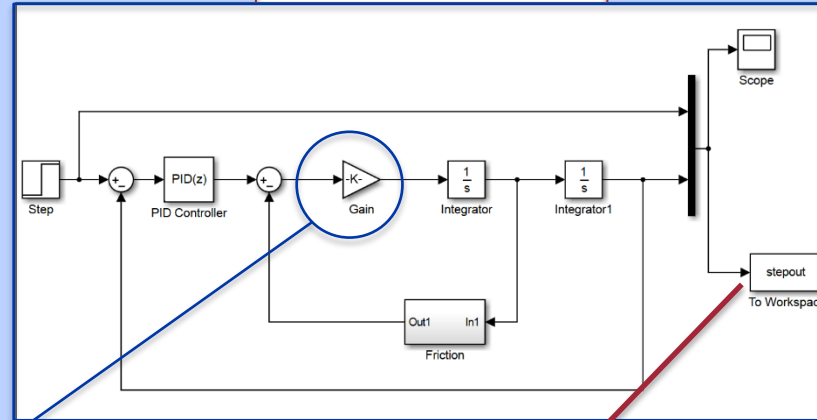
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Data Value
(numerical
values)

Data Type
(variable types,
units, range,
tolerance)

Data Semantics
(interpretation)

Data Metadata
(restrictions,
assumptions,
source)

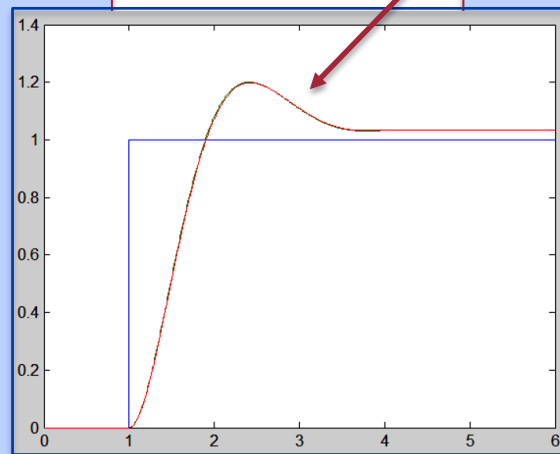


Model Property
(patterns,
component
inventory, interfaces)

Model Semantics
(interpretation)

Model Metadata
(restrictions,
assumptions,
source)

Model Behavior
(time history
response, invariant
properties)



Models and their characteristics

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- **Format**
 - e.g. SysML, AADL, Modelica, Simulink, ...
 - e.g. XML, CSV, Binary, Excel, proprietary, code
- **Purpose**
 - All models have a purpose
- **Content**
 - Scope: What has been included and what excluded/assumed?
 - "The database is the Model" or "the Model is the database"
- **Meta data**
 - Versioning, Life cycle state
- **Structures**
 - Derived from real world vs. Abstracted from real world

Interoperability

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- **Tools**

- **Classic problem: My tool cannot read your model/data**

- **Organizations and extended enterprise**

- **We use different tools and/or paradigms**
 - **Our modeller cannot read/understand your model**
 - **Our modeller has used different conventions**
 - **Modelling style**
 - **Naming**

Extraction

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- **Consistency and Comparison**
 - To compare need to be able to extract things that should be the same and test
- **Search**
 - Does a model include X where X is a part or a function or an action?
- **As a source: Onward through life...**
 - For some models payback comes later

Change management

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- **Traceability**

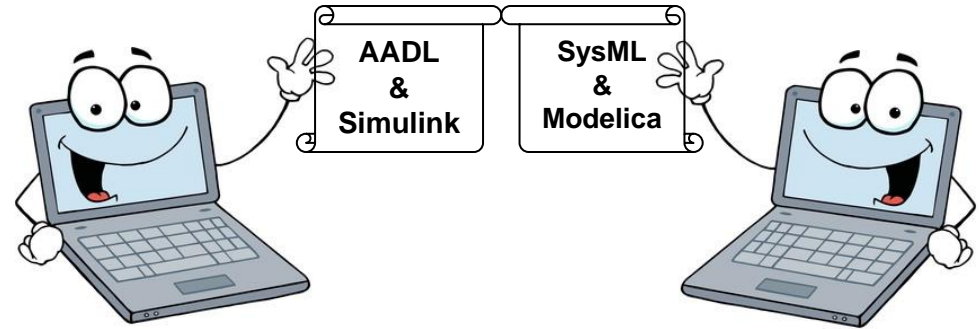
- **Between Models**
- **Between things in the Models**

- **Only if you can either extract or point at things within models**

The challenges

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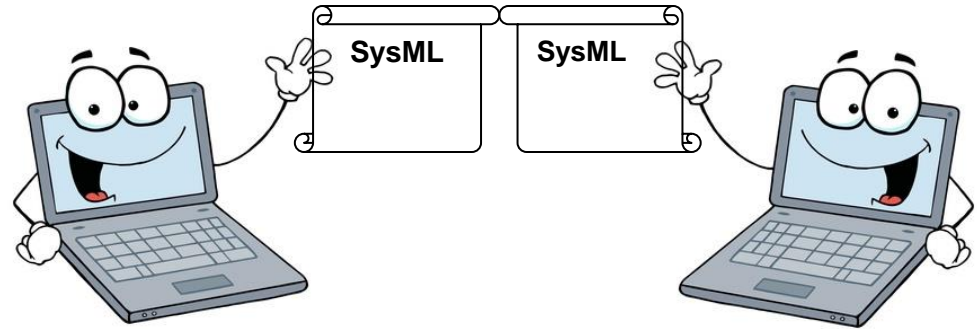
- Different languages



