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Towards a set of open reference ontologies for reasoning and text interoperability across the manufacturing domain - an update on the Industrial Ontologies Foundry project.

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TLP Community of Interest Workshop, 2021 Model-Based Enterprise Summit,
NIST, April 12 - 16, 2021

What and why for ontologies?

Finding information is no longer a major theoretical challenge

- *Intelligent search and text* analytics tools (e.g. Watson Discovery),
- Current generation RDF triple stores and *semantic reasoning engines* (e.g. RDFox),
- Unsupervised *pretrained Transformer NLP* models (e.g. GPT4)

Given we have these tools….why are ontologies needed for industrial engineering applications?

An ontology defines **machine-interpretable** definitions of **shared concepts**, and **relations between** concepts, using **formal explicit** descriptions.

Ontologies enable **reasoning.**

https://www.ibm.com/cloud/watson-discovery, http://www.gpt-4.com/ , https://www.oxfordsemantic.tech/

Example of value adding use of ontologies in engineering design

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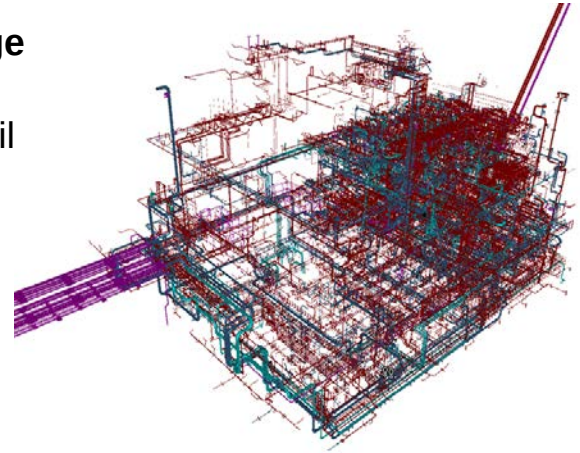
The challenge

Topside, oil and gas facility

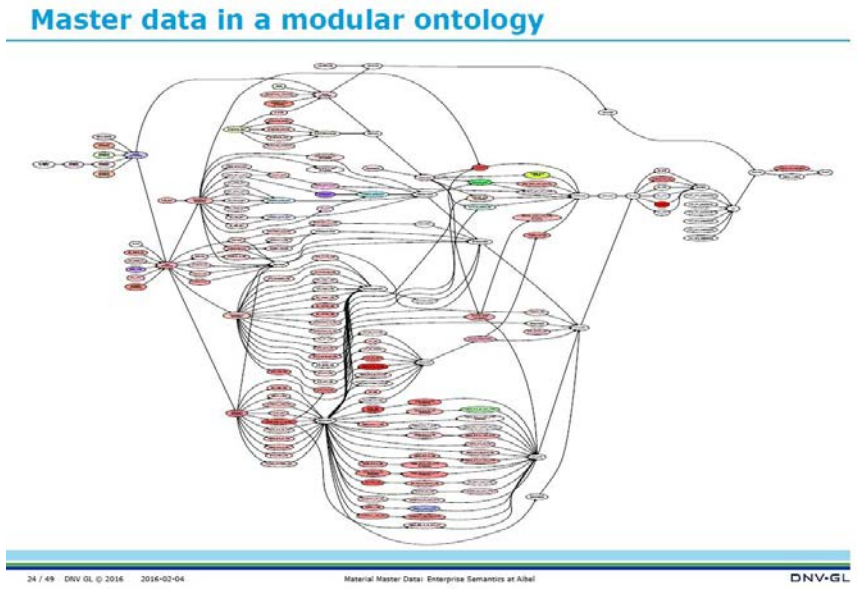


Piping: 37 000 fittings, 11 000 flanges, 63 000 m piping
Value ~$US 25 million

Manual Valves: 3800 items
Value ~$US 35 million

54 different pipespecs.
2400 different types of valves available
1700 different design material numbers
3,5M man-hours of construction

