Good morning and Welcome!

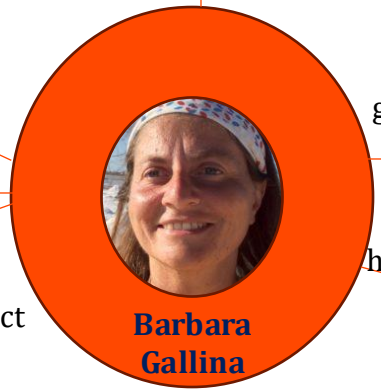
conducts research aligned with

Associate professor of dependable software systems

plays role

employed at

Mälardalens universitet



Barbara Gallina

gives presentation on

Ontology-based representation for assurance and compliance

has e-mail address

barbara.gallina@mdu.se

DVA437 Safety Critical Systems Engineering-H24
OAI400 Functional Safety of Battery Management Systems (BMS)-H24

manages & teaches

runs research project

Collaborates within

#49-4DASafeOps – Standards, Assurance Case, Process, Product-Aware SafeOps – focus on variability management
#50-ET4CQPPAJ – Trace Evidence 4 Continuous Quality Product Process Assurance Justification – focus on traceability

has partner

Collaborates within

Software Center

BOSCH DEIF GRUNDFOS

A graph-based knowledge representation!

Assuming the underlying existence of:
an ontological underpinning
and reasoning engine

it is Knowledge Graph!

Outline

- **What is a knowledge graph?**
- **What is an ontology?**
- **How can an ontology be developed?**
- **How can an ontology be represented?**

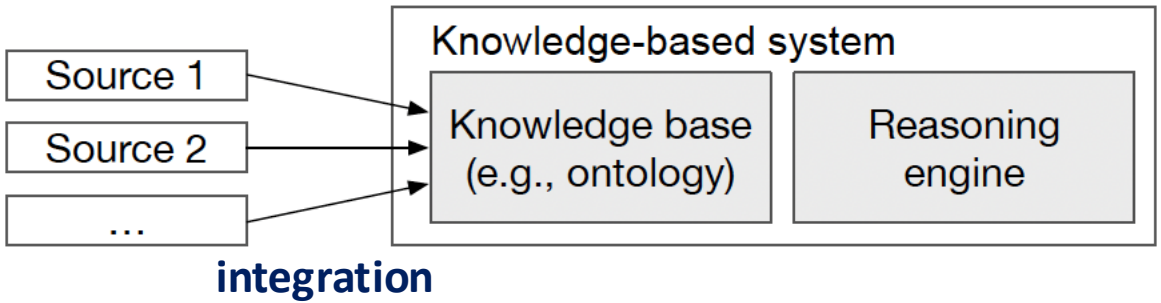
- **Why does all this matter for assurance and compliance?**

- **What is assurance?**
- **What is compliance?**

- **Pieces of solution towards the ontology-based representation for assurance and compliance**

What? Knowledge Graph

“A knowledge graph acquires and integrates information into an ontology and applies a reasoner to derive new knowledge.”



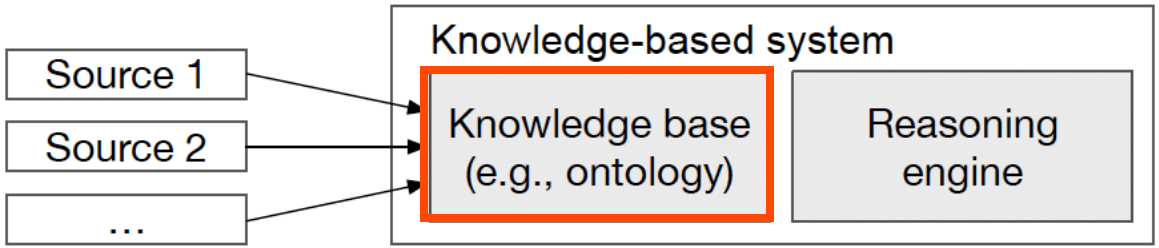
Lisa Ehrlinger and Wolfram Wöß. *Towards a Definition of Knowledge Graphs.*
Joint Proceedings of the Posters and Demos Track of the 12th International Conference on Semantic Systems- SEMANTiCS2016 and the 1st International Workshop on Semantic Change & Evolving Semantics (SuCCESS'16)
co-located with the 12th International Conference on Semantic Systems (SEMANTiCS 2016)
Leipzig, Germany, September 12-15, **2016**.

