2018 Annual INCOSE
Great Lakes Regional Conference
SYSTEMS AT THE CROSSROADS
17 - 20 October 2018 | Indianapolis, Indiana

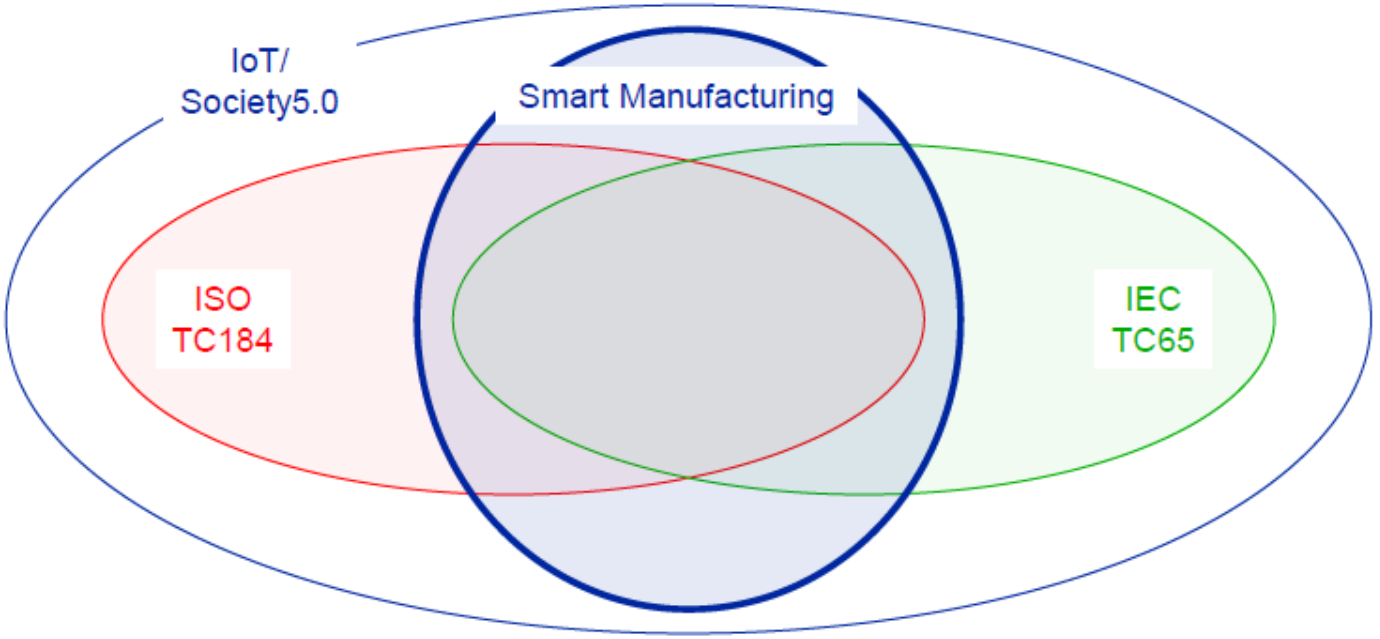
Harmonizing world views of Smart Manufacturing

ISO TC184 – IEC TC65 JWG21 Smart Manufacturing Reference Model

What is JWG21 all about?

JWG 21 Smart Manufacturing Reference Model

- New ISO – IEC initiative in response to many independent initiatives by both national and international organizations
- Goal is to codify emerging best practices before silo effect overcomes efficient international commerce



JWG21 Administration

- September, 2016: ISO TMB Resolution 104/2016 (ISO-TC84-SAG_N0192)
- "The Technical Management Board, noting the recommendations from the ISO Strategic Advisory Group on Industry 4.0/Smart Manufacturing related to existing ISO Technical Committees, requests that ISO/TC 184 and IEC/TC 65 consider working jointly on an ISO/IEC standard, taking into account the RAMI4.0 and the NIST models, in order to create a unified reference model for Smart Manufacturing."
- ISO/TC 184 and IEC/TC 65 will work in the mode of operation 5 for JWG 21 (Mode 5 —Integrated liaison)
- "Joint Working Groups and Joint Technical Committees ensure integrated meetings for handling together the realization of standards under a principle of total equality of participation."

Convenors: Fumihiko Kimura for ISO and for IEC - Martin Hankel, then Ingo Weber, and now Dennis Brandl (IEC)

Very ambitious Terms of Reference

JWG shall prepare a standardized unified Reference Model to support ISO and IEC activities in Smart Manufacturing. The Reference Model shall comprise a single model, possibly with a set of consistent and coherent sub-models, and align with the requirements of stakeholder groups, including manufacturing system users, suppliers, integrators, standardisers, and consumers of manufactured products.

The Reference Model shall support or interface to other reference models that support the requirements of the stakeholder groups for: all phases of the lifecycles of products and their components from concept to eventual disposal, including manufacturing; all phases of the lifecycles of manufacturing facilities and their components and resources; the interactions between these lifecycles in the manufacturing system context; all business and operational functions within a distributed supply chain, including resource management and allocation; and, the integration, interoperability and operation of multiple systems to support these functions.

The JWG shall consider available standardised reference models for manufacturing automation. The Reference Model and its interfaces shall inform and align with the final definition of Smart Manufacturing being addressed in ISO SMCC and IEC SyCSM, and their subsidiary TCs and SCs.

JWG 21 Activities to date

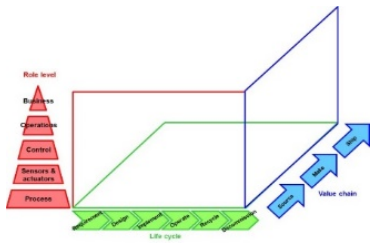
- Kick-off meeting in July, 2017
- 74+ registered participants – now about 100 with 44 at last meeting
- 16 one hour webinars from 11 countries in Aug. and early Sept., 2017
- 2nd meeting with ~40 participants from 12 countries
  - No agreement on definition of Smart Manufacturing – still no agreement!
  - Gathered topics related to JWG21 Scope
  - Reviewed each webinar
    - Identified relevant dimensions of smart manufacturing
    - Identified additional topics related to smart manufacturing reference model(s)
  - Established subgroups to progress work
- Subgroup virtual meetings in Nov., Dec., 2017 and early Jan., 2018
- Then meetings in Tokyo (#3), Beijing(#4), and Frankfurt(#5) with more virtual meetings
- Next meeting in Chicago(#6), Nov. 12/14, then Paris(#7), February 26/27 and March 1, 2019

Initial participant presentations

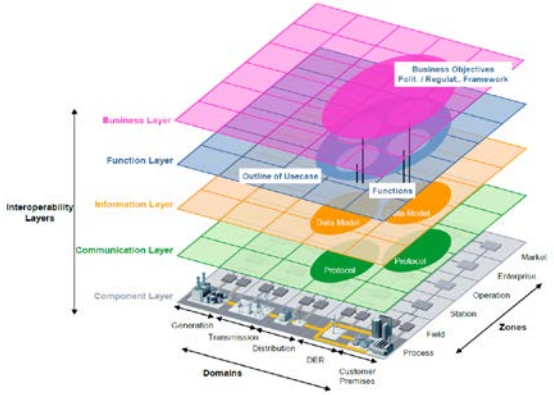
No	Country	Topic	Who
1	CN	IMSA - Intelligent manufacturing - System architecture	DING, Lu
2	ES	Spain activities	Michel Iñigo Ulloa
3	FR	TC184_N1733_French_proposal_for_TR_Big_Picture	Joseph BRIANT
4	DE	RAMI4.0	Hankel, Martin
5	DE	Industry4.0 component - Industrie-4.0-_Plug-and-Produce-zvei	Hoffmeister, Michael
6	IIC	IIC_PUB_G1_V1.80_2017-01-31 and IIRA-1-7-ajs	Jean-Pierre DESBENOIT
7	IT	Italian activities	Paolo Pinceti; Dighero, Stefano
8	JP	URM-MM	NONAKA, Youichi
9	JP	IVRA - Industrial Value Chain Reference Architecture	Ogura Nobuyuki
10	KR	RAMI 4.0+ modification proposal	Soonhung Han
11	SE	Sweden activities	Charlotta Johnsson; Thomas Lundholm
12	UK	UK activities	Aydin Nassehi
13	US	NIST model	Yan LU
14	CA	ISO standards	Wally Leonard
15	US	ISO 15704	Richard Martin
16	US	ISO standards	Dan Carnahan