The challenges

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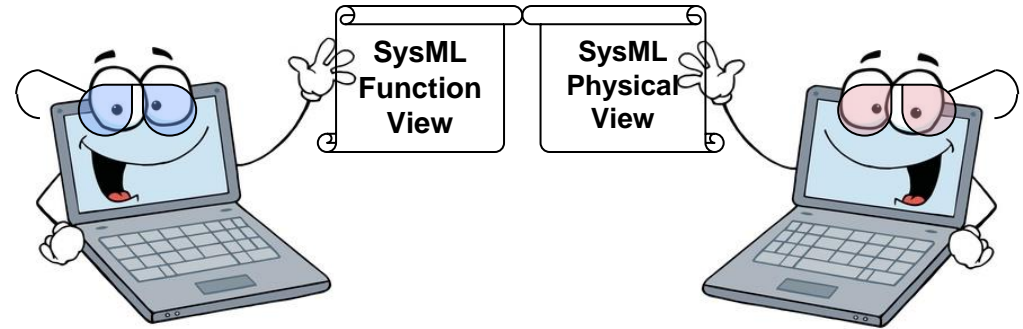
- Different languages
- Same Language - different usage
- Modelling style
- Modelling conventions
- Human/Organization Factors
 - Naming & Identifiers
 - Taxonomies
- Processor style



The challenges

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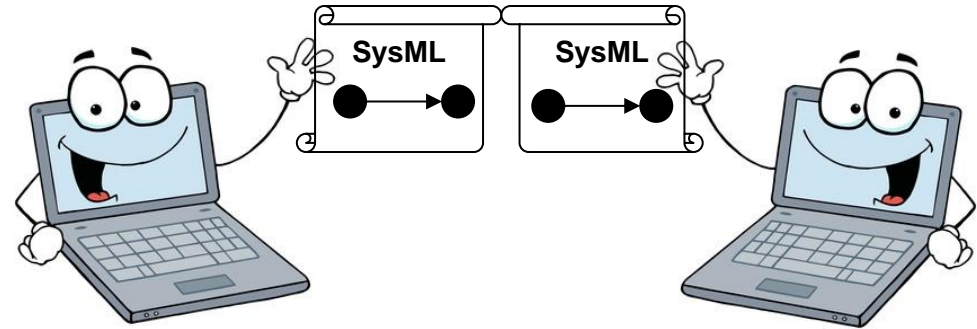
- Different languages
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The challenges

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- Different languages
- Same Language - different usage
- Modelling style



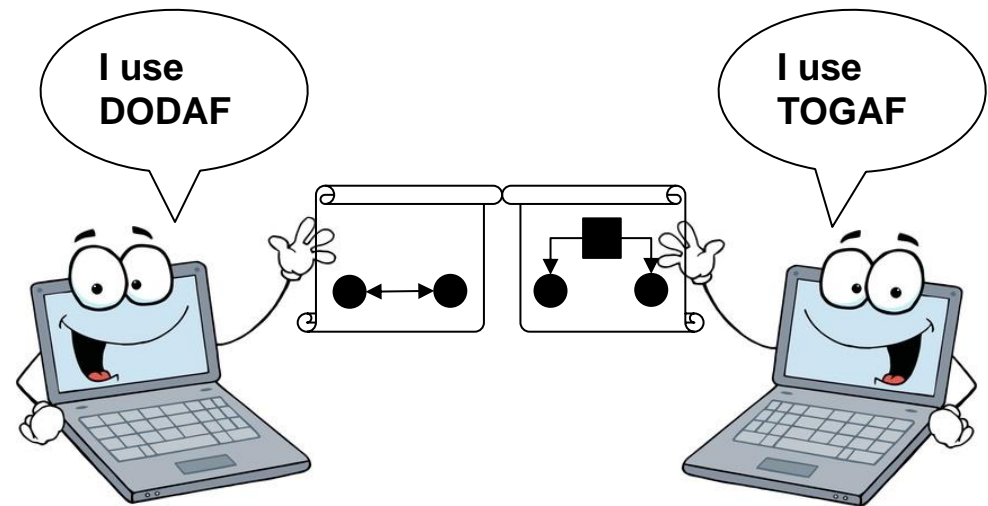
A has a Port
called C and
B has a Port
called C
The ports are
connected

A is
connected
to B via
Ports. The
connection
carries
signal C

The challenges

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- Different languages
- Same Language - different usage
- Modelling style
- Modelling conventions



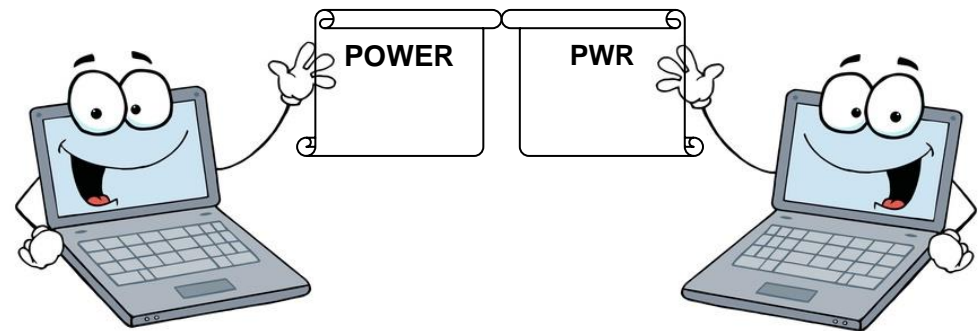
The challenges

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- Different languages
- Same Language - different usage
- Modelling style
- Modelling conventions
- Human/Organization

