



Standardized Ontologies as the Glue to Secure a Quality Digital Thread & its Impact on Business

Mikkel Haggren Brynildsen,
Chief Data Scientist, Data & AI, Grundfos.

PLM Road Map™ EMEA & PDT Europe 2023
The Digital Thread in a Heterogeneous, Extended Enterprise Reality
A call for PLM Professionals to share their knowledge & experience
CIMdata 15 & 16 November -eurostep-

GRUNDFOS 
Possibility in every drop



GRUNDFOS 
Possibility in every drop

One of the world's leading pump and water solutions companies

- 16,000,000** units produced per year
- 20,000+** employees
- 87.9%** owned by the Poul Due Jensen Foundation
- 1945** when it all started
- DKK 28.7bn** net turnover in 2021
- 5%** of revenue reinvested



Mikkel H. Brynildsen
Ph.D.
Chief Data Scientist, Grundfos "Data & AI"
mbrynildsen@grundfos.com

M. H. Brynildsen @ PLM Road Map EMEA & PDT Europe 2023

Agenda

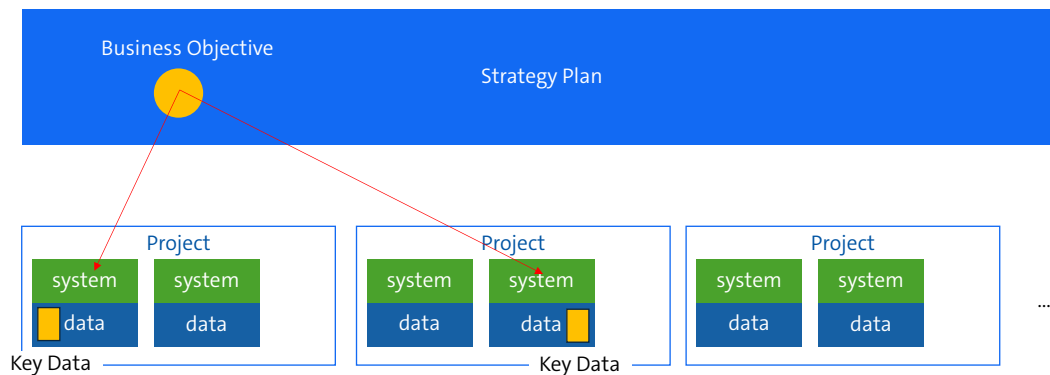


- Data Strategy
- Ontology explained by example: Operating instructions, machine readable datasheet
- Hierarchies, Taxonomies, Knowledge Graphs and Data models in PLM

Data Strategy



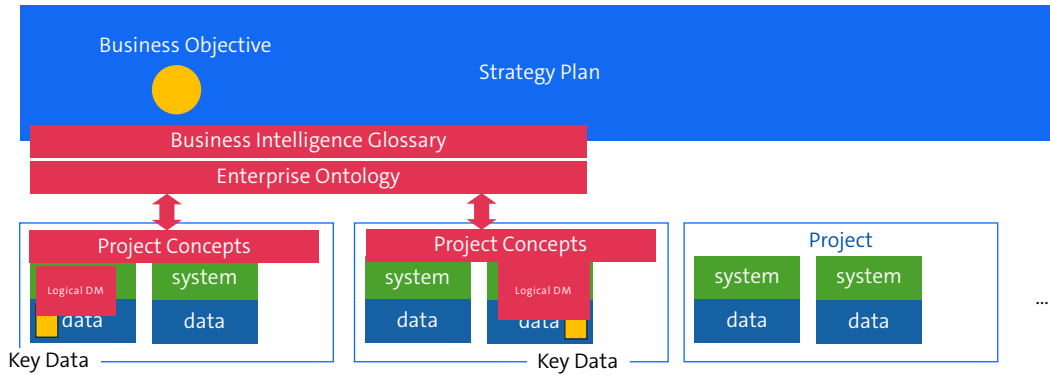
Data strategy is a coherent plan specifying the why, what, and how concerning the data needed to ensure the desired business outcomes.