Sample of NB “pretty pictures” for JWG21

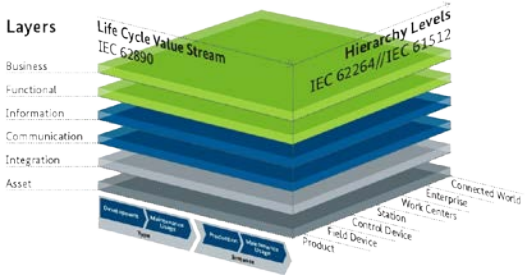
TC184 – N1733



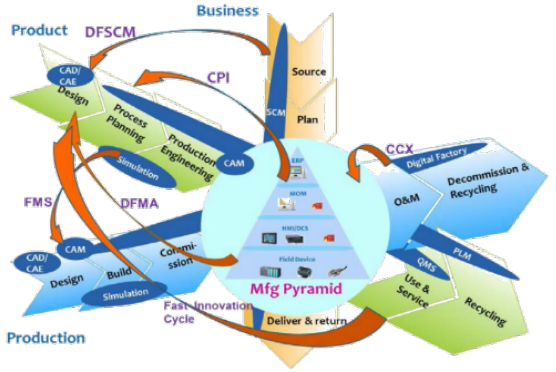
Smart Grid



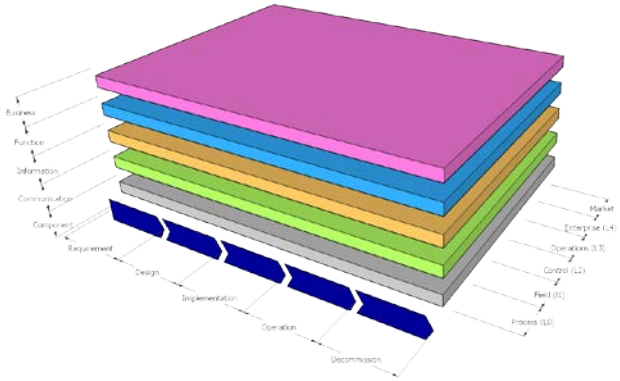
Germany – RAMI4.0



USA - NIST



France – Big Picture



Japan - SMU

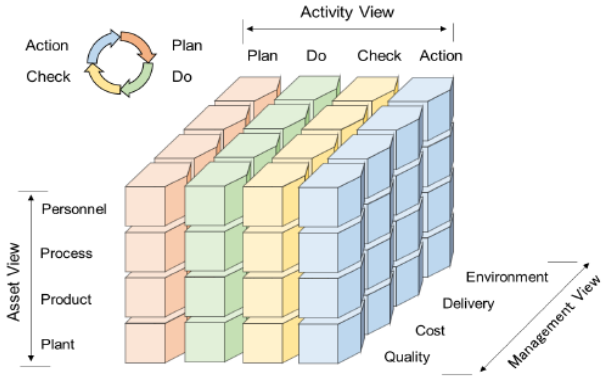
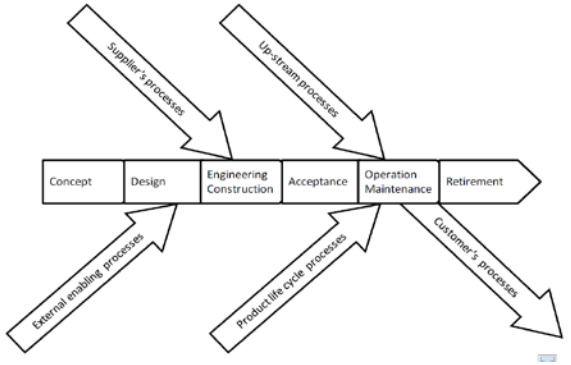
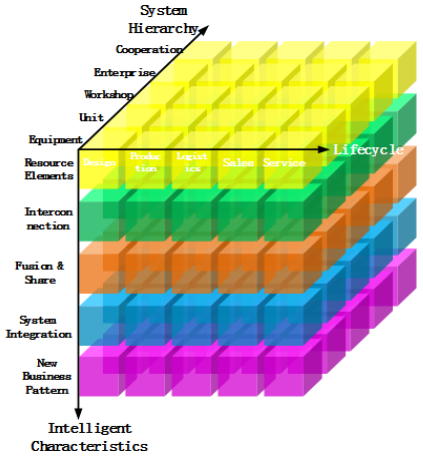


Figure 1: Three Views of Smart Manufacturing Unit

Japan - URM



China - IMSA



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How did we proceed?

Identified presentation dimensions

- Lifecycle CN, FR, IIC
- Lifecycle & Value stream DE
- Lifecycle JP2, US Dan, US RM
- Life phases UK
- Order Lifecycle US DB
- Personnel lifecycle US DB
- 3 Life cycles US Lu
- Supply chain JP2, US Lu
- System hierarchy CN
- Functional hierarchy DE, JP2
- Hierarchy (Equipment, Functional) FR, US Lu ISA95
- Intelligent functions CN
- Smart technologies UK
- Architecture Layers DE
- System hierarchy UK
- Smart Grid interoperability layers DE
- Viewpoints: Business, Usage, Function (incl. Domains), Implementation IIC
- Overview of exiting models JP1
- Views in SMU JP2

Additional presentation topics

- 3 dimensions SE
- Views
- Explanation for the model
- Sequence in the dimensions
- CN Basic: Terms, Metadata, Data Repository, Safety, Security, Management, Inspection/Evaluation, Reliability, and NO Availability
- ES Use Areas and Technologies
- Sectors FR, IIC
- Type of process FR
- Value chain FR
- Sub dimensions and Sub-Sub dimensions
- FR Topic: Security, Safety, Energy efficiency, Environment
- Interoperability FR
- Type of standard
- Usage for Marketing / Technical
- Changes in Automation DE
- Indirect connected Hardware DE
- Value networks DE
- Heterarchy communication DE
- Asset definition check in DE
- Economic and production KPI
- Unique identified properties (29005-2 or URL) DE
- Identifier resolution protocol DE
- Proprietary properties possible DE
- Asset administration shell conceptual models DE
- Structure of information in the Admin shell DE
- Sub-models like recipes from 61512 DE
- Intelligent functions CN
- Smart technologies UK
- Architecture Layers DE
- System hierarchy UK
- Smart Grid interoperability layers DE
- Viewpoints: Business, Usage, Function (incl. Domains), Implementation IIC
- Overview of exiting models JP1
- Views in SMU JP2
- Engineering and large structures decomposed into small ones DE
- Intelligent products DE
- Directions between Viewpoints (Guidance, Validate) IIC
- System characteristics & crosscutting functions IIC
- Use Cases JP1, JP2, US Dan
- Guidance trough all JP1
- Application oriented JP2
- Data portability US Dan
- Support the PDCA feedbacks JP2
- Small steps in development etc. Scrum JP2
- Service orientation thinking SE
- How to build Digital Factory SE
- Event based and non hierarchical twittering SE
- Workflows . Management processes UK
- Interactions inside one dimension and between dimensions UK
- Presentation view before the RM US Lu
- General use cases US Lu
- Synchronisation between Lifecycles US Lu
- Explicit syntax and semantic encoding US Dan
- Concept dictionary US Dan
- Info and Infrastructure for modelling US RM
- Views US RM
- Abstract to concrete, generic-partial-particular US RM
- Terms & Definition for us USRM
- Future oriented RM US RM

No way this is possible!!