Factors

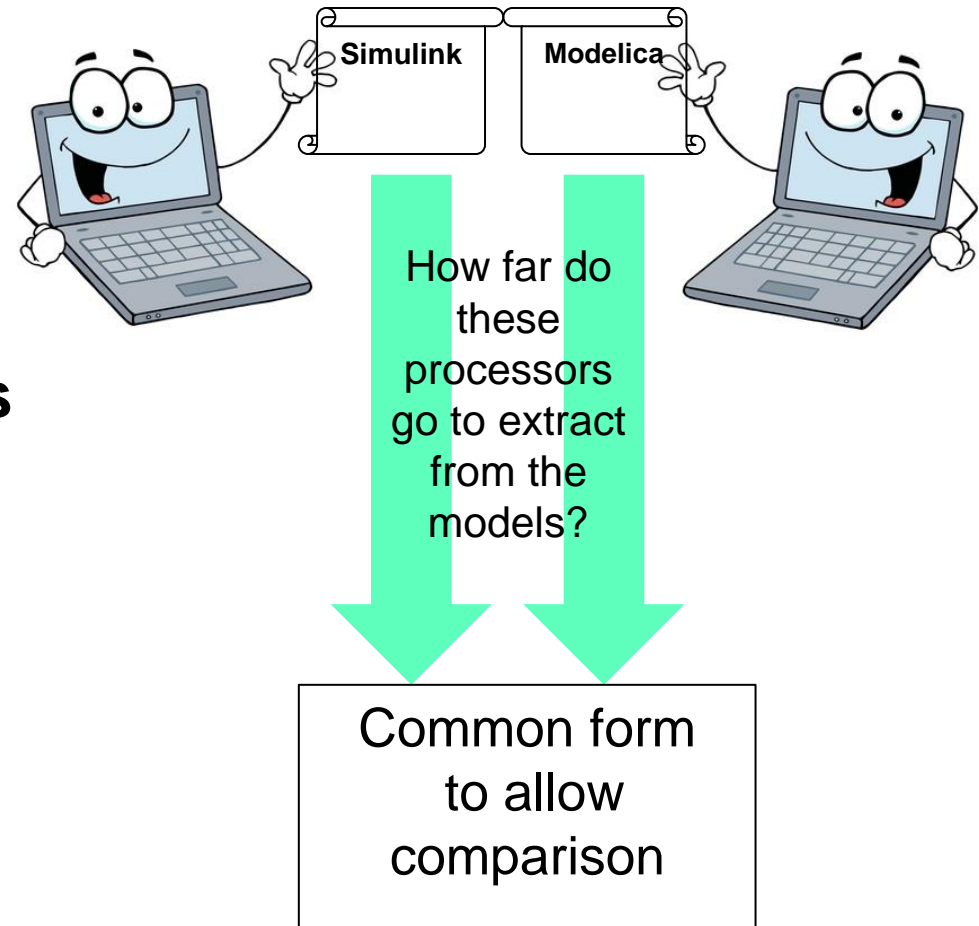
- Naming & Identifiers
- Taxonomies



The challenges

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- Different languages
- Same Language - different usage
- Modelling style
- Modelling conventions
- Human/Organization Factors
 - Naming & Identifiers
 - Taxonomies
- Processor style



Interoperability

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- **Bad news: Frustrating when not possible to interoperate**



- **Good news: Failure to interoperate reduces duplication!**

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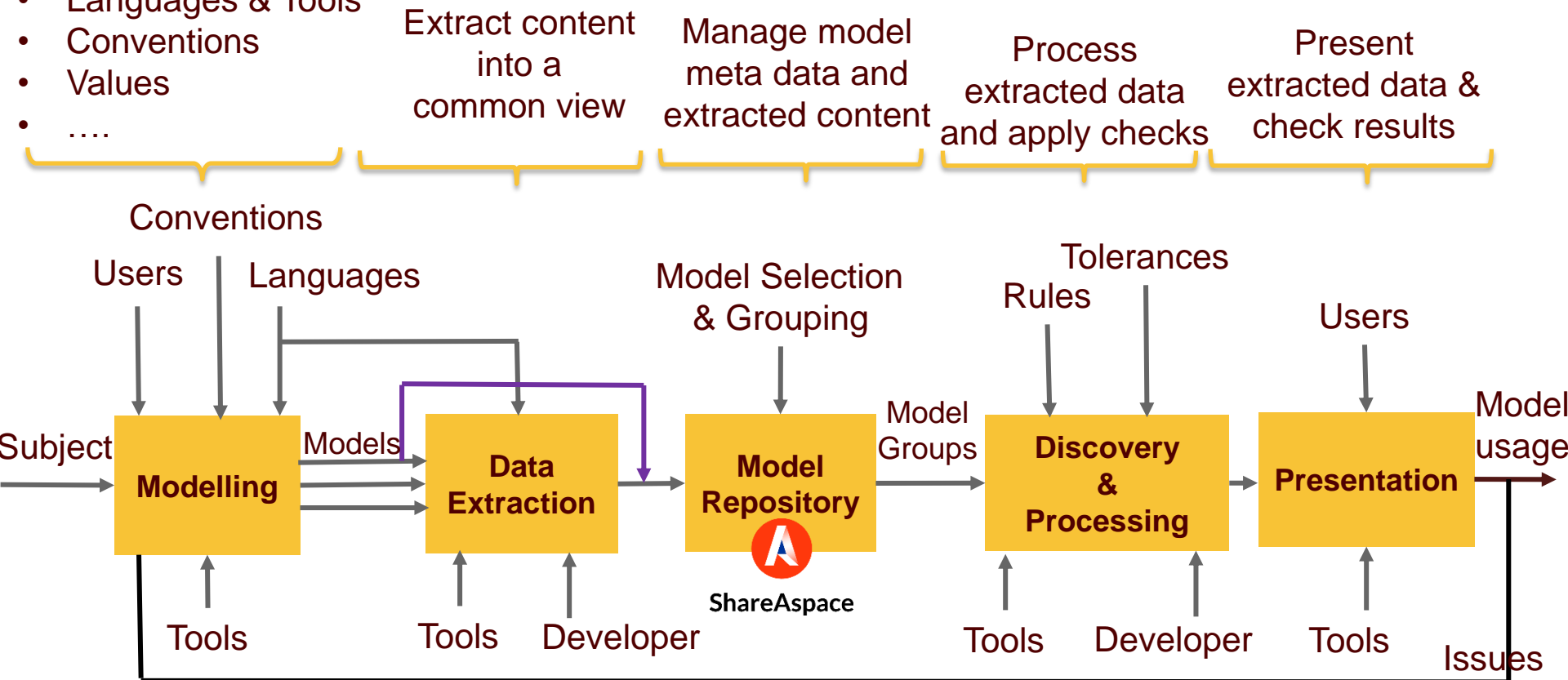