Data Strategy



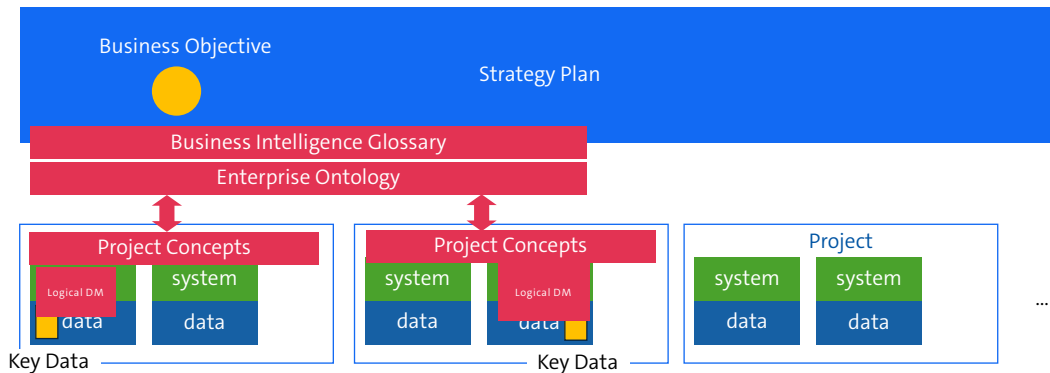
Data strategy is a coherent plan specifying the why, what, and how concerning the data needed to ensure the desired business outcomes.



Data Strategy



Data strategy is a coherent plan specifying the why, what, and how concerning the data needed to ensure the desired business outcomes.

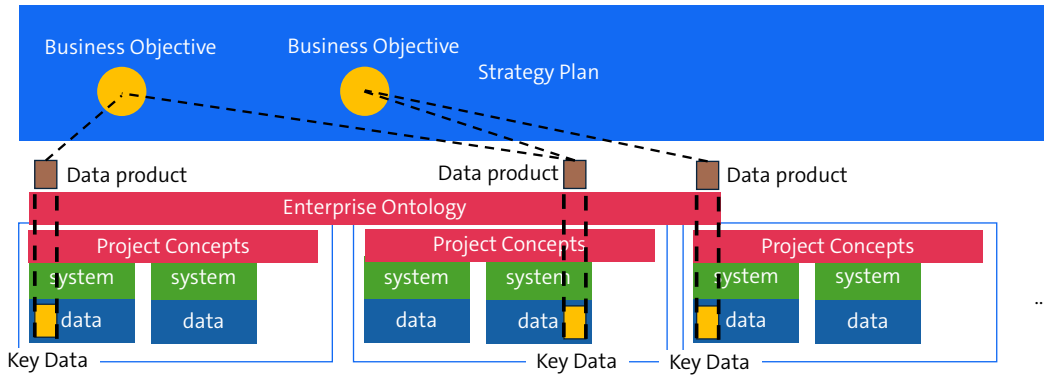



... = covered by data governance, data catalogs, data quality

Data Mesh



Data products are reusable, enterprise standardized key data modules



 = data products are treated just as any other sub-assembly of sold products. This means quality assurance, business owners, lineage, documentation, usage terms and conditions, service level agreement, access protocols, user groups, etc.

M. H. Bynildsen @ PLM Road Map EMEA & PDT Europe 2023

6

Why we are interested in Semantic Web



- RDF is being used as the “protocol” to digitalize information in many industrial applications (including IOT)
- RDF and semantic web technologies are open and community-driven (limited vendor lock-in)
- Standards (including upper ontologies) give us a language to communicate data in our business.
- The words "semantic layer" and "ontology" are no longer mysterious to business.

<https://rds.poscaesar.org/ontology/lis14/ont/core/>

<https://marketplace.colibra.com/listings/knowledge-graphs-powered-by-colibra/>

<https://api.sap.com/api/SAPSemanticLayer/overview>

<https://docs.oracle.com/en/database/oracle/oracle-database/23/rdfm/owl-concepts.html#GUID-3EC5F30E-9175-4B7B-946C-3117BC30610A>

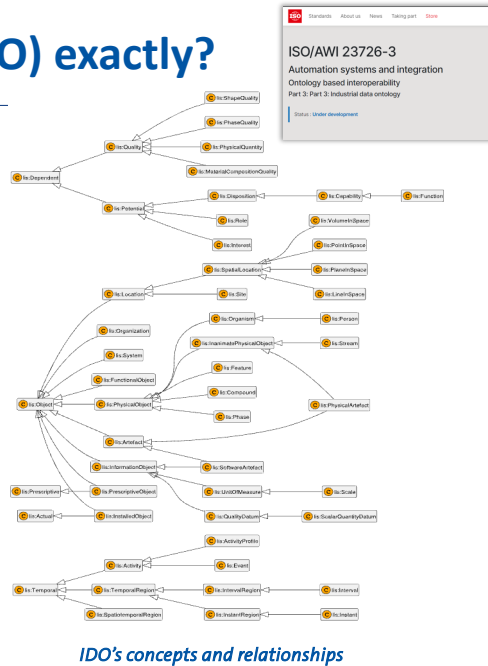
<https://learn.microsoft.com/en-us/azure/digital-twins/concepts-ontologies-adopt>

M. H. Bynildsen @ PLM Road Map EMEA & PDT Europe 2023

7

What is Industrial Data Ontology (IDO) exactly?