The solution: Semantic Material Master Data

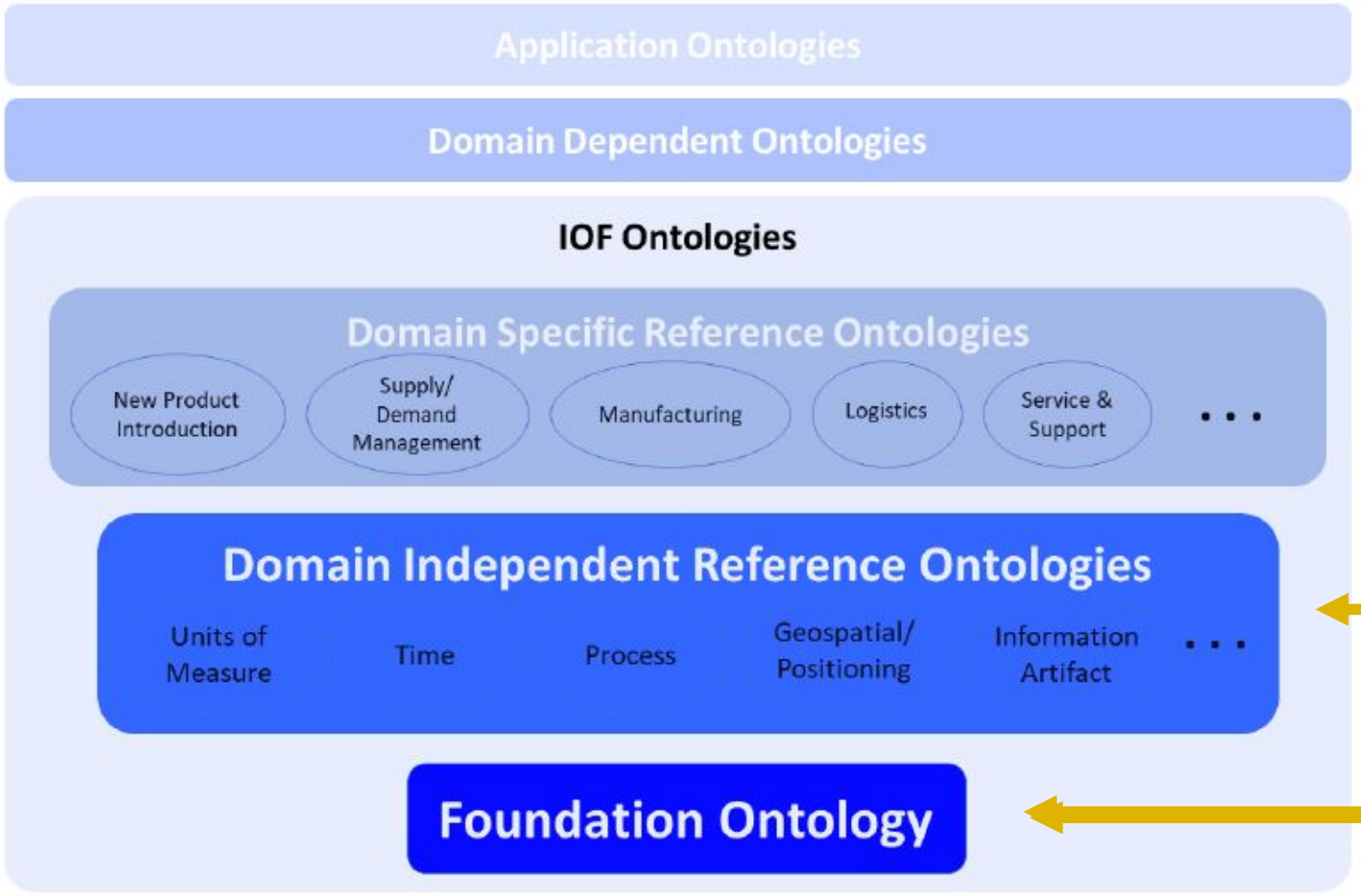


The benefits

- **Cost reduction of 5%** for bulk material orders which in large projects amounts to more than €100 million
- Quality control - **a reduction of errors in the specification of bolt lengths from 15% of all design drawings to a low 0.5%.**
- **Reuse** of products/equipment and standardization of processes
- Basis for future digital twin