SAVI experience – Model pre-flight checks

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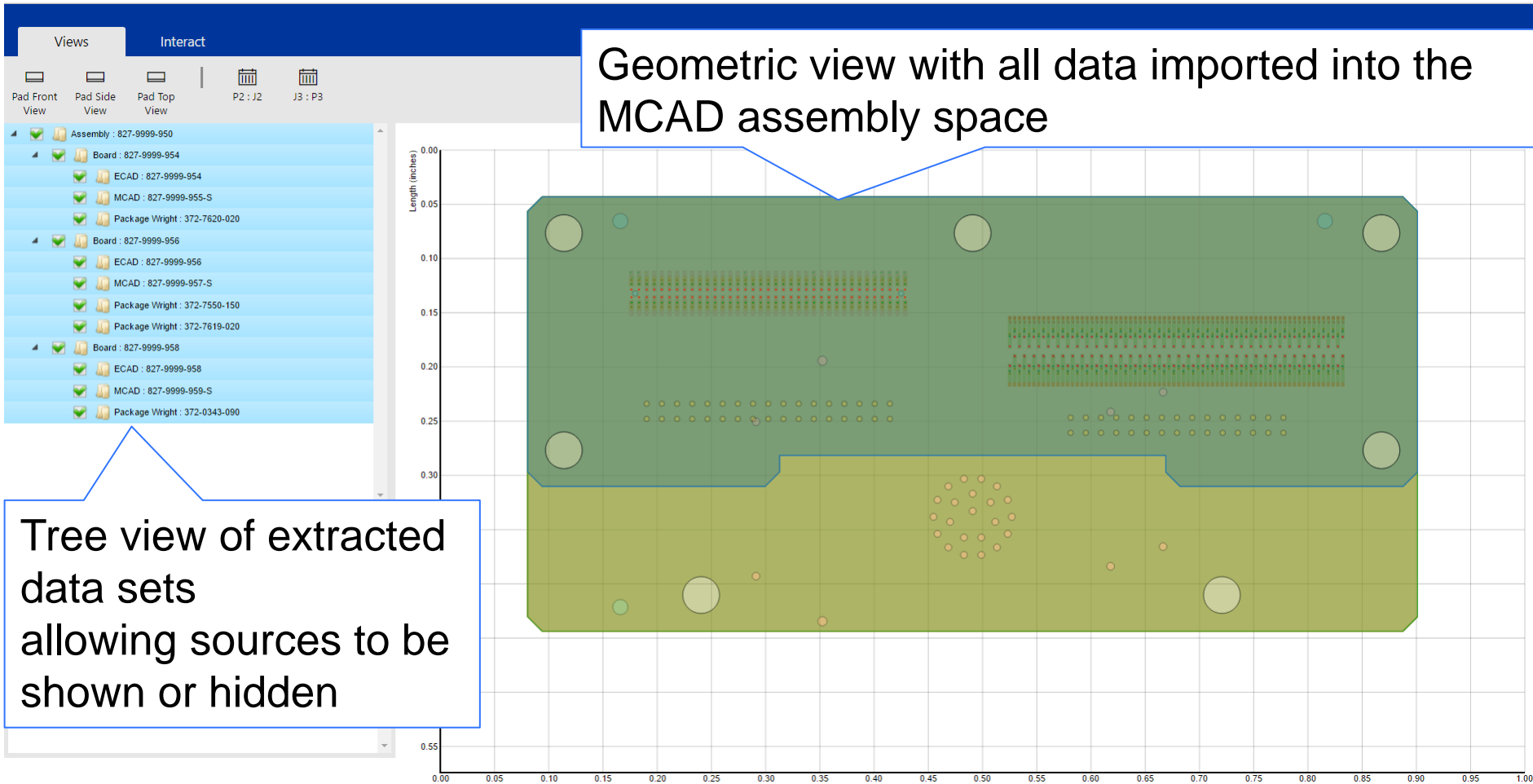
Root cause of the problem: differences in