Do you know any knowledge graph?

The Semantic Web!

What? Ontology

An ontology is a formal description providing human users a shared understanding of a given domain



What? Ontology engineering

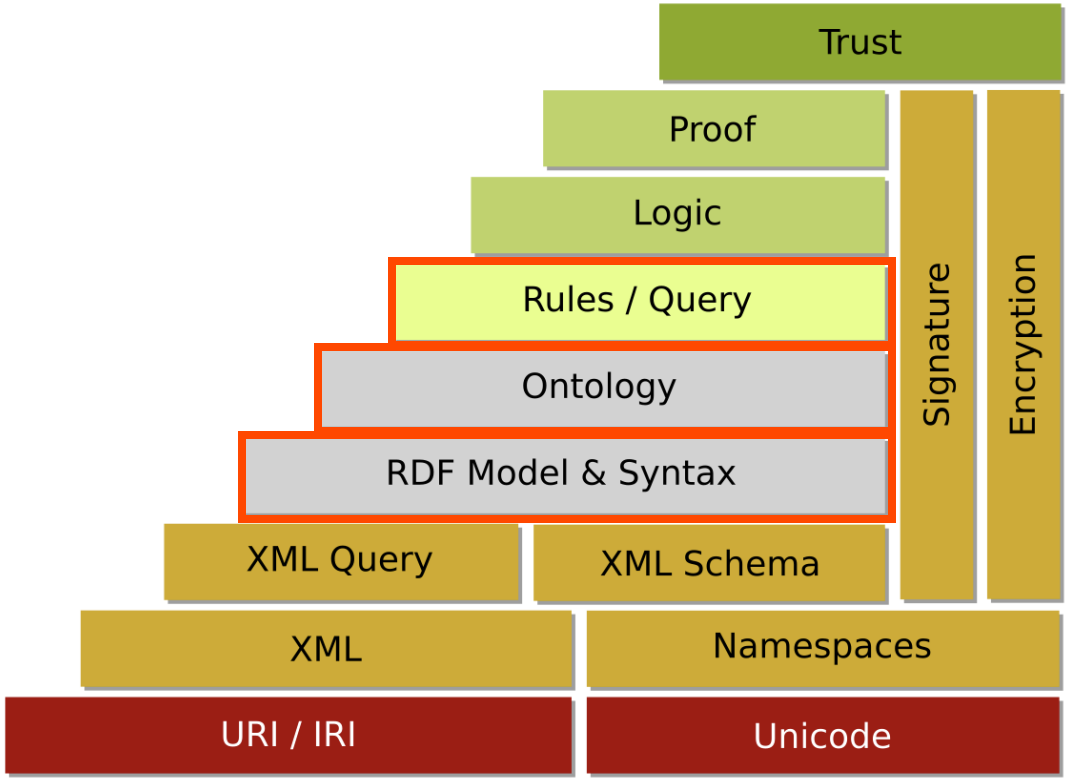
METHONTOLOGY:
From Ontological Art Towards Ontological Engineering

Mariano Fernández, Asunción Gómez-Pérez, Natalia Juristo

Specification – purpose specification, *competency questions (*)*
Conceptualisation – terms distinguished from verbs
Formalisation – transform the conceptual model of the ontology into a formal model
Integration
Implementation
Maintenance

(*) questions that the ontology must be able to answer
Competency questions capture the functional requirements of the ontology

What? Ontology representation



Source: https://it.wikipedia.org/wiki/File:W3c-semantic-web-layers.svg

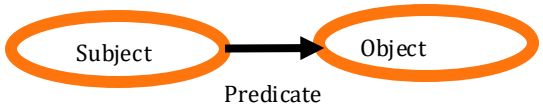
What? RDF –Resource Description Framework

A standard for capturing triples

a simple language for writing statements about Web resources identified by URIs.