Let's see if smaller group efforts help

TF1 – Scope and document structure
TF2 – Life cycle analysis
TF3 – Hierarchy analysis
TF4 – Layers analysis

} because this is what RAMI4.0 uses

TF5 – Use case analysis – because this is what we'd like to use
TF6 – Other topics analysis – because these have no other home
TF7 – Terms and Definitions – because we do not speak the same language

TF2, TF3, TF4, and TF5 gave preliminary results in Beijing, TF7 outlined plan for lexical analysis, and TF1 had an outline and draft scope for SMRM technical report. However, the path forward was not clear with such diversity as input.

We floundered and paused to reflect upon how to proceed.

Back to basics - Modeling 101

Models describe essential and relevant parts of an area of concern.

Models do not duplicate reality but are limited approximations of the subset of reality under consideration.

Extent of model detail is relative to its purpose.

Full model description always includes purpose, assumptions, and constraints.

To compare or unify reference models we need to identify common elements of architecture in those models – what's the pattern here?

Express the Smart Manufacturing Reference Model pattern with a meta-model

- Guidance for meta-model expression, use:
  - ISO/IEC/IEEE 42010 – Architecture description
  - ISO 15704 – Requirements for enterprise-reference architectures and methodologies
- Where possible, introduce new terms for critical concepts not used by "National" presentations – a meta-language
- The term "model" must refer to the content of an SMRM, not the SMRM itself, i.e. refer to SMRM as a "framework"
- Keep the "picture" relatively simple, use short labels, minimize concepts, finesse ambiguity
- Use Cmap tool (https://cmap.ihmc.us) to express meta-model

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Crafting a meta-model for SMRM

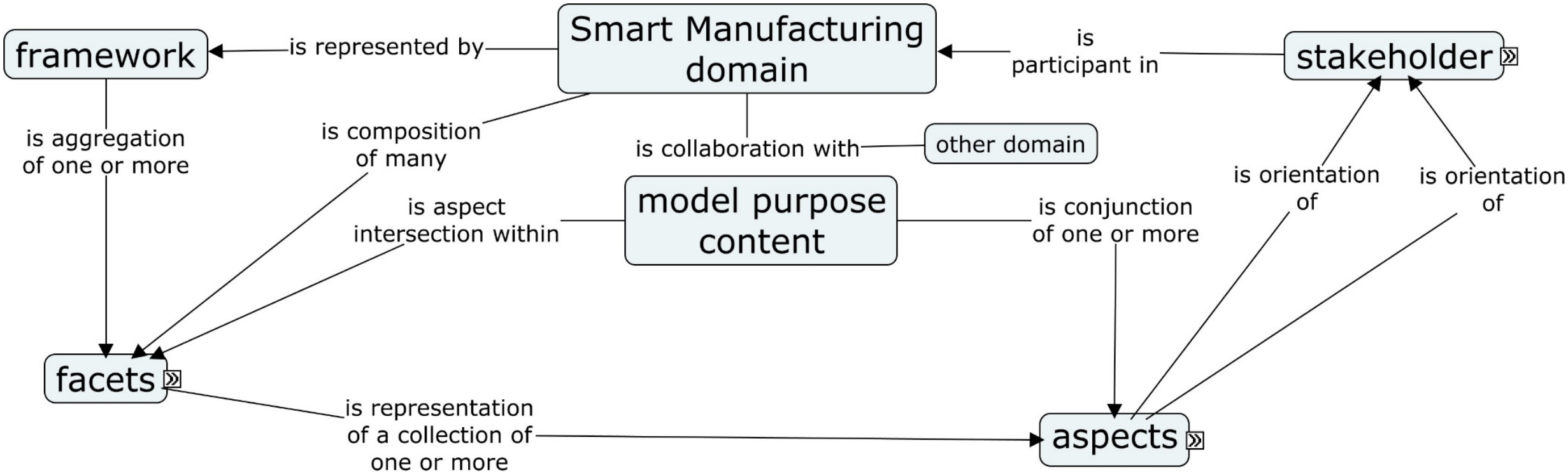
SMRM meta- model architecture objectives

1. Capture the essence of each "National" SMRM presentation – all 14 of them!
2. Integrate discussion points articulated by JWG21 participants – 4 meetings and dozens of conference calls
3. Avoid using terminology lacking consistent use among "national" SMRM presentations or favoring any of them
4. Provide a concise "language" for development of SMRM
5. Include concerns of both standards developers and standards users
6. Provide opportunity for both technical and marketing representations – if we cannot sell it, we fail