- ISO/AWI 23726-3 (IDO) is part of ISO/AWI 23726 (OBI) (Ontology-Based Interoperability) managed by ISO / TC 184 / SC 4 Industrial Data
- “An ontology for representing industrial data and information, building vocabularies and manage asset models that employ reference data libraries and exploit OWL reasoning”
- Derived from / inspired by
 - ISO 15926-2:2003
 - ISO/IEC 21838-2:2021 – Basic Formal Ontology (BFO)
- Formulated in W3C’s OWL 2 language
- Enables precise modelling
- 54 classes, 4 datatype properties, 88 object properties
- Developed and applied in Norwegian Energy (O&G) industry
- Formerly known as ‘ISO 15926-14 Data model adapted for OWL2 Direct Semantics’



IDO's concepts and relationships

M. H. Ravnildsen @ PLM Road Map EMEA & PDT Europe 2023

IDO based model Standardized Modelling Patterns – as software!



Contents [index](#)

© Signatures are organised according to their namespace. Click arrow to expand list. Click text to display page in right window. Items in the list with a colour box represent a namespace. A package is a set of templates constructed for a particular purpose, often as part of a specific project.

Expand all Contract all

▼ <http://rds.posccaesar.org/>

► [ontology/](#)

```

? List<owl:Class> ?type,
! ? xsd:string ?label,
! ? xsd:string ?description,
? List<rdfs:Resource> ?seeAlso,
? ottr:IRI ?definedBy,
? owl:Class ?datumClass
} :: {
  plmtp1:RDLIndividual(?uom, ?type, ?label, ?description, ?seeAlso, ?definedBy)
} .
                    
```

© The pattern of the template is illustrated by expanding a generated instance. Below the generated instance is shown in different serialisations, and its expansion is presented in different formats.

Generated instance

stOTTTR

plmtp1:RDLUOM(x:argument1, (x:argument2-1, x:argument2-2), _:argument3, _:argument4, (_:argument5-1, _:argument5-2), x:argument6, x:argument7)

RDFwOTTR

Visualisation of expanded RDF graph

© Each resource node is linked to its IRI. Type relationships are not visualised, rather each node contains its type.

▼ Hierarchical horizontal layout (dot)

```

graph LR
  A["owl:NamedIndividual, x:argument2-2, x:argument2-1, x:argument1"]
  B["rdfs:comment"]
  C["rdfs:seeAlso"]
  D["rdfs:label"]
  E["rdfs:seeAlso"]
  F["rdfs:isDefinedBy"]
  G["x:argument6"]
  A --> B
  A --> C
  A --> D
  A --> E
  A --> F
  A --> G
                    
```

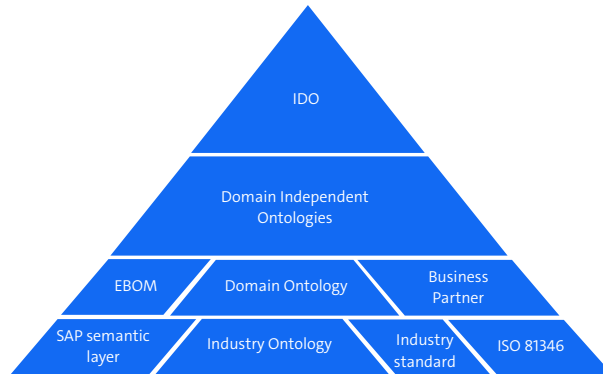
► Hierarchical vertical layout (dot)
 ► Spring model layout (neato)

Contents

- Ido
- Metadata
- Parameters
- Patterns
- Dependencies
- Metrics
- Serialisations
- Profiles