An RDF document is a set of RDF statements

An RDF statement expresses a relationship between two resources.
The **subject** and the **object** represent the two resources being related
The **predicate** represents the nature of their relationship
The relationship is phrased in a **directional way** (from subject to object) and is called in RDF a **property**.
We can visualize triples as a connected **graph**. Graphs consists of nodes and arcs.

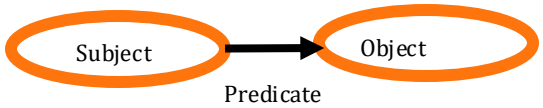


Informal textual representation of the previous graph-based representation

Barbara Gallina	**plays role**	**Associate Professor of Dependable Software Systems**
Barbara Gallina	**gives presentation on**	**Ontology-based representation for assurance and compliance**
Barbara Gallina	**runs project**	**#49-4DASafeOps**
#49-4DASafeOps	**has partner**	**Bosch**

Source: https://www.w3.org/TR/rdf11-primer/#section-data-model

What? RDF –Resource Description Framework



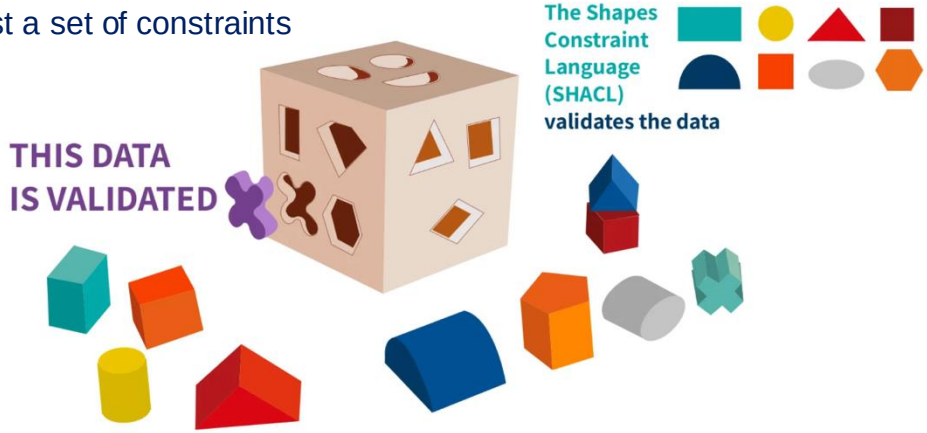
RDF graphs can be textually specified. Different textual syntax can be used:
-Turtle
-RDF/XML
-etc.

What? OWL

OWL-Web Ontology Language
Allows for the definition of the semantics of RDF statements.
The main building blocks of an OWL ontology are classes.

What? SHACL

A standard for a language for validating RDF graphs against a set of constraints



[source: https://www.ontotext.com/knowledgehub/fundamentals/what-is-shacl/]

What? SPARQL

SPARQL-SPARQL Protocol and RDF Query Language
A standard for querying the knowledge graphs, as well as constructing them

Query forms:

-SELECT - Returns all, or a subset of, the variables bound in a query pattern match

-CONSTRUCT -Returns an **RDF graph** constructed by substituting variables in a set of triple **templates**

-ASK - Returns a boolean indicating whether a query pattern matches or not

-DESCRIBE -Returns an **RDF graph** that describes the resources found

Why does all of this matter for assurance and compliance?