- Users & Enterprises
- Languages & Tools
- Conventions
- Values
-

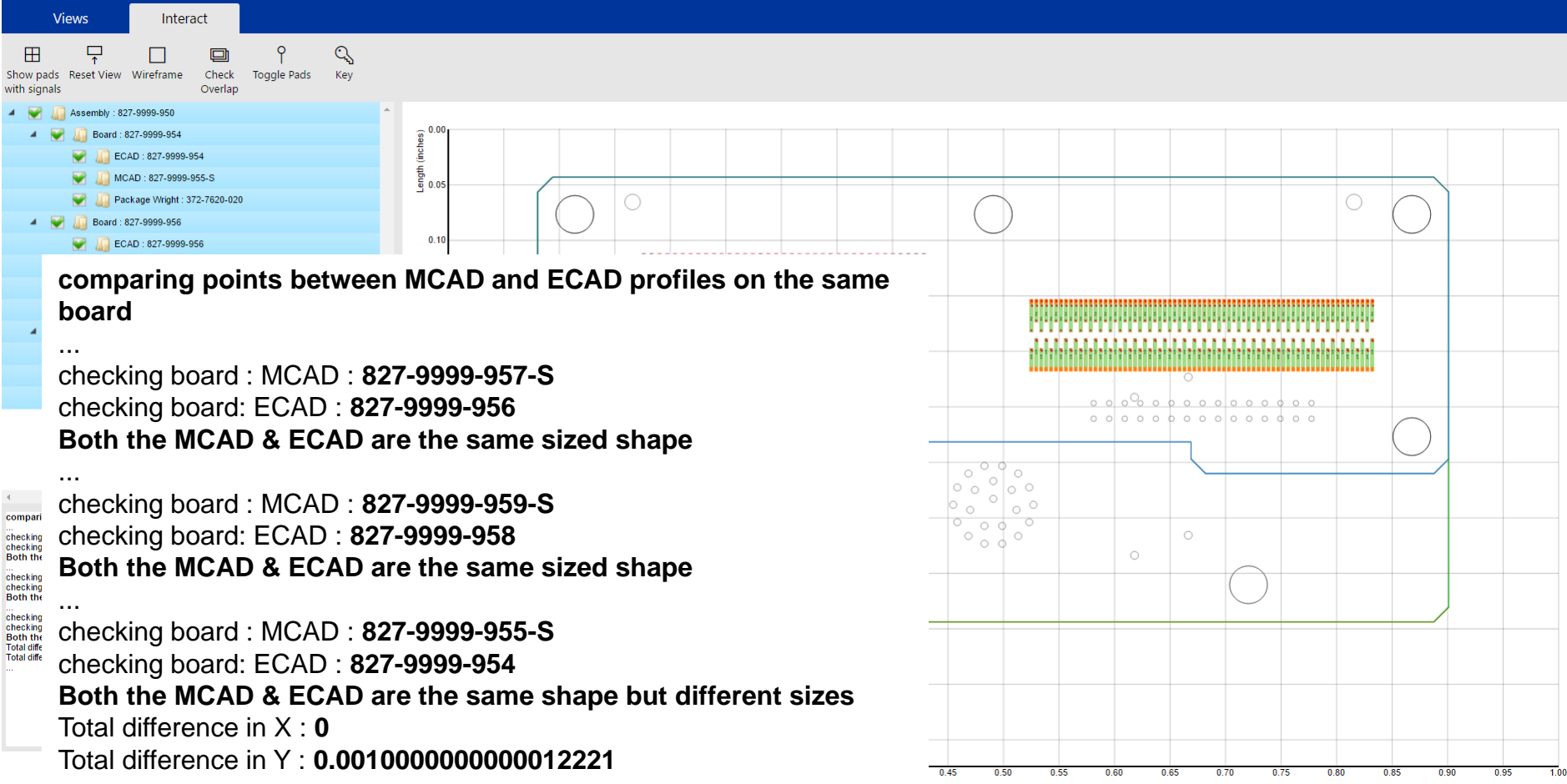


Virtual Integration: ECAD and MCAD and more

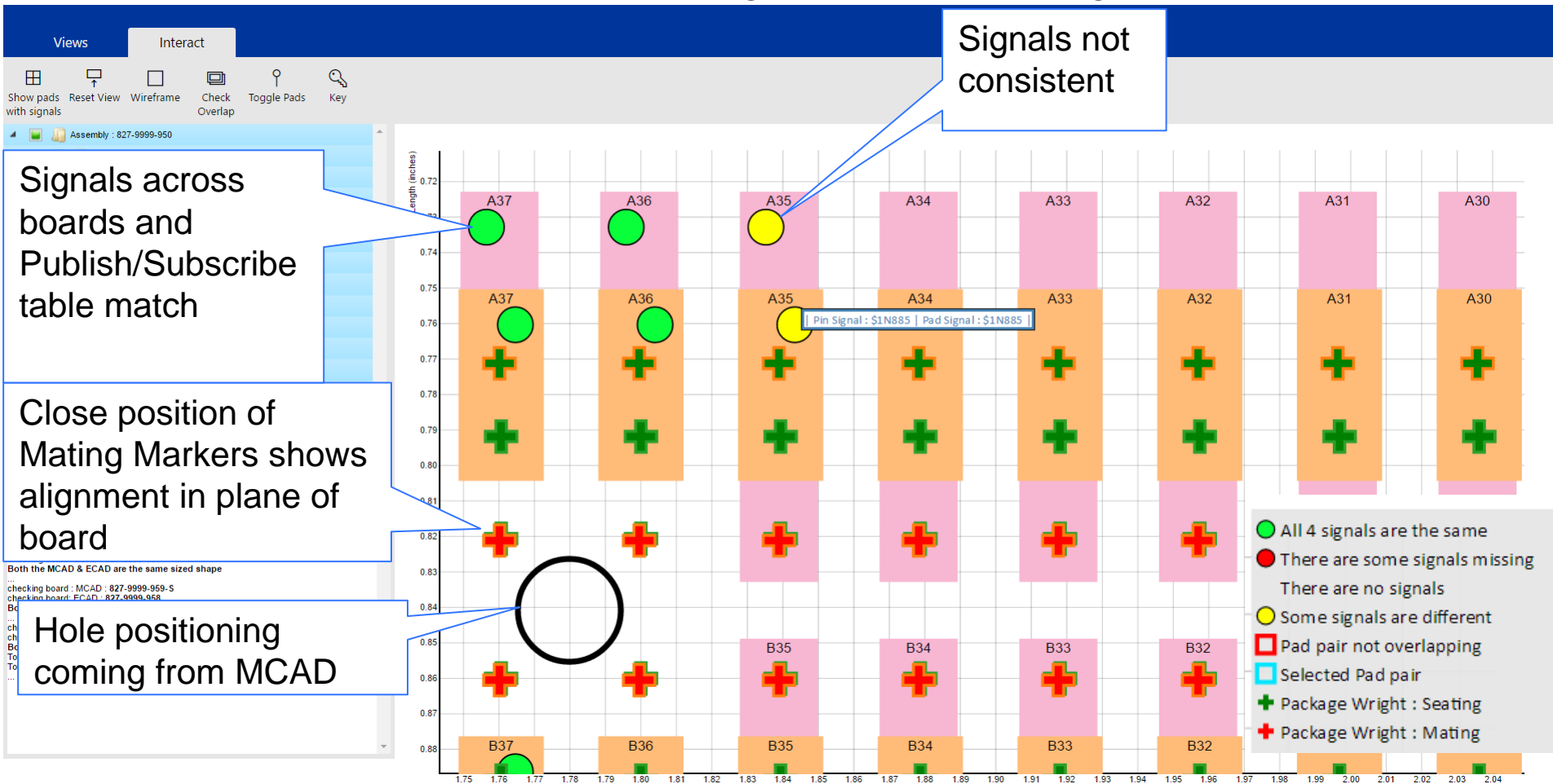
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Q1: How well do the MCAD and ECAD boards match up?



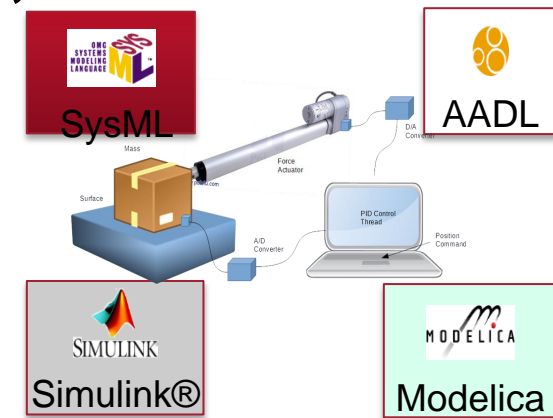
Q2: How well do connectors align? Q3: Are the signals consistent?