Example as presented by Berit Gjellan, Vice President – Engineering Manager, **Aibel,** Ontology for Engineering and Procurement, IIOW 2019, Oslo

Industrial Ontology Foundry (IOF) hierarchy



Common Core Ontology (CCO)
Information Artefact Ontology (IAO)

ISO/IEC 21838-2:2020 Information technology – Top-level ontologies (TLO). Part 2: Basic Formal Ontology (BFO)

IOF

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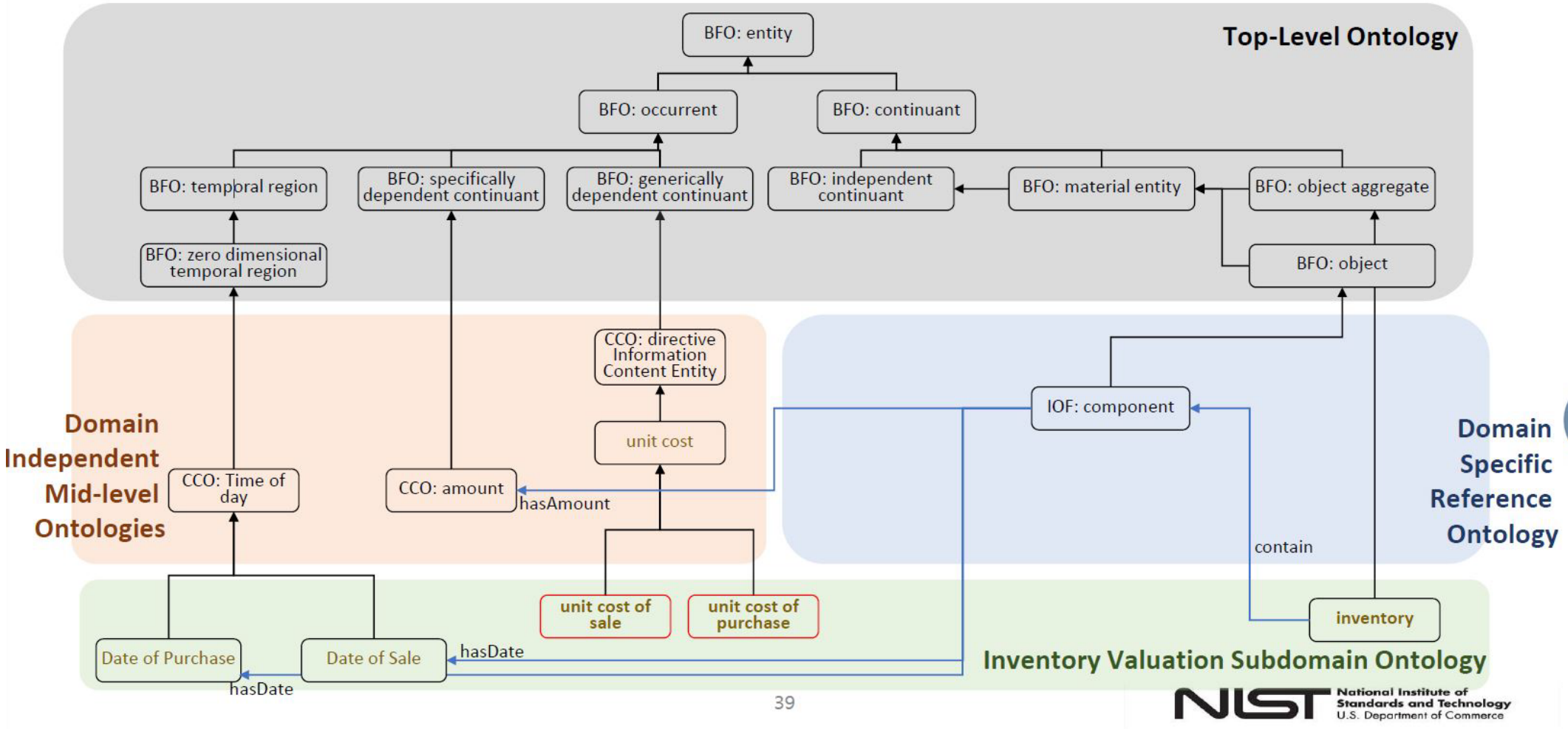
Use of IOF to develop new interoperable ontologies



Ref: Analysis of IOF Ontology architecture (2020),
S.Kulvatunyou, M.Lee, IOF Meeting.