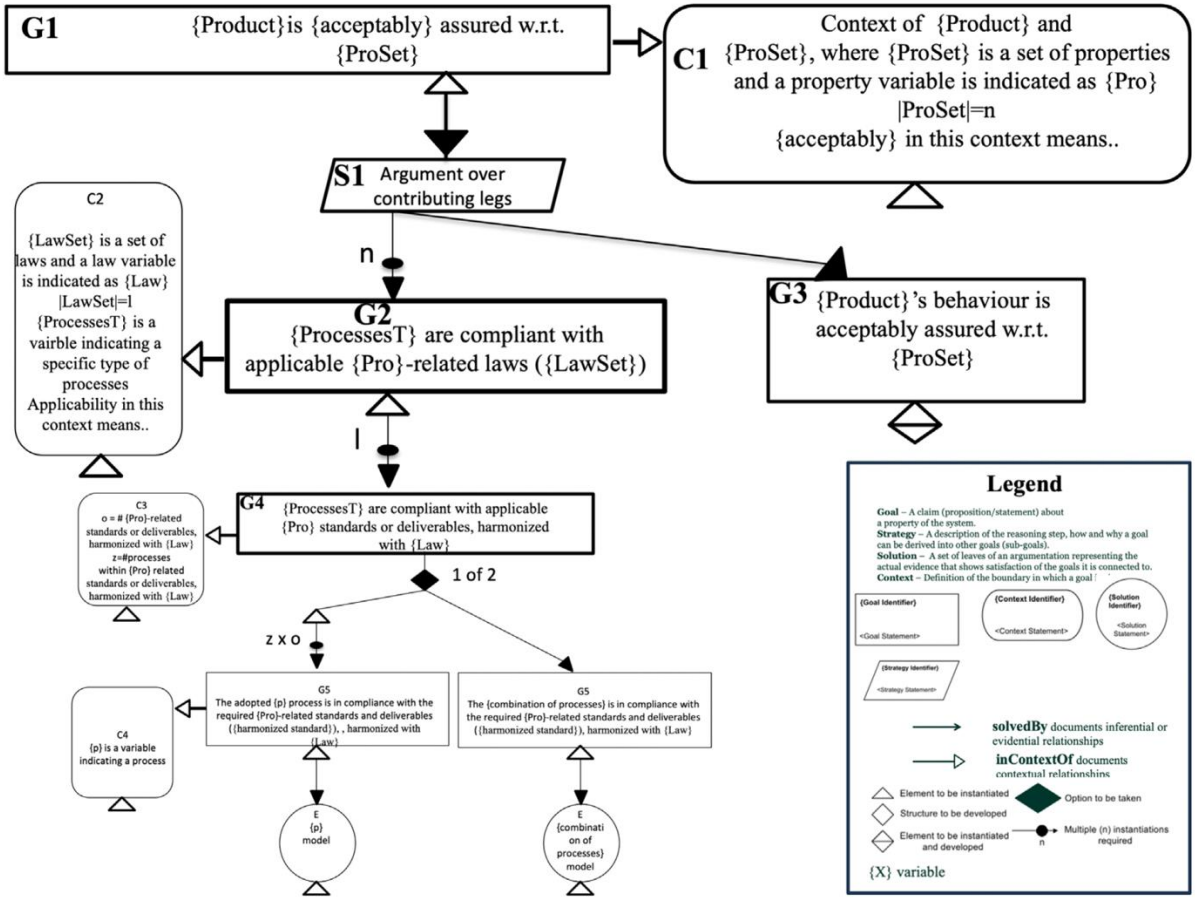
What? Assurance

Assurance **“grounds for justified confidence that a claim has been or will be achieved”**

[ISO/IEC JTC 1/SC 7, ISO/IEC 15026: Systems and software engineering — Systems and software assurance, Part 1: Concepts and vocabulary (2019)]