Model consistency checking

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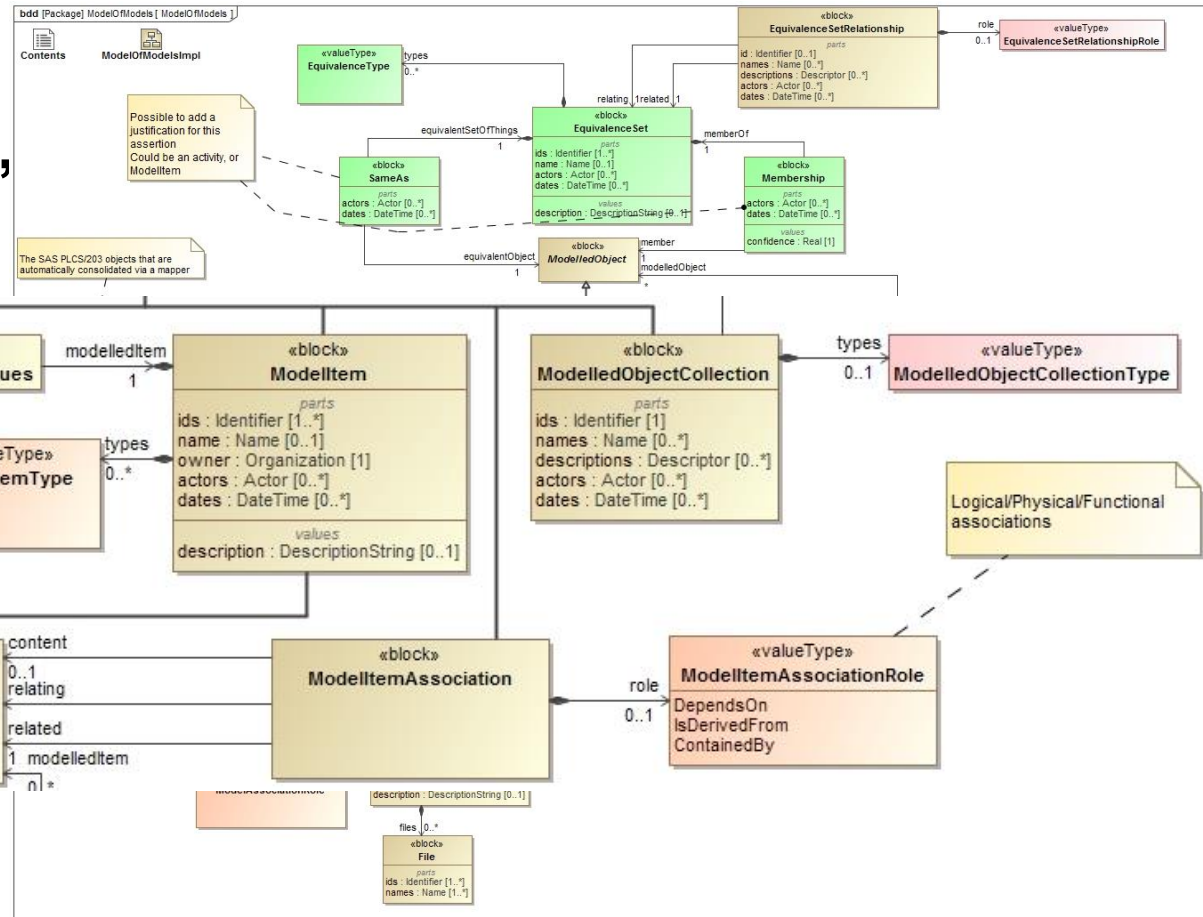
- In the generic case, need to identify where “things” should be consistent, then test if they are consistent
- Extracted a single form from all models, i.e. into the “model of models”
- Enabled:
 - Rule engine used to find equivalences
 - The user to identify equivalences and look for consistency
 - Edit results from the rule engine
 - Identify patterns that should match across models
 - Apply rules to determine/test consistency
- Used fuzzy comparison due to differences in names and conventions



Model of Models

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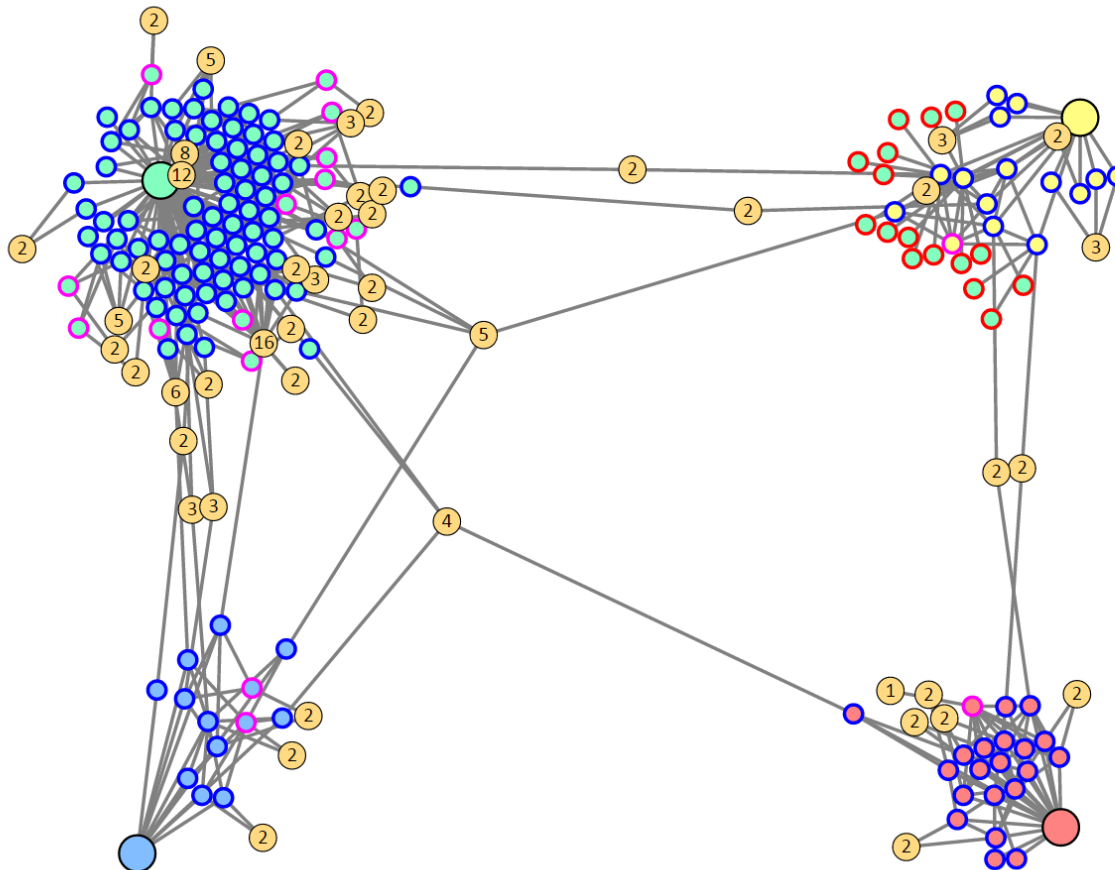
- Extract view from each model using “Model of Models”