How ontologies help us to query our data

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Ontology-based Data Access (OBDA) help us write better queries without knowing the details of the underlying data model.

For example, we can query for all processes, despite the concept of process not existing in our relational database.

Relational Database

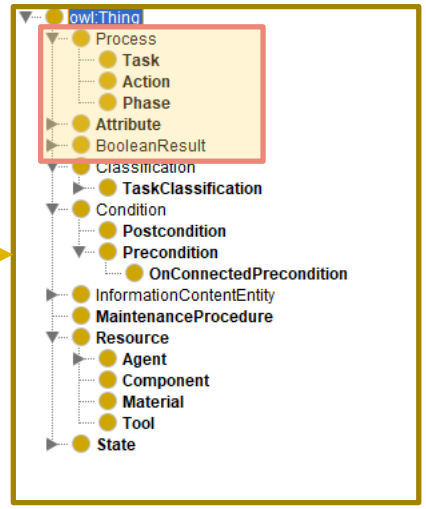
```
5
6 •   SELECT * FROM proc.phase;
```

Result Grid | Filter Rows:

idPhase	Name
1	Pre-condition
2	Work Exection
3	Close Out
NULL	

Maps to

Ontology



ONTOP Tool used to create mappings:

Ref: Diego Calvanese, Benjamin Cogrel, Sarah Komla-Ebri, Roman Kontchakov, Davide Lanti, Martin Rezk, Mariano Rodriguez-Muro, and Guohui Xiao. Ontop: Answering SPARQL Queries over Relational Databases. In: Semantic Web Journal 8.3 (2017), pp. 471–487.

```
PREFIX proc:  <http://www.semanticweb.org/procedure-ontology#>
SELECT ?x ?name
WHERE {
    ?x rdf:type proc:Process .
    ?x proc:name ?name .
}
```

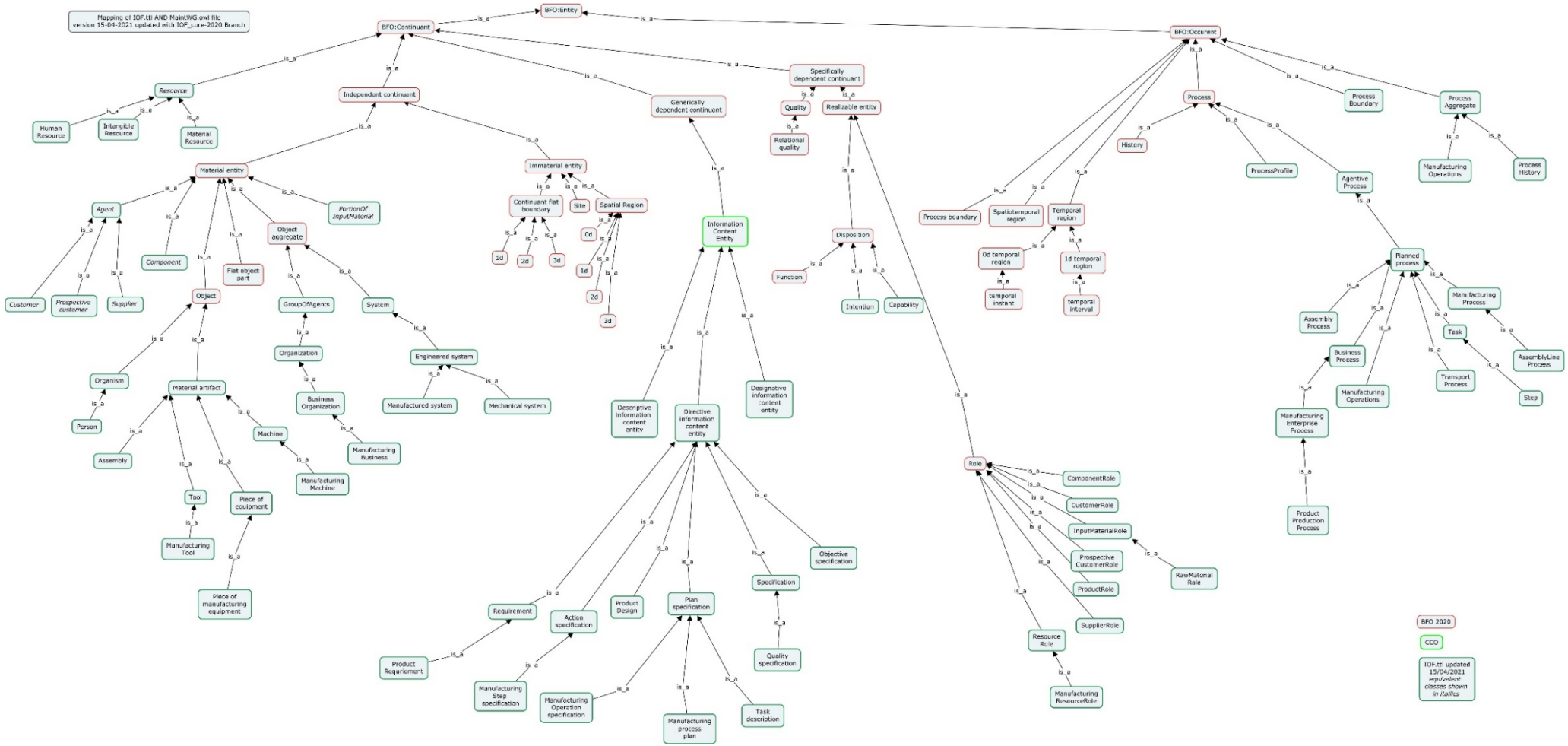
Execution time: 0.075 sec - Number of rows retrieved: 3