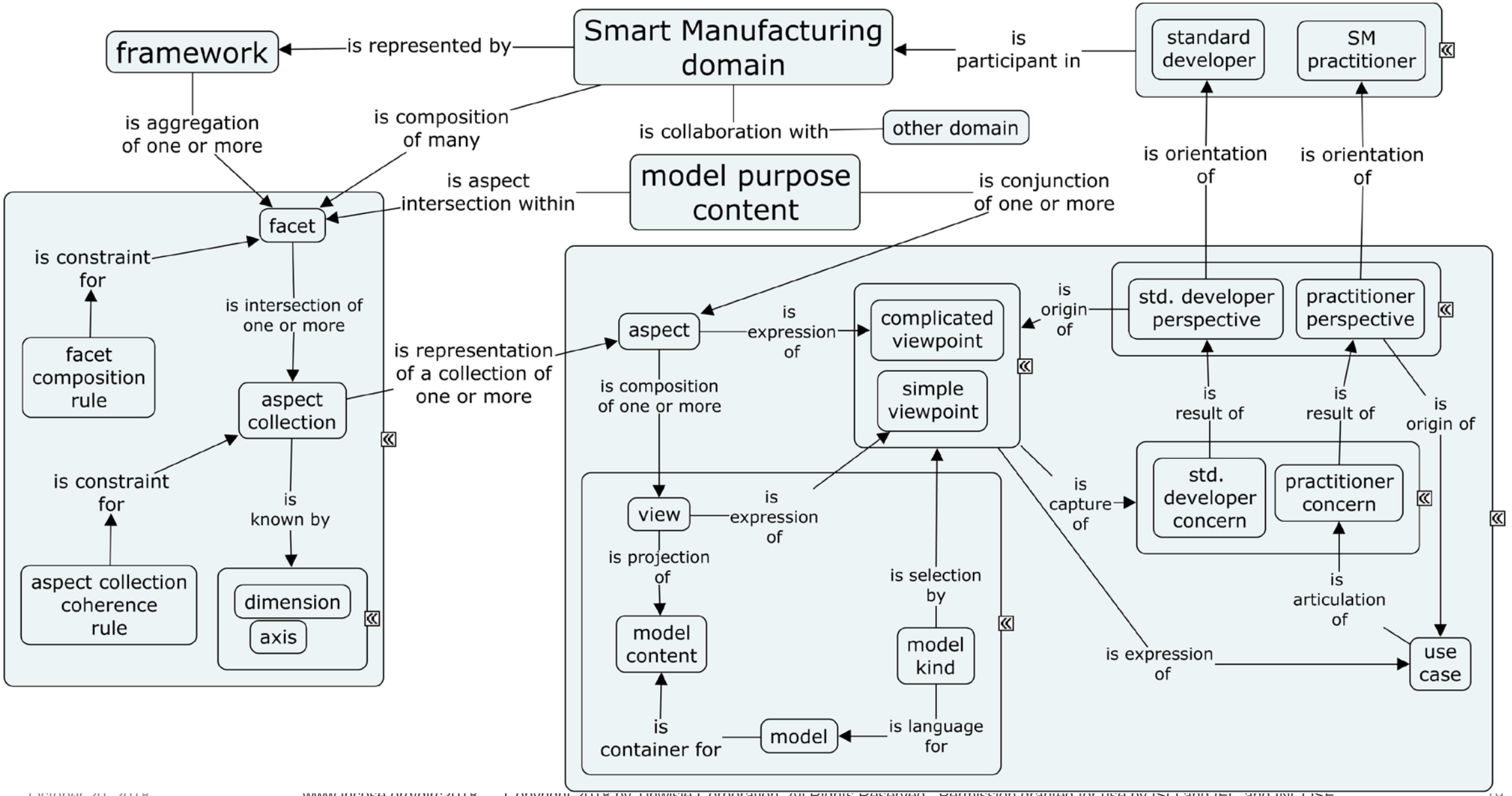
Initial meta-model assumptions

- A modelling view, the only kind of view we can create conceptually, consists of a projection of content from an explicit or implicit model – a very broad interpretation of 'model'.
- A reference model must allow a wide variety of content types - it must accommodate multiple purposes for model.
- Collections of things does not imply an ordering of those things even if a natural ordering exists – life cycle dilemma.
- Coherence and composition require an expressed relationship among constituents.
- And certainly a few more exist for discovery.