M. H. Ravnildsen @ PLM Road Map EMEA & PDT Europe 2023

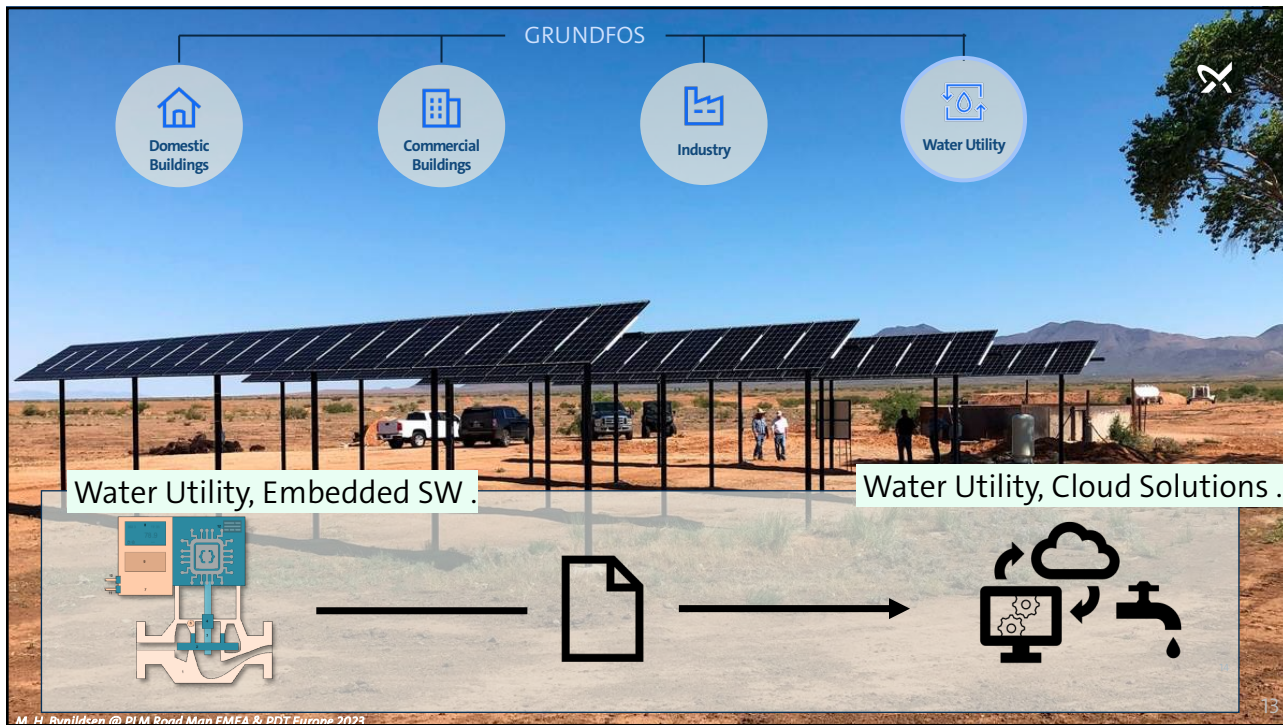
IDO Upper ontology



Ontology explained by example:
instructions, machine readable datasheet

Standardized Ontologies as the Glue to Secure a Quality Digital Thread & its Impact on Business

PLM Road Map & PDT Europe 2023





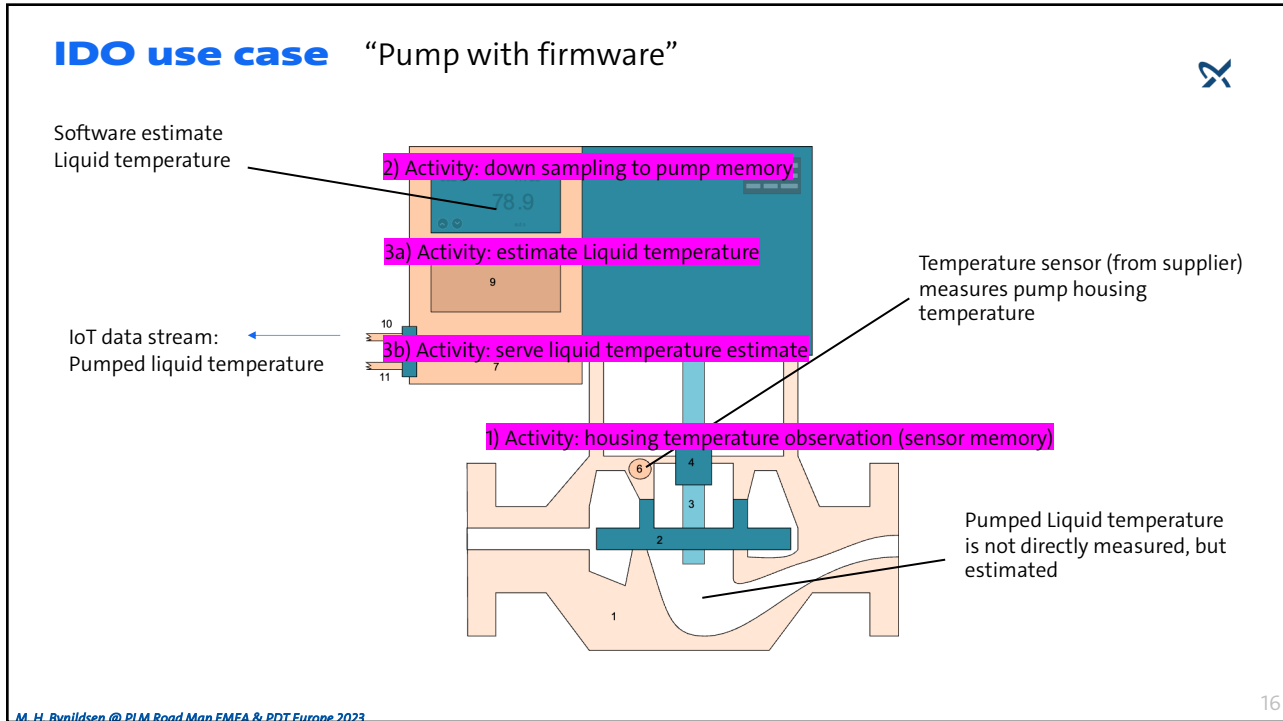
M. H. Rumliden @ PLM Road Map FMFA & PDT Europe 2023