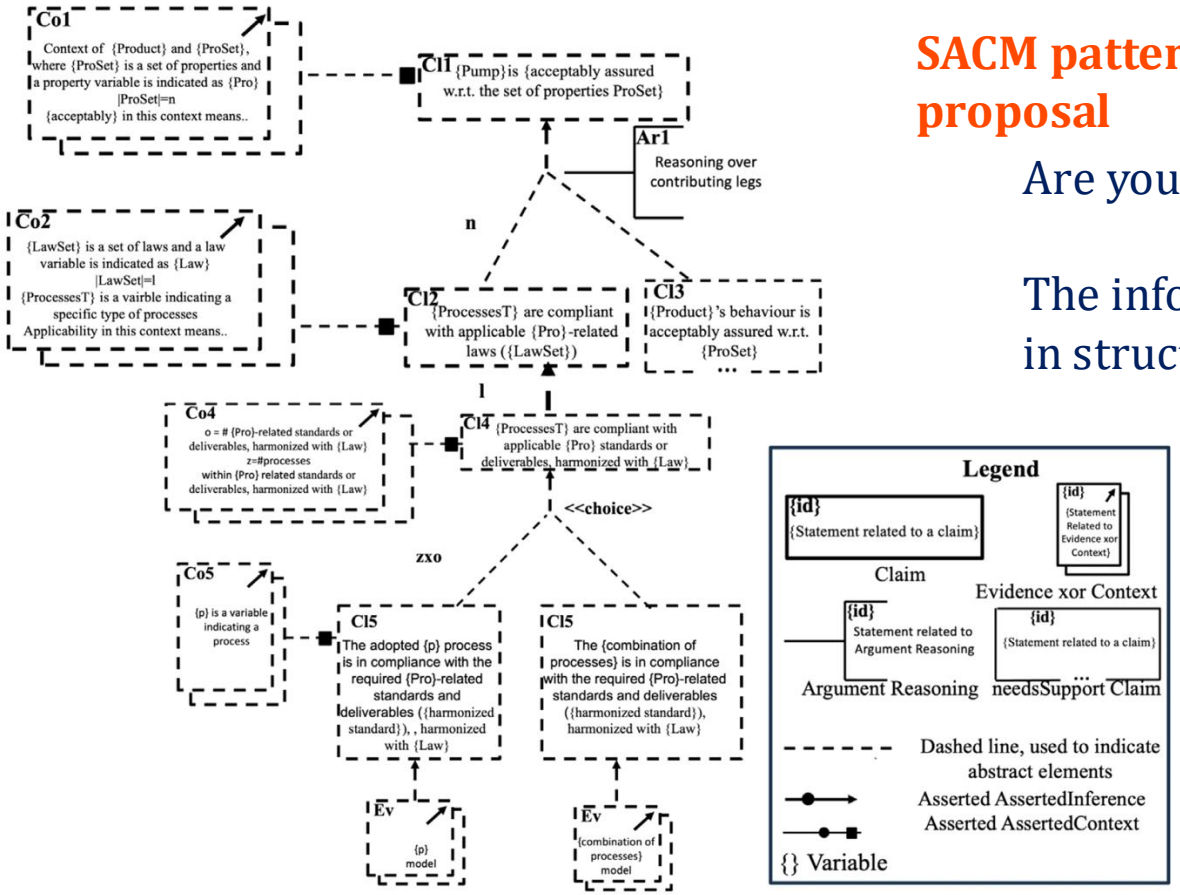
Multiconcern assurance means grounds for justified confidence that multi-concern claims have been or will be achieved, as well as arguments that those claims about multi-concerns are justified by the evidence about the system

What? Assurance



GSN pattern proposal

What? Assurance



SACM pattern proposal

Are you instead **text-inclined**?

The information could be rendered in structured prose!