Show signals
Clear
Reset View
Spread Out
Equiv Sets in same model
LineWidth
Colour links
Colour Legend

running time:0min


fac
fac
fac
rule
AADInstance
SysML
ModelicaFlat
Simulink
EquivalenceSets
ModelledObjectCollections
ModelItems
ModelValues



The original test case models

Human interaction is required

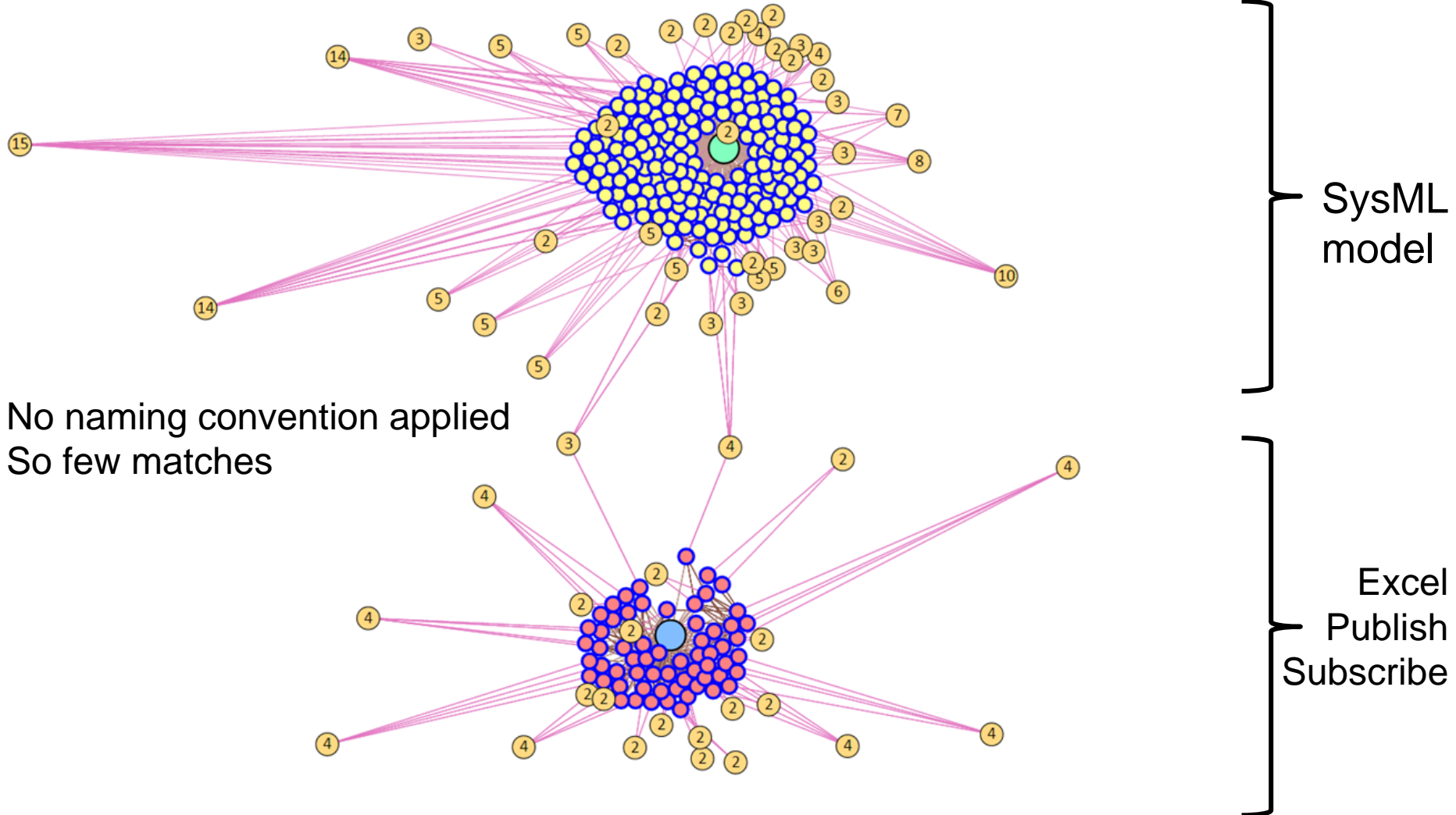
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 Equivalent Set : Position Sensor,positionsensor1,PositionSensor ✕

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_4097_B6B1_6B2EB7ED7685+EAPK_61A274C3_BF29_40f8_9DDB_6F54CF00CDAB+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