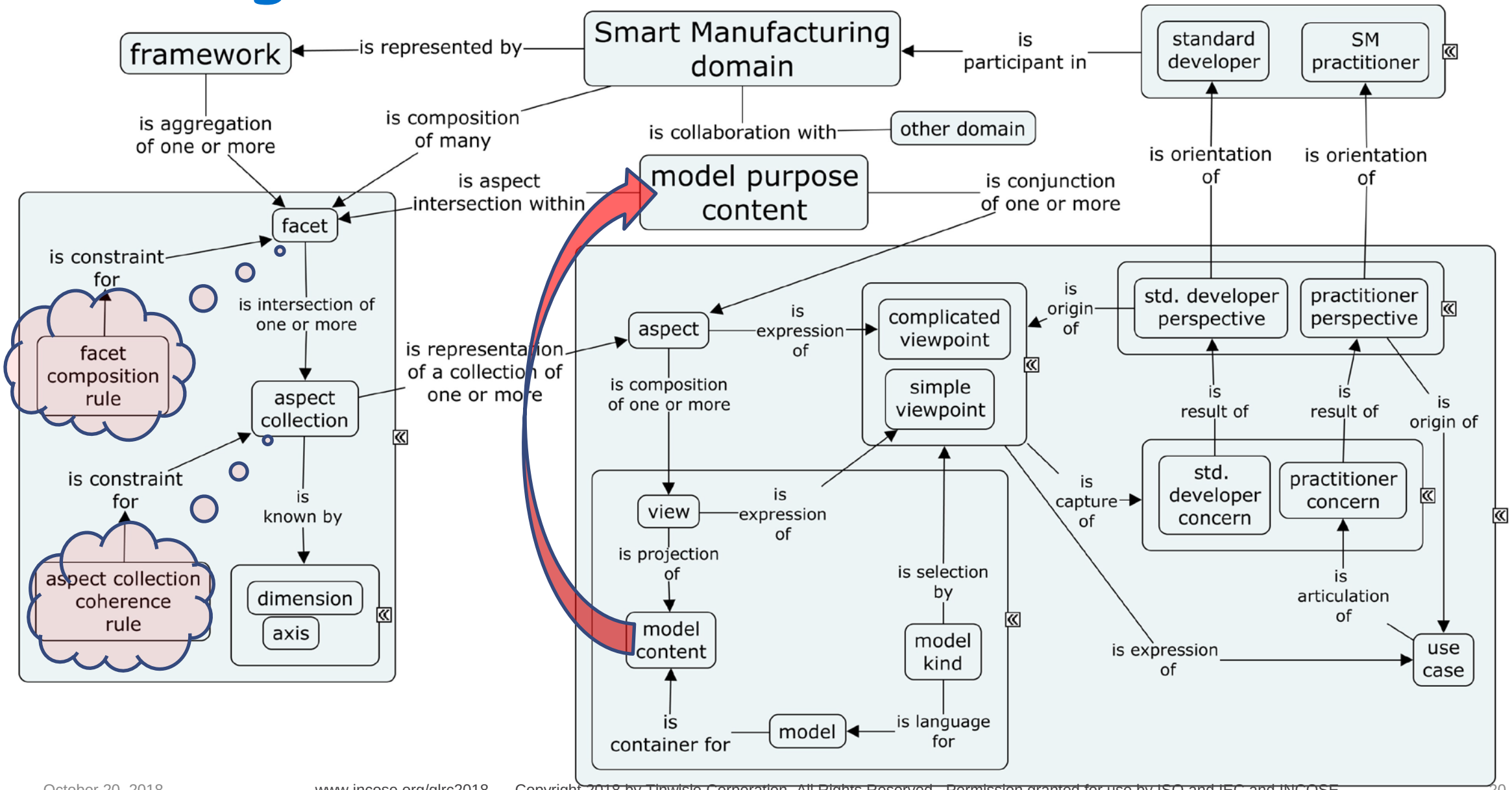
SMRM meta-model from 10,000 meters



Taking a closer look



Making the meta-model work for SMRM



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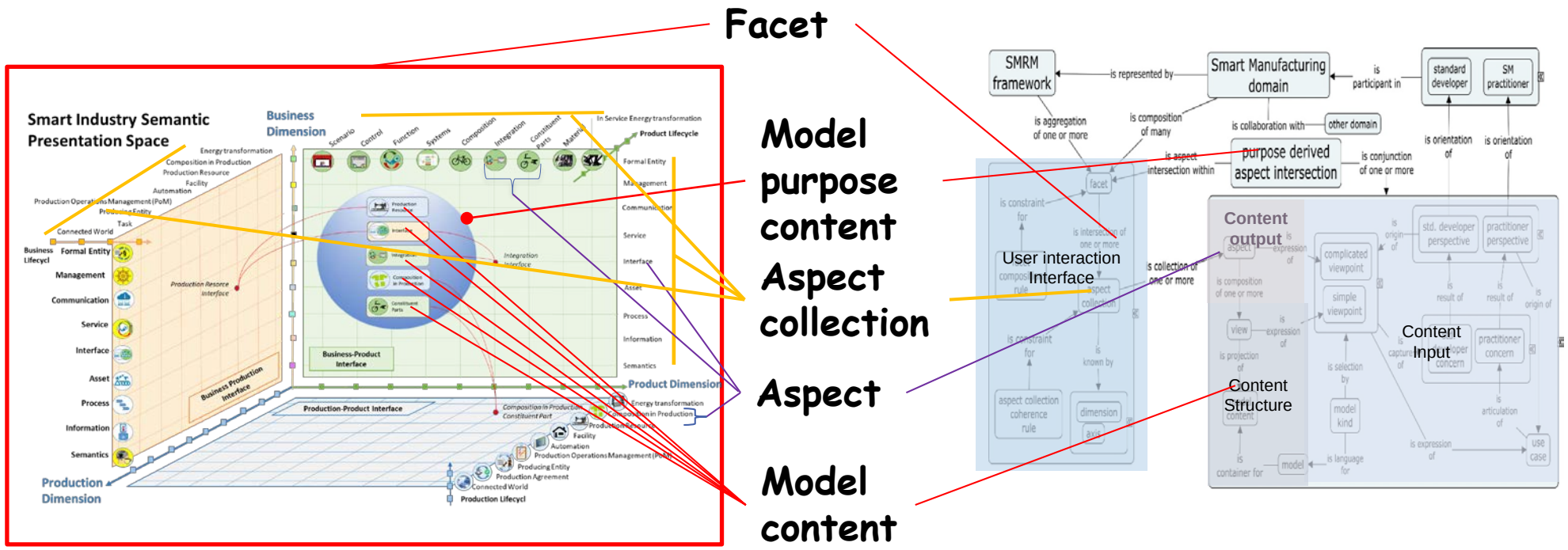
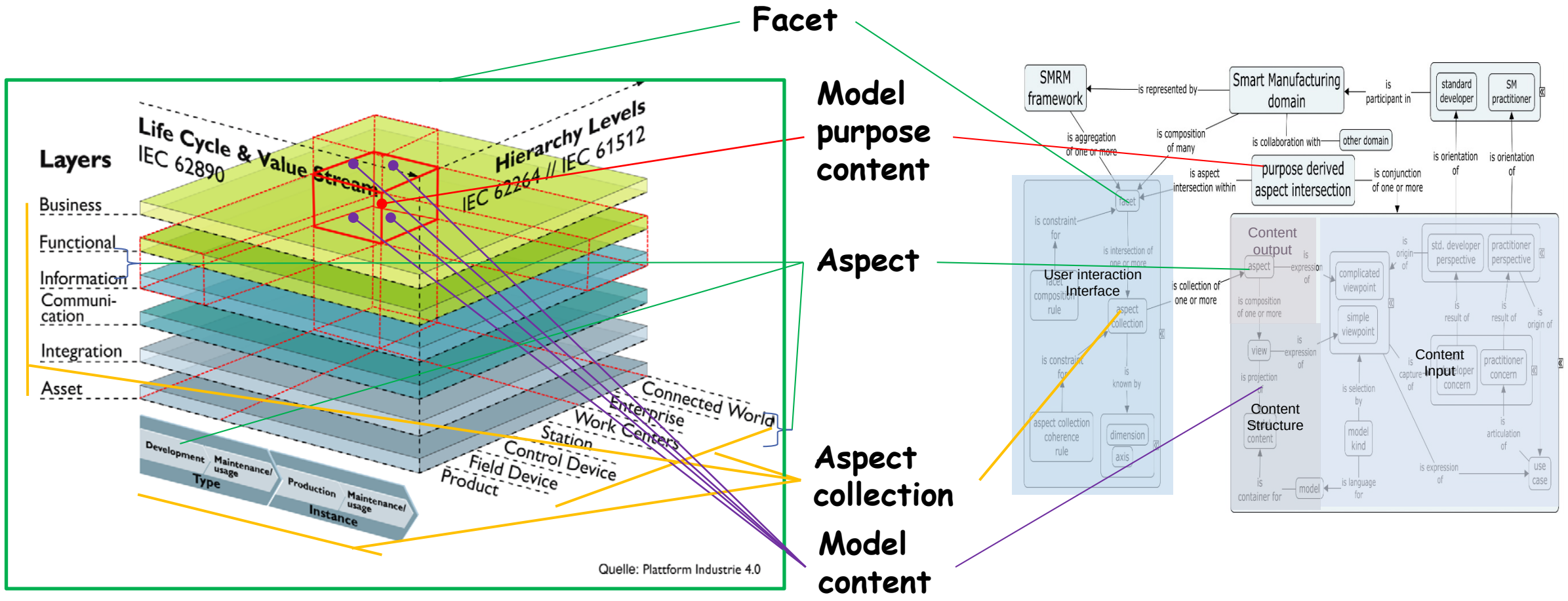
Mapping meta-model to models?

Scandinavian Smart Industry Framework mapping to SMRM Meta-model



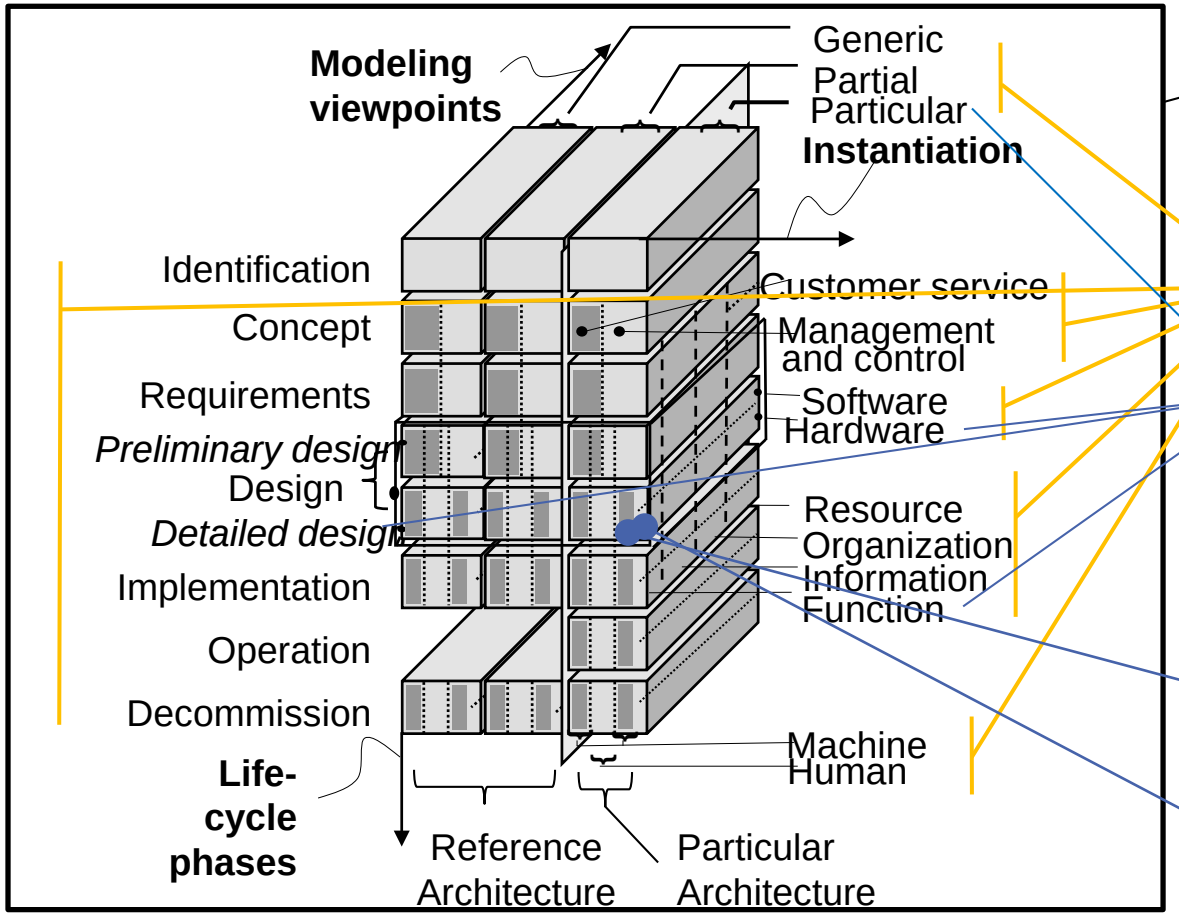
The **model purpose content** is the cross product of the content of the intersecting aspects, i.e. the model content projected to compose the view(s) that comprise each of the intersecting aspects. As shown above: Business(Interface), Product(Integration, Constituent Parts), Production(Production resource, Composition in Production).

RAMI4.0 mapping to SMRM Meta-model



The **model purpose content** is the cross product of the content of the intersecting aspects, i.e. the model content projected to compose the view(s) that comprise each of the intersecting aspects. As shown above: Layers(Functional, Information), Hierarchy Levels (Connected World, Enterprise), Life Cycle & Value Stream (Development).