SPARQL results | SQL Translation

x	
<http://www.semanticweb.org/procedure-ontologyphase_1>	"Pre-condition"^^xsd:string
<http://www.semanticweb.org/procedure-ontologyphase_2>	"Work Exection"^^xsd:string
<http://www.semanticweb.org/procedure-ontologyphase_3>	"CloseOut"^^xsd:string

Thanks to Caitlin Woods (UWA) for this slide

IOF ontology for industrial maintenance



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Consider end-use when selecting labels (entity types) – do you want to support reasoning?

Nestor
Item
Problem
Solution

Wikidata
Capital
Author
Image
Child
…1453 other entity types

UWA TLP Phase 0

- Item
- Activity
- State

UWA TLP Redcoat Phase 1

- Item
- Activity
- Location
- Time
- Attribute
- Cardinality
- Agent
- Consumable
- Observation
  - Observed_state
  - Quantitative
  - Qualitative
- Specifier
- Event
- Unsure
- Typo
- Abbreviation

4000 annotations
HME MWOs

UWA TLP Redcoat Phase 2

- Item
- Activity
- Location
- Time
- Attribute
- Cardinality
- Agent
- Consumable
- Observation
  - Observed_state
  - Quantitative
  - Qualitative
- Specifier
- Event
- Unsure
- Typo
- Abbreviation
- Identifier

1000 annotations
Pump MWOs

UWA TLP Redcoat Phase 3 (current)

- Item
- Activity
- Observed_state
- Location
  - Absolute_loc
  - Relative_loc
- Time
- Attribute
  - Attribute_desc
  - Attribute_value
- Action
  - Function
  - Malfunction
- Cardinality
- Agent
- Consumable_or_commodity
  - Consumable
  - Commodity
  - Waste_biproduct
- Specifier
- Identifier
  - Item_ID
  - Make
- Unsure
- Typo
- Abbreviation

~500 annotations
Pump MWOs

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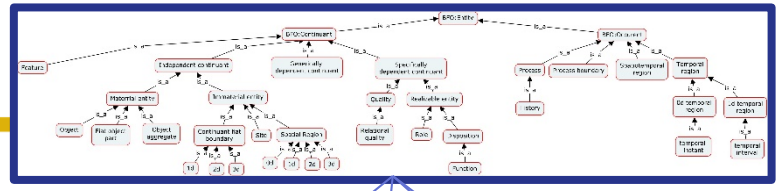
Reasoning …