IDO based domain ontology

Requirements

- 1) Engineers should document their engineering using standardized digital artifacts (SysML, UML, WoT, IEC/ISO 81346,...)
- 2) We need to be able to store and retrieve master data about what software is combined with what hardware for enterprise-size portfolio (~600.000 types of pumps).
- 3) We want to reuse community-released, standardized, modelling patterns and reasoning modules for equipment, qualities and quality data (POSC Caesar Association (PCA)).
- 4) We want to minimize the amount of bespoke semantic analysis scripts being written.

M. H. Rumliden @ PLM Road Map FMFA & PDT Europe 2023



IDO WoT Standardized Information Handover

WoT Thing Description files

Standardized IoT profiles about pumps.

<https://www.w3.org/WoT/>

“The LIQUID_TEMP range is [-40, -39, -38, ..., 119, 120]”

```

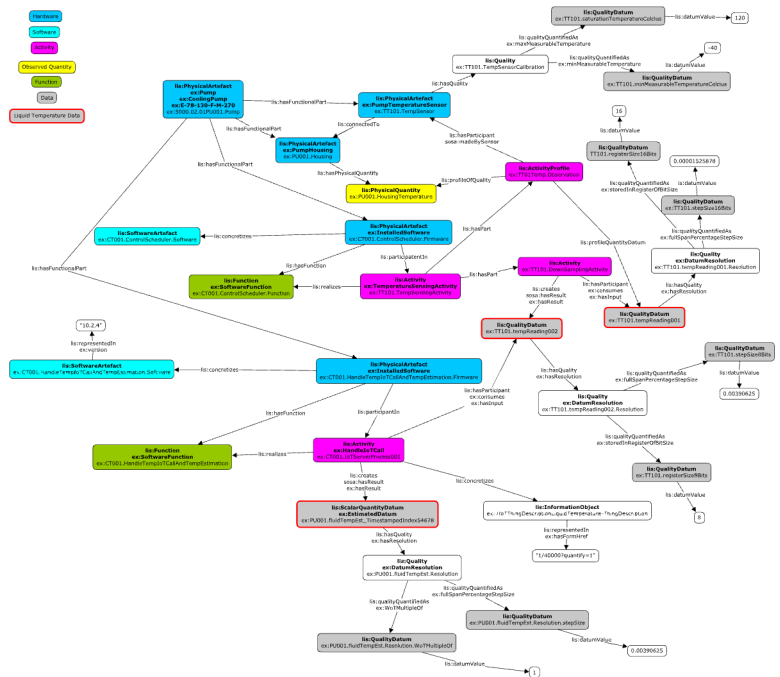
{
  "@context": [
    "https://www.w3.org/2019/wot/t4/v1",
    {
      "acme": "https://www.acme.com/linkeddatabserver/iotprotocol#",
      "assets": "https://www.acme.com/linkeddatabserver/assets#",
      "unit": "https://www.qudt.com/unit#",
      "modbus": "https://www.w3.org/2019/wot/modbus#",
      "lis": "http://rds.posccaesar.org/ontology/lis14/rd1/",
      "ex": "http://example.org/pumpwithfirmware"
    }
  ],
  "id": "assets:3ea24c16-afc2-4d61-af6a-2964d76f160a",
  "@type": [
    "Thing",
    "ex:E-78-130-F-M-270"
  ],
  "title": "E-78-130-F-M-270",
  "properties": {
    "acme:LIQUID_TEMP": {
      "type": "number",
      "readOnly": true,
      "description": "Liquid Temperature",
      "lis:PhysicalQuality": "ex:Temperature",
      "unit": "unit:DEG_c",
      "minimum": -40,
      "maximum": 120,
      "multipleOf": 1,
      "forms": [
        {
          "href": "modbus+tcp://127.0.0.1:60000/1/40001?quantity=1",
          "op": [
            "readproperty"
          ],
          "modbus:entity": "HoldingRegister"
        }
      ]
    }
  }
}
    
```