GERA model mapping to SMRM Meta-model



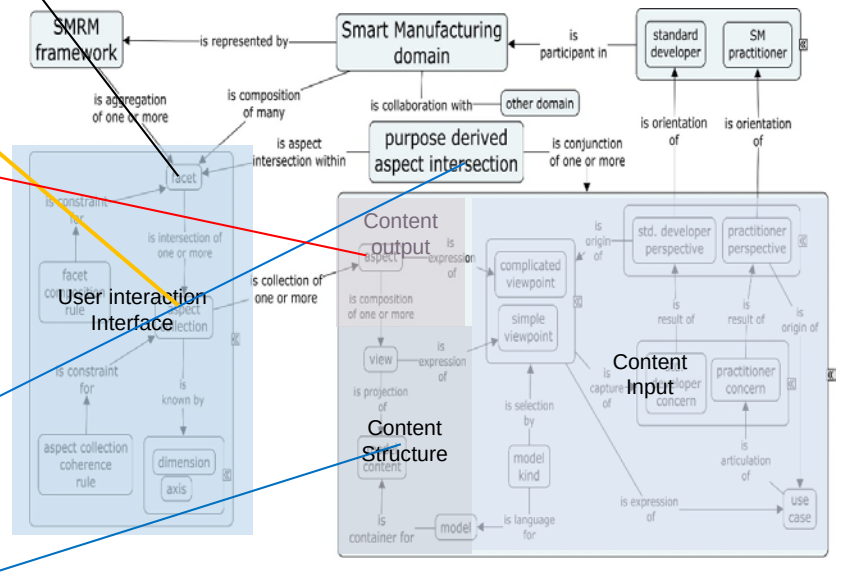
Facet

Aspect collection

Aspect

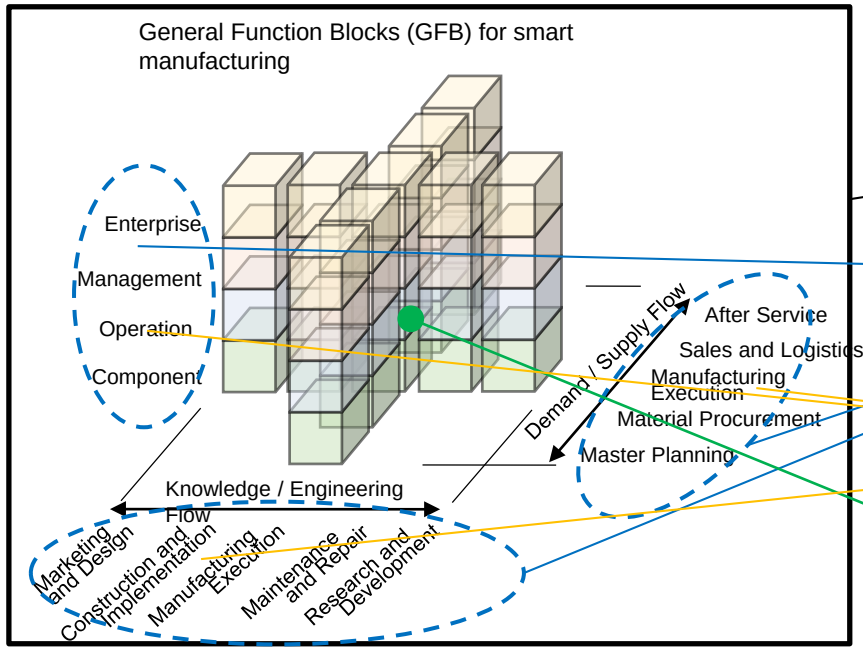
Model purpose content

Model conten



The model purpose content shown above: Life cycle phase (Detailed design), Instantiation(Particular), Viewpoint(Function), Manifestation(Hardware). Notice the overlay or partitioning of the sub-dimension for Manifestation on the Modelling Viewpoints surface of the 3-D representation. In total, this representation shows six different aspect collections on one 3D structure.

SMU and GFB mapping to SMRM Meta-model



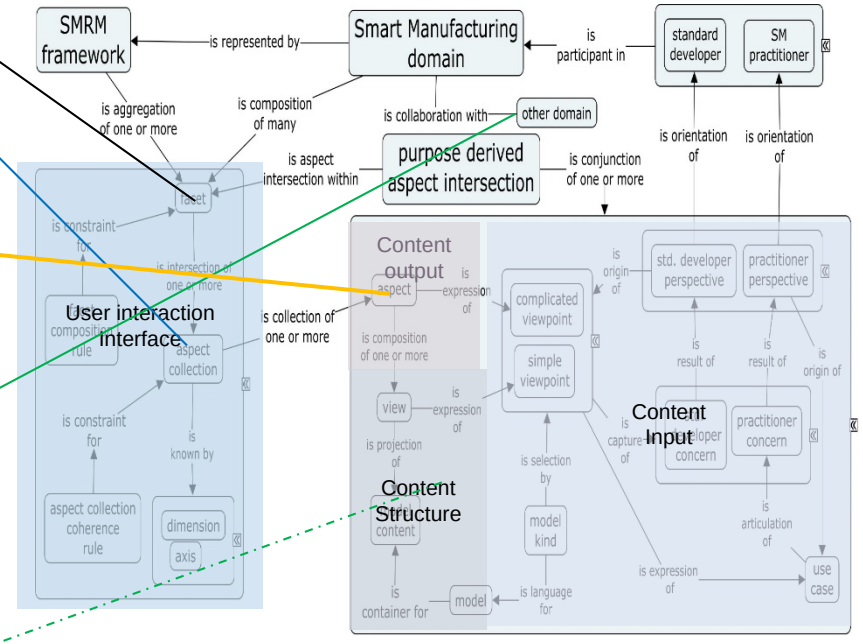
Facet

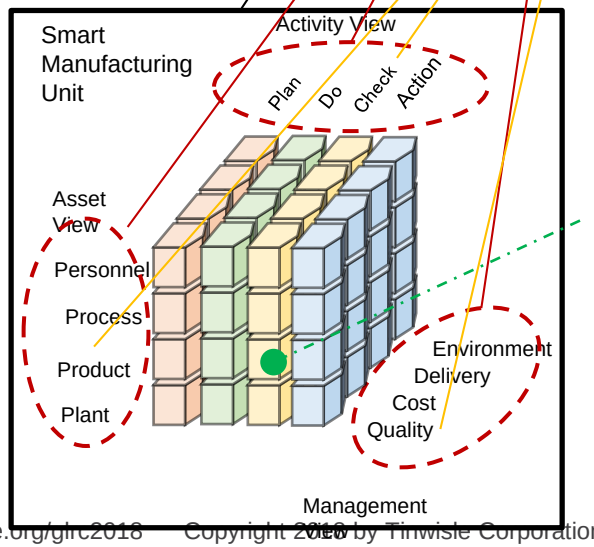
Aspect collection

Aspect

Model purpose content

Model content





Facets combine to express the **model purpose content**. SMU for Aspects of Product, Quality, Check intersects with Aspects of Operations, Knowledge/ Engineering Flow Manufacturing Execution and Demand/Supply Flow Manufacturing Execution. e.g. a protocol model for inspection of product quality during production.

Facets may be nested, a shown here, or partitioned to meet the needs of a specific modelling purpose and realized system. Notice that this nesting provides many opportunities to identify stakeholder concerns.