What? Compliance

Compliance **“meeting all the organization’s compliance obligations”**

[ISO 37301:2021 Compliance management systems — Requirements with guidance for use]

Compliance obligations - **“ requirements that an organization mandatorily has to comply with as well as those that an organization voluntarily chooses to comply with. ”**

[ISO 37301:2021 Compliance management systems — Requirements with guidance for use]

Compliance Obligations: example

29.6.2023 EN Official Journal of the European Union L 165/1

I

(Legislative acts)

Machinery Regulation

REGULATIONS

REGULATION (EU) 2023/1230 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 14 June 2023

on machinery and repealing Directive 2006/42/EC of the European Parliament and of the Council and Council Directive 73/361/EEC

(Text with EEA relevance)

Compliance Obligations: examples

- **On 17 October 2024, the Regulation on horizontal cybersecurity requirements for products with digital elements and amending Regulation (EU) 2019/1020 entered into force.**

- **On 25 July 2024, the Directive on corporate sustainability due diligence (Directive 2024/1760) entered into force.**

- **On 17 August, 2023, Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries has entered into force.**

- **On 1 August, 2024, The AI Act - Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence has entered into force.**

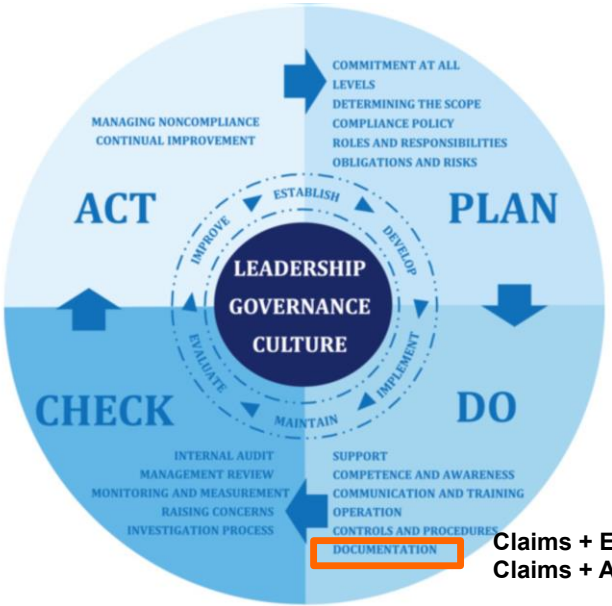
- **Product Liability Act ...**

When is it necessary to care about assurance and compliance?

…continuously…

Typical *Kaizen* PDCA cycle

Change for the better
Continuous improvement

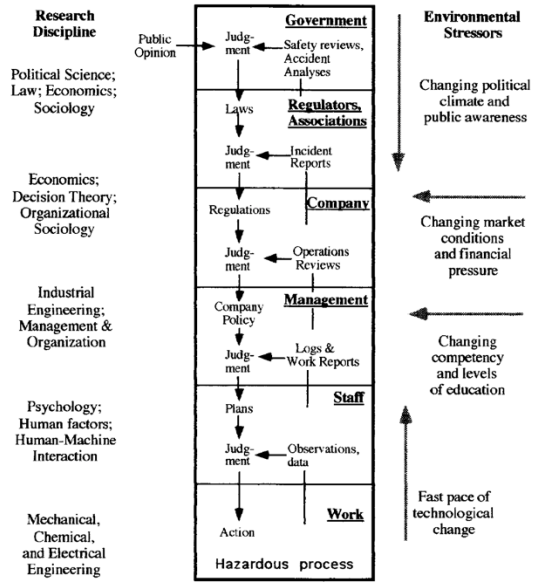


Claims + Evidence
Claims + Argument + Evidence

[ISO 37301:2021 Compliance management systems — Requirements with guidance for use]

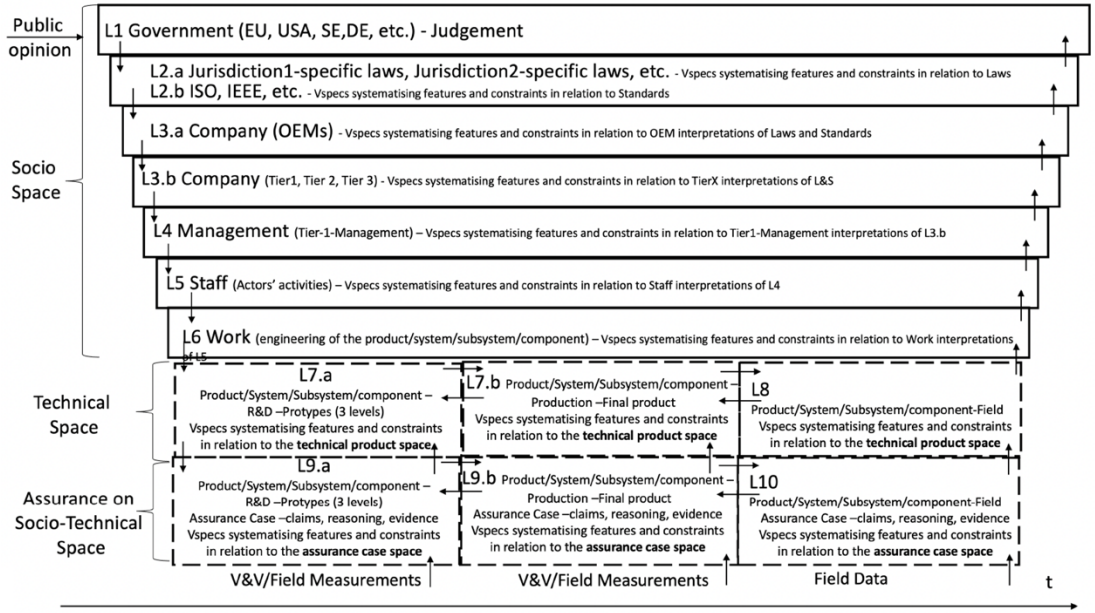
Vision: Knowledge graph capturing the socio-technical system

[Gallina et al.2024a]



J. Rasmussen, "Risk management in a dynamic society: a modelling problem," *Safety Science*, vol. 27, no. 2, pp. 183–213, 1997.

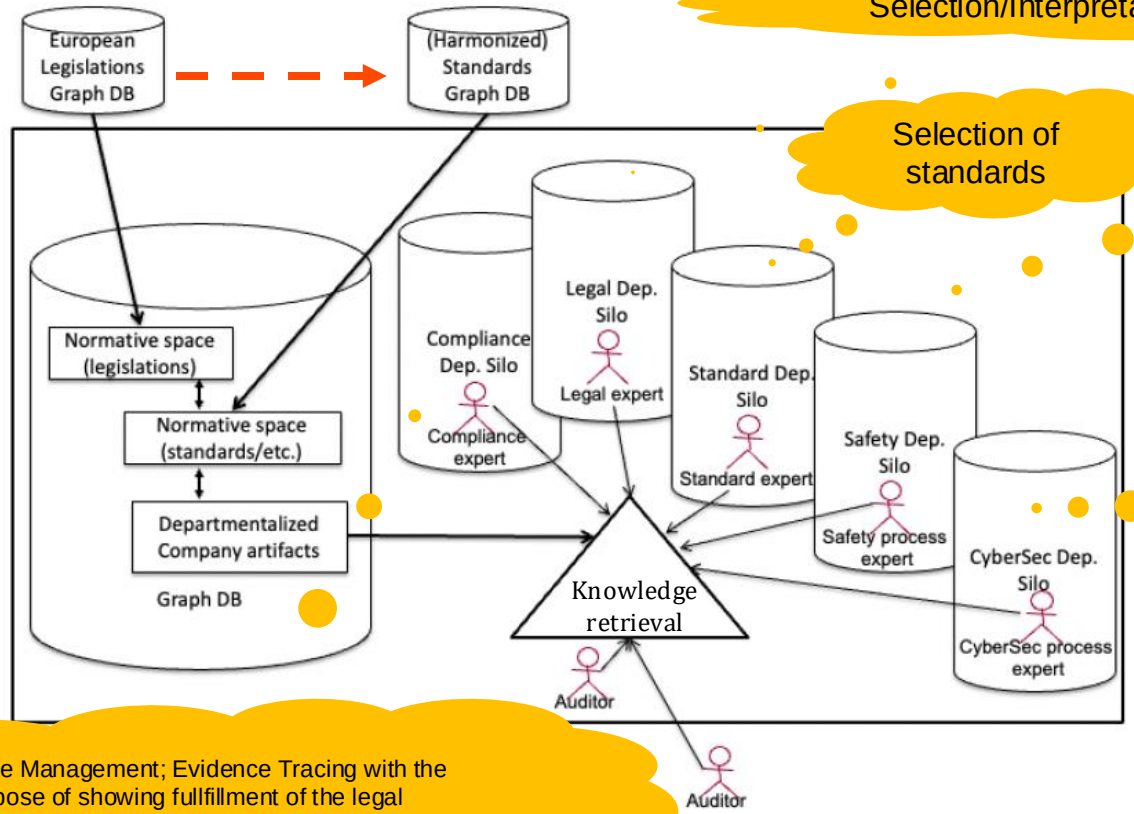
J. Rasmussen and I. Svedung, *Proactive Risk Management in a Dynamic Society*. Swedish Rescue Services Agency, 2000.