17

M. H. Ravnildsen @ PLM Road Map EMEA & PDT Europe 2023

IDO use case

- “Pump with firmware”



Based partly on patterns here:



<https://rds.posccaesar.org/doc/patterns/>

M. H. Ravnildsen @ PLM Road Map EMEA & PDT Europe 2023

IDO based model, benefits



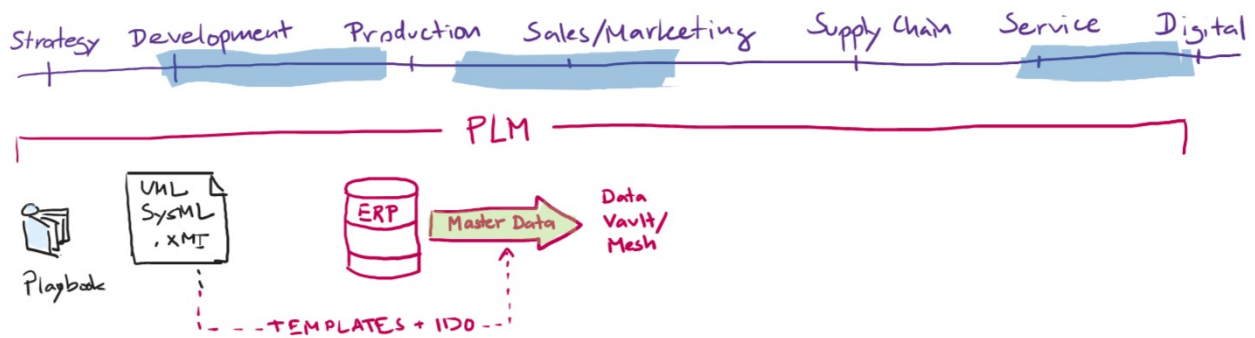
- 1) Digital offerings and the connectivity teams get standardized quality operating instructions (WoT TD Files) for IoT products on demand to produce digital offerings.
- 2) In product development: IoT Profiles of new and changed IoT products can be validated, on the combined HW+SW perspective.
- 3) The Enterprise can roll out hot-fixes and new IoT features to all digital offerings through a streamlined standards-based system.
- 4) The Enterprise can expand the information handover system to handle external manufacturers IoT operating instructions. The modelling is based on industry standards. IoT alliances can be build.

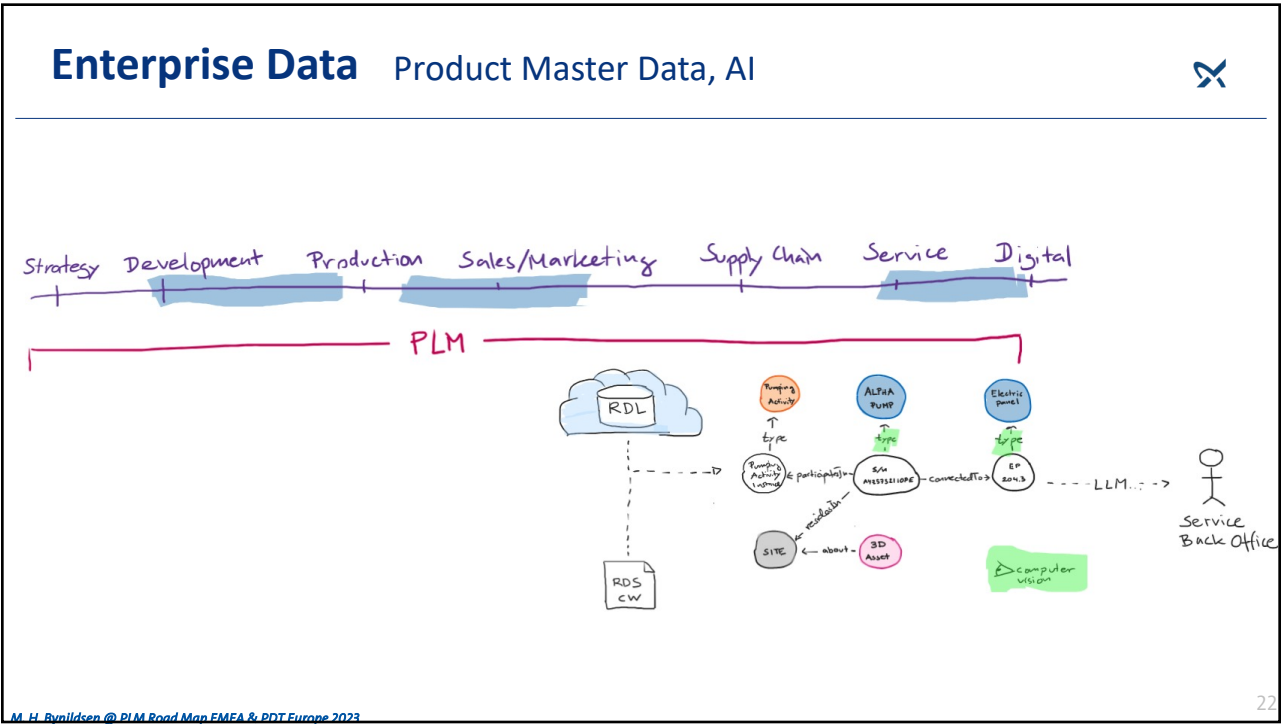
M. H. Ravnildsen @ PLM Road Map EMEA & PDT Europe 2023