Big Picture Matrix mapping to SMRM Meta-model

Standard and/or project classified along the Life-cycle axis	Object of standardizati-on	Place in the "Big Picture"			Way of integration	Sector of activity (application)	Point of view (aspect)	Interoperabilit barrier
		Life-cycle axis	Value chain	Enterprise				
NP= Not Pertinent	P = Product S= System M = Model T = Tool I = Interface O = Overview	ND = Needs determination D = Design CI = Construction & Implementation UD = Usage & Decommission	BSE = Buy side exchange FAM = Resources, Facilities & Assets Management SSE = Sell Side Exchange	SA = Shop Floor Automation PM = Production management BM = Business management	F = Federation U = Unification C= ????	(text)	Explicit name (Product, resource,process….) NS = No specific PoV	C= Conceptual T=Technologica l O =Organzational
ISO 15704 *Requirements for enterprise reference architectures and methodologies*	T	NP	NP	NP	U		NS	
IEC/ISO 62264-1 *Enterprise control*	O,I	SYS-D, SYS-CI, SYS-UD	NP	PM	F		NS	
IEC/ISO 62264-2 *Object model attribute*	M	SYS-D,SYS-CI	NP	PM	F		PROC-PROP	
IEC/ISO 62264-3 *Activity models of*	M	SYS-D,SYS-CI	NP	PM	F		PRODUCTION-PROP	
IEC/ISO 62264-5 *Business to manufacturing transactions*	M	SYS-UD	NP	PM, BM	F		TRANSACTION-PROP	
ISO 15745-1 *industrial syst. Integration*	O,S,P	PROD-D,PROD-CI	FAM	SA	F		PROD-PROP	
ISO 15531-1 *MANDATE Industrial manufacturing management data- part 1 general overview*	O	SYS-D,SYS-CI	FAM	PM	U		RES-PROP, PROC-PROP	

Facet

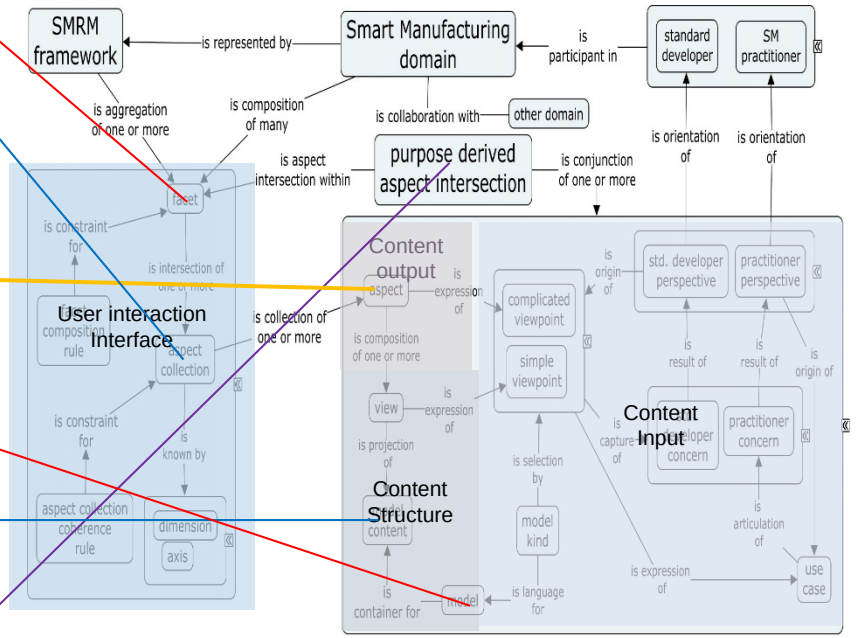
Aspect

Aspect collection

Model

Model content

Model purpose content



While the meta-model does map to this work, the Big Picture Matrix is not a reference model in the sense of the Big Picture model. The Big Picture Matrix is not intended as guidance for development of a model, but rather is a mechanism for classifying existing standards according to various attributes identified in the Big Picture Matrix information schema, which is a derivative of the Big Picture reference model.

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What does mapping tell us?

Aspect collections

- Similarly labeled collections contain different aspects
- Collections range from regularly ordered to not ordered
- Aspects occur only once in a particular collection
- Collections variety widely in aspects included
- Collections sometimes have sub-collections
- Collections are model purpose specific
- Collection representation is most often linear
- Aspects within a collection interact with each other
- No collection is use case or smart technology specific

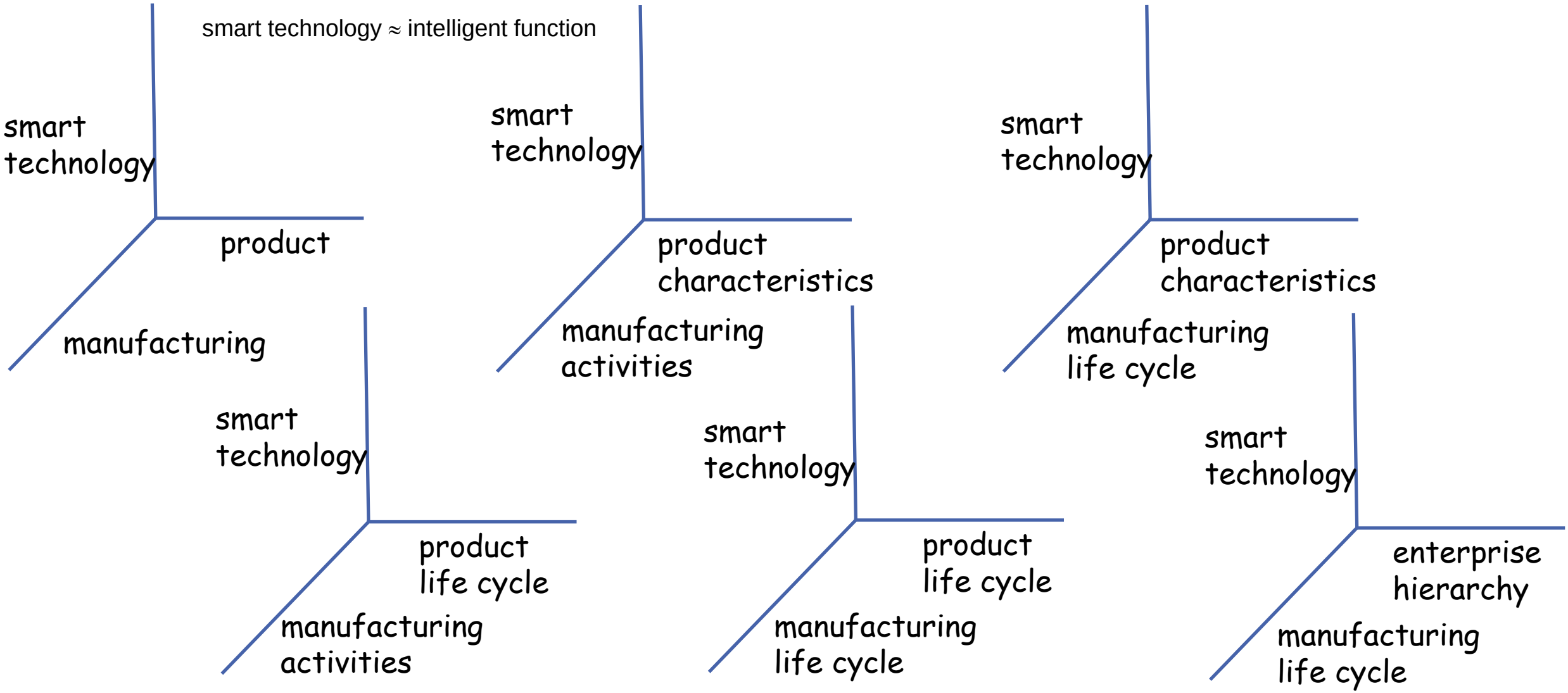
Facet composition

- A particular aspect usually appears in only one collection within a facet
- A facet can be partitioned into several sub-facets
- One facet can be model content for another facet
- Facets occur for many different configurations of aspect collections
- Facets of more than 3 aspect collections are difficult to comprehend
- Interaction of aspects within a collection are difficult to represent.