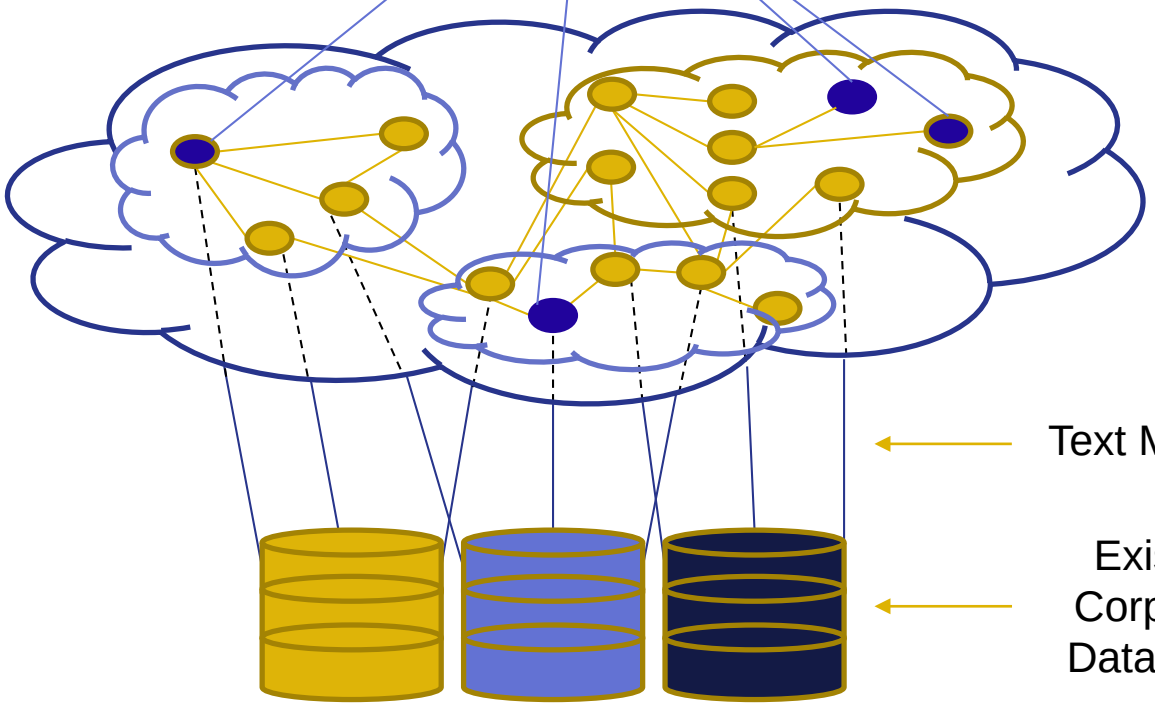


Domain-specific and **Reference Ontologies** – all constructed with **shared, open upper ontology**

Ontological mapping

Natural language query

Maintainer, engineer and analyst



Text Mapping

Existing Corporate Databases

Asset Owner ERP	External Remote Op. Centre	External maintenance provider
Costs, asset register & history	Sensor data	Maintenance observations & work done

Figure adapted from Kharlamov, E. et al (2016) Semantic access to streaming and static data at Siemens

Ontologies – what is the value proposition?

- To enable **reasoning**
- To share common understanding of the structure of information among people and **software agents**
- To enable **reuse** of domain knowledge
- To make domain **assumptions explicit**

In engineering:

- Consistency, quality control and transparency are important
- There are safety and cost consequences to our decisions, and
- Alignment to International Standards is necessary.

BUT

Ontologies are costly to produce and maintain – hence the need for **reusable, modular, interoperable ontologies** from the **Industrial Ontology Foundry**

More information on the IOF

Website: https://www.industrialontologies.org/

Membership: ~ 200 from industry, government and academia

Mission:
Create a set of core and open reference ontologies that spans the entire domain of digital manufacturing.

Global, digital collaboration process: Slack, GitHub, Google, Confluence, regular Working Group meetings

Governance: The IOF will release ontologies under MIT and CC BY 4.0 (or similar) licenses. The Open Application Group (OAGi) will manage this process.

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