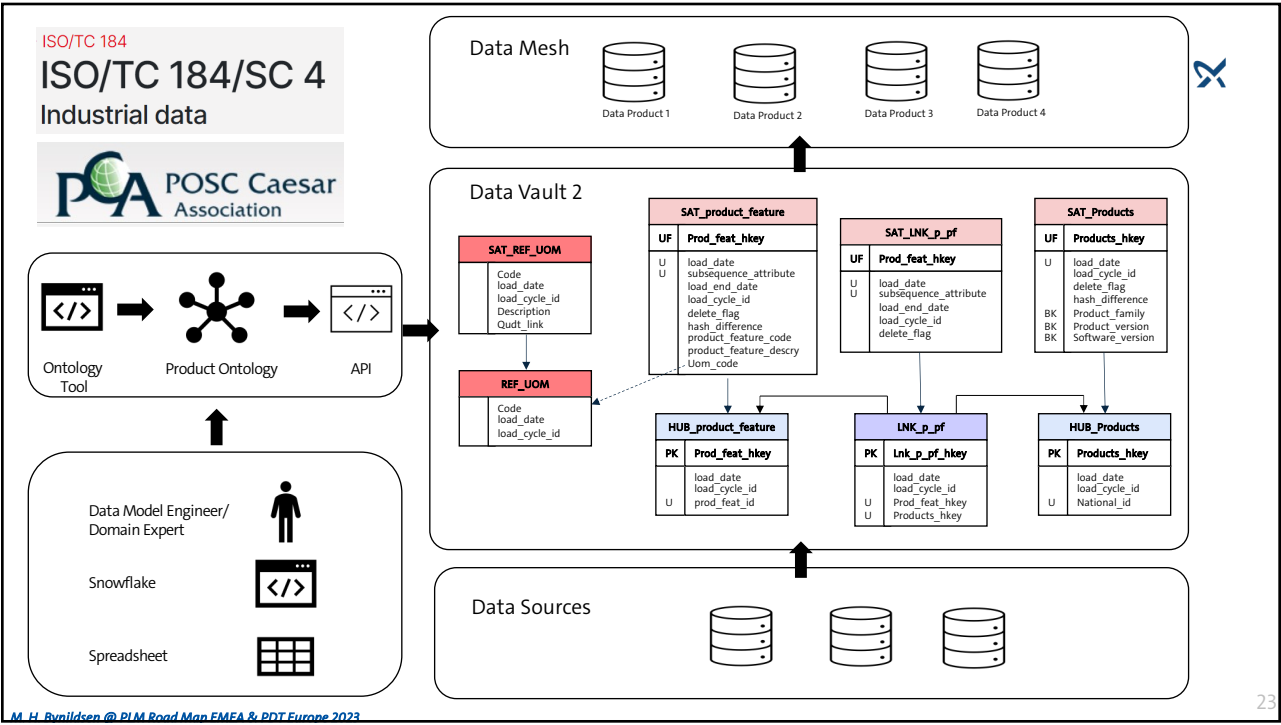
Hierarchies, Taxonomies, Knowledge Graphs and Data models in PLM