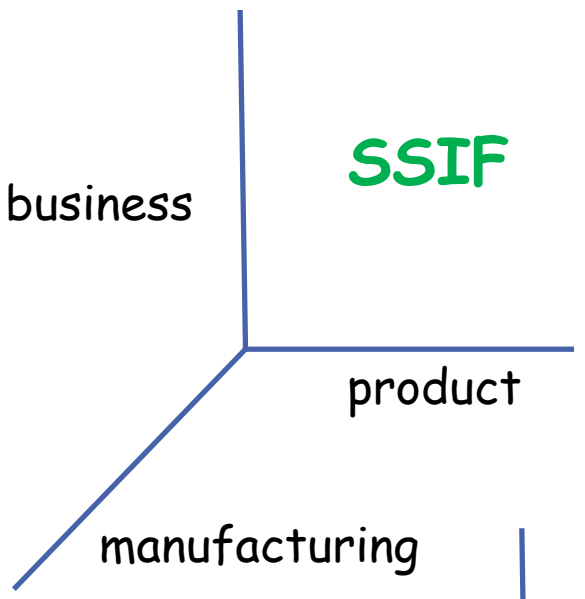
Model purpose content

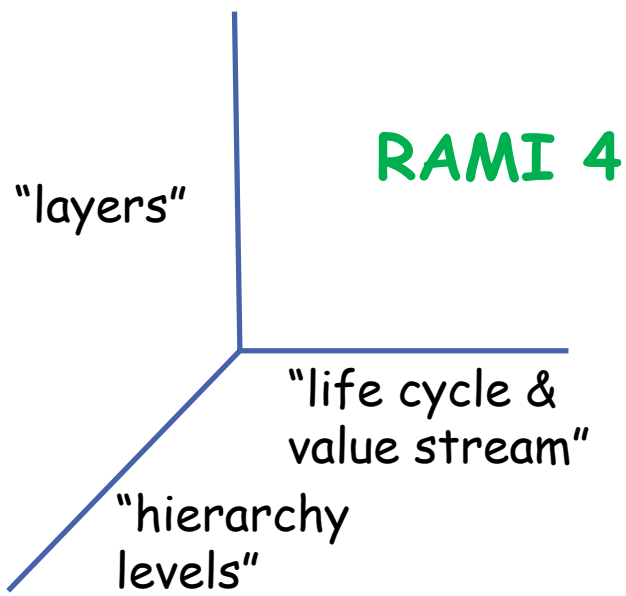
- Existing smart manufacturing models have little smart technology content – we brought what we knew, not what we want to know!
- Purpose content can emerge from interaction of aspects or be a label for that interaction.
- A SMRM will need multiple representations of the manufacturing domain space to identify the many aspect interaction content expected in the future.
- The linkage between use cases and model purpose content is poorly understood.

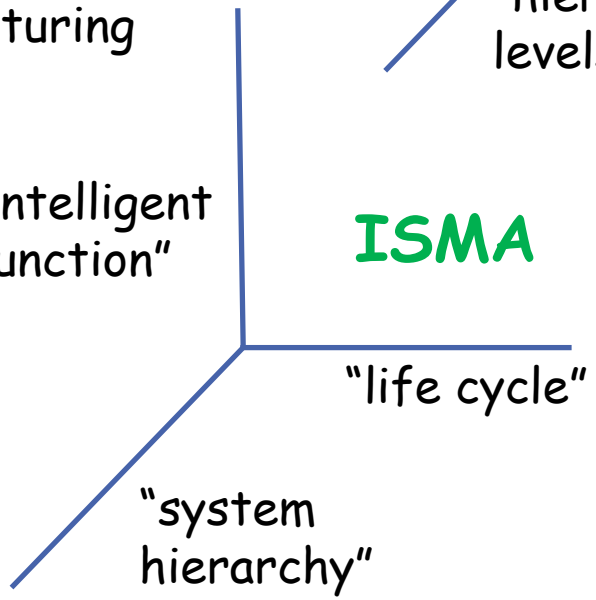
Smart Manufacturing Reference Model Framework: one reference model framework, many facets

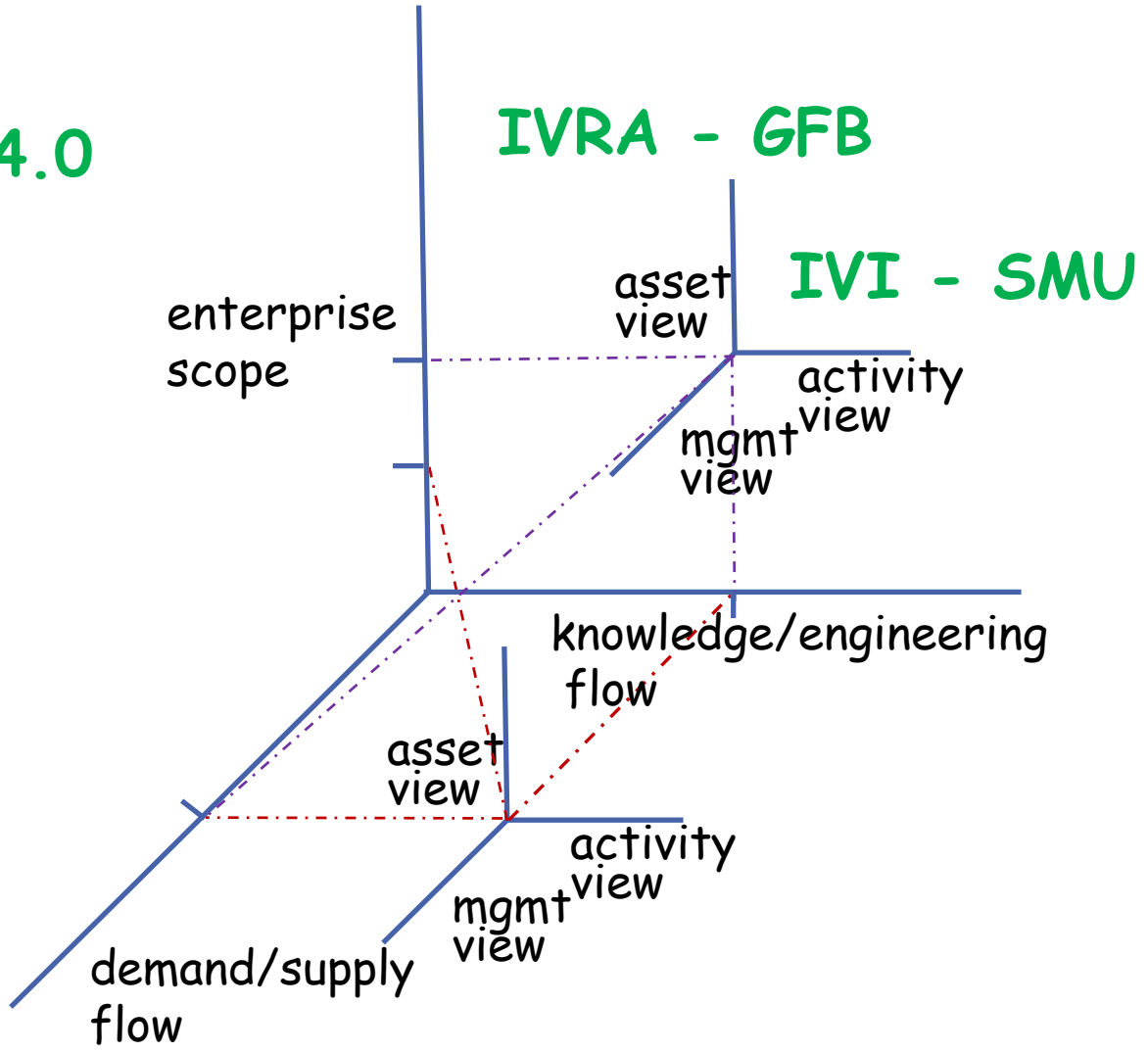


Even more opportunity for modelling using the SMRM Framework









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