B. Gallina, Peter Munk, Markus Schweizer.
An Extension of the Rasmussen Socio-technical System for Continuous Safety Assurance.
Proceedings of 8th International Workshop on Critical Automotive Applications: Robustness & Safety (CARS), Leuven, Belgium, April 8th, 2024. Soon available at HAL archives ouvertes.fr

B. Gallina, T. Young Olesen, E. Parajdi, and M. Aarup.
A Knowledge Management Strategy for Seamless Compliance with the Machinery Regulation.
30th European & Asian Systems, Software & Service Process Improvement & Innovation (EuroSPI), Communications in Computer and Information Science (CCIS), vol. 1890, Springer Cham, pp. 220-234, DOI: 10.1007/978-3-031-42307-9_17, Grenoble, France, August 30.-September 1. 2023.

Vision: Knowledge Engineering within Highly Regulated Companies



Selection/Interpretation of laws

Selection of standards

Safety Risk Assessment and control

Security Risk Assessment and control

Sustainability Risk Assessment and control

Evidence Management; Evidence Tracing with the purpose of showing fullfillment of the legal requirements; Variability management with the purpose of reusing as well as managing the impact of changes

Vision: Goals

- **Capturing conceptually connected heterogeneous information in order to:**
  - **guarantee seamless traceability,**
  - **enable semi-automated multi-concern assurance argumentation**
  - **streamline auditing / regulatory compliance demonstration**
- **Braking the silos by connecting people with heteterogeneous background or competence**
- **On demand-Knowledge Retrieval**
- **Flexible evolution**

IEC 62853

Edition 1.0 2018-06

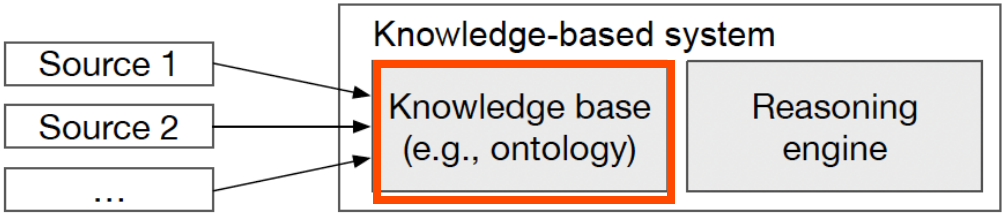
Frame of reference

Let's reconsider how knowledge graphs fit into the picture

Law-related knowledge

Standards-related knowledge

...



Pumps product line and corresponding regulations [ET4CQPPAJ]

The physical world meets the digital world

- Transforming the pump to a digital pump using IoT connectivity, AI and sensing capabilities