Enterprise Data Product Master Data

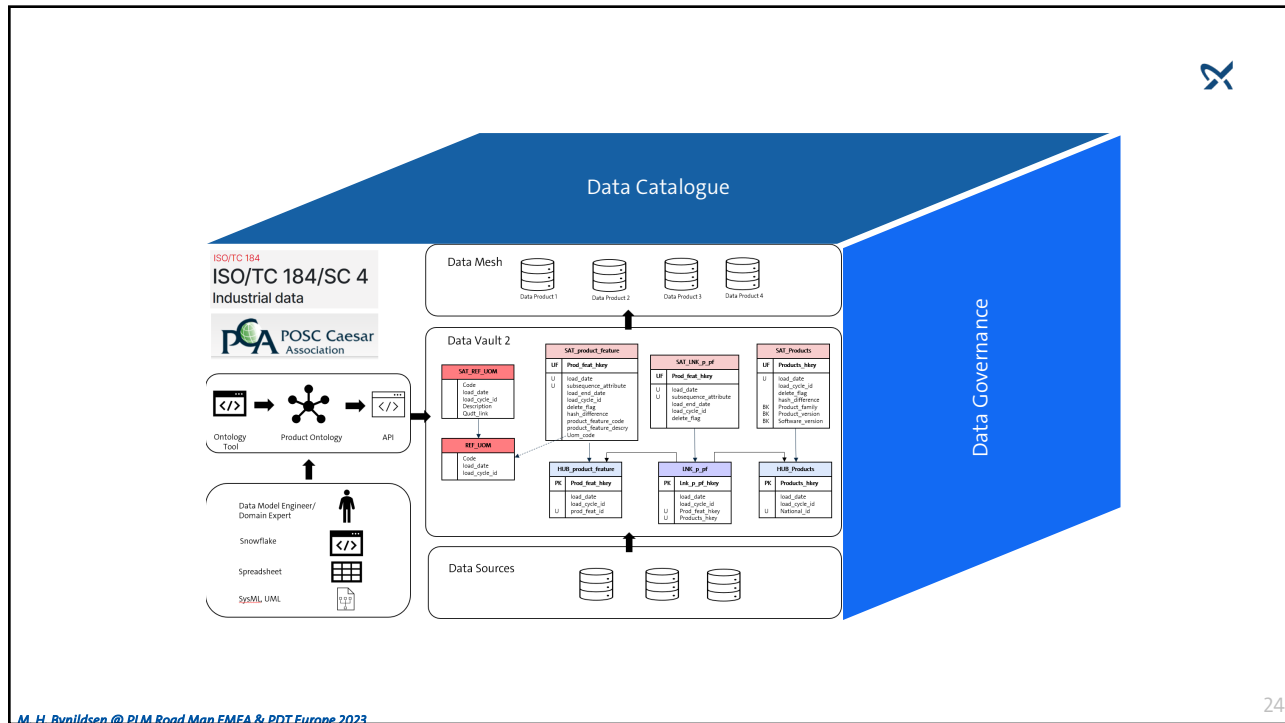




M. H. Bynildsen @ PLM Road Map EMEA & PDT Europe 2023



M. H. Bynildsen @ PLM Road Map EMEA & PDT Europe 2023



M. H. Bynildsen @ PLM Road Map EMEA & PDT Europe 2023

24

Why semantic web, now?

(when linked data arguably did not take off? ...)



1. Business reason: Automated Enterprise Data Warehouse tech like “Data Vault 2.0” are emerging to deliver “360°” solutions, (“360° product”, “360° customer”, “360° asset”, ...), you need to integrate data across platforms.
2. When you map taxonomies to taxonomies with relationships you have ontologies, in a broad sense. This HAS to happen. The enterprise cannot escape ontology in some form.
3. The W3C OWL (web ontology language) language and the SKOS (simple knowledge organization system) ontology are proven platform agnostic methods, with open-source tooling. DCAT is used by governments to harmonize metadata to make public data sets searchable...
4. Existing platforms also feel these trends and introduce semantic layers and proprietary knowledge graphs (or similar). We will soon have an “Enterprise zoo” of ontologies to map.
5. Semantic web methodologies can help you build a platform agnostic business centric warehouse, not a “source system” warehouse.
6. Using the semantic web methodologies, if not the serialization and tools will help the enterprise achieve quality of your enterprise ontology.

M. H. Bynildsen @ PLM Road Map EMEA & PDT Europe 2023

25

Do this



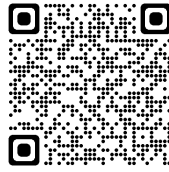
Get in control of your hierarchies (using ontologies)

Build taxonomies and connect them in a standardized way, if the PLM vendor uses open standards, it is easier.

If you want to be part of a community of peers, use semantic web standards like RDF, OWL, SKOS, DCAT and “triple store” databases.

Consider [ISO/AWI 23726-3](#) Industrial Data Ontology (IDO)

Thank you!



“IDO” iso.org page

References



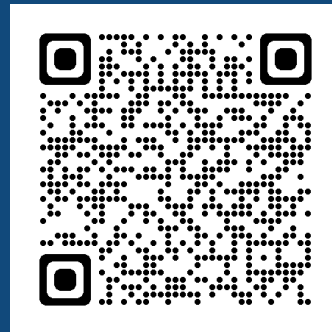
[ISO/AWI 23726-3](#)

<https://www.w3.org/WoT/>

<https://rds.posccaesar.org/>

Contact:
mbrynildsen@grundfos.com

Thank you!



“IDO” iso.org page