SAVI experience – Matching on Names for one system

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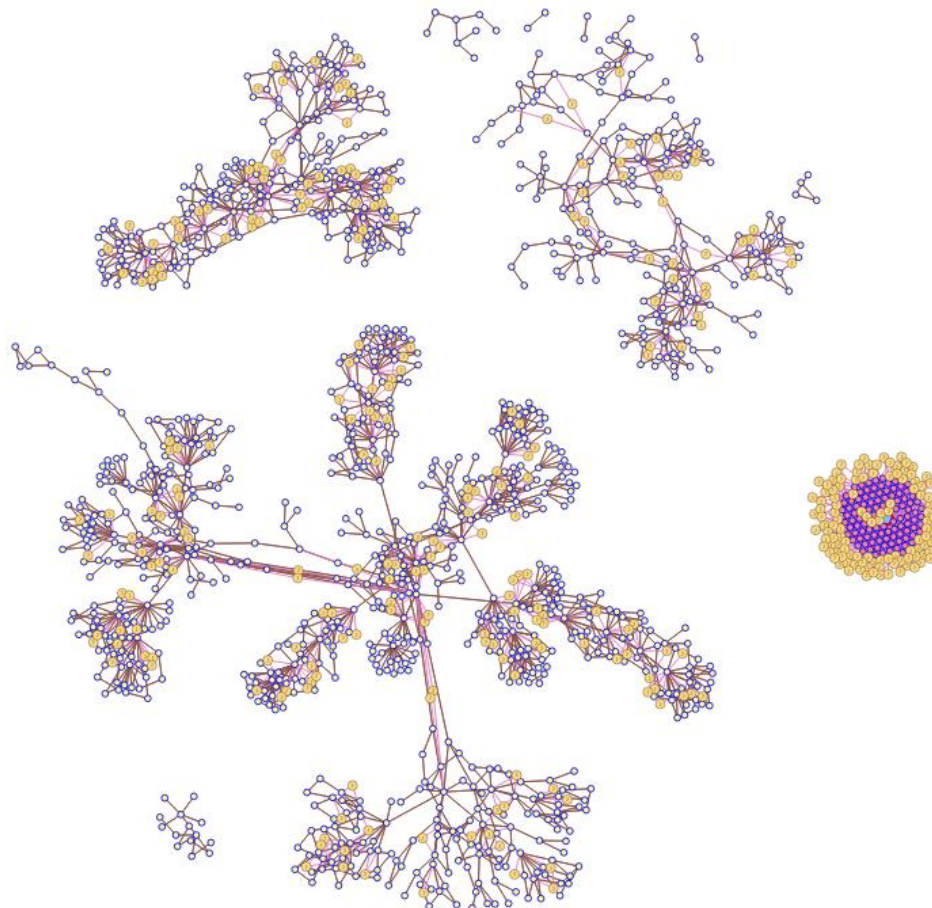


SAVI experience – Matching on connections

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SCADE
Publisher Subscriber
EquivalenceSets
ModelledObjectCollections
ModelItems
ModelValues

ModelItemAssociations
DerivedFromModels



Same models as previous slide

Looked for matching connections across models

None found!

Reason: differences in naming and modelling style

- **SAVI work explored discovery and processing based on starting from just the models**
 - Would expect to develop libraries of model checks and use thesauri and abbreviations to aid discovery
 - Use of standardised breakdowns in modelling would also help
- **In practice the engineer will be reasonably well placed to check some aspects of consistency**
 - Such as use of key values for properties
- **However the scale of large products means there is value in aiding discovery**
- **Worth considering how MoSSEC might help**
 - More on this later

Other experiences

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- **Consider SysML**
 - Has a consistently available format common across tools
 - XMI
- **Eurostep has:**
 - worked with SysML as a means to define models for standards and mappings between models
 - Using class diagrams and parametric diagrams
 - developed a major implementation of the PLCS standard for a customer
 - Automated software development
- Both of these are also forms of extraction in that the target is not the originating tool or similar
- Including SAVI work, 5 SysML tools has meant 5 different processing capabilities for data written in the same format

Conclusions concerning Extraction and Consistency

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- **Extraction can be done!**
 - Both intellectual effort and cost can be substantial
 - Harder than it should be!!
 - Use of naming conventions and taxonomies would help
- **Consistency checking needs extraction from more than one model if it is not to be human driven**
 - Model of models approach is viable and will allow traceability into diverse model types
- **Consistency is a property of a group of models**
 - Need capability to handle model groups with joined up extracted data and derived elements

Community failure re XMI

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- **XMI is a good example of a standard that does not have an agreed way to use it**
 - Others are ISO 10303-28 and ReqIF
- **Most vendors of UML/SysML tools use it to preserve system state**
 - So their XMI can change with tool version as well as content
- **INCOSE seems resigned to limited tool interoperability**
- **The answer was supposed to be Canonical XMI but it is poorly supported**
- **It has been seen as acceptable for vendors to offer to read each other's XMI to give some interoperability**
 - This fails anyone trying to use the content in other ways

Extraction vs. openness vs. standards

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- **The SAVI work relied on different levels of standards to enable extraction of data from models**
 - XML as a base syntax allowed XSLT to be used to extract
 - SysML (XMI)
 - AADL (via export from OSATE)
 - STEP standards (ISO 10303) allowed extraction without having to read proprietary formats
 - AP214 MCAD
 - AP210 ECAD
- **Domain specific languages (e.g. Modelica) present a challenge without available parsers or XML format**

Follow-up

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- **One way to ensure consistency is to provide values as part of a simulation specification which is then “populated”**
 - This is part of the design intent of the MoSSEC standard:
- **Modelling and Simulation information in a collaborative Systems Engineering Context**
 - New work item under ISO TC 184/SC 4
 - Originates from Airbus led EU research projects
 - Not Aerospace specific
 - Key problem: Enable an Aircraft Architect to know where a value came from and where has it been used
 - Capture Audit Trail of System Simulation across organizations and disciplines

- **MoSSEC reuses a lot of PLCS/AP233 structures**
 - Details of specific simulations could be handled using native, AP209 or even AP233
 - Working at Meta data level
 - Traceability from studies to models to results and more
 - Provision of key values and model data for analysis/simulation

MoSSEC scope

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MoSSEC Business Object Model coverage



Slide from Adrian Murton presentation to NAFEMS SDMWG, Jan 2017 – used with permission

Silos or Cylinders of Excellence?

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At first sight
some of these silos
appear to be the same





The snag is
you have to
release
the inner silos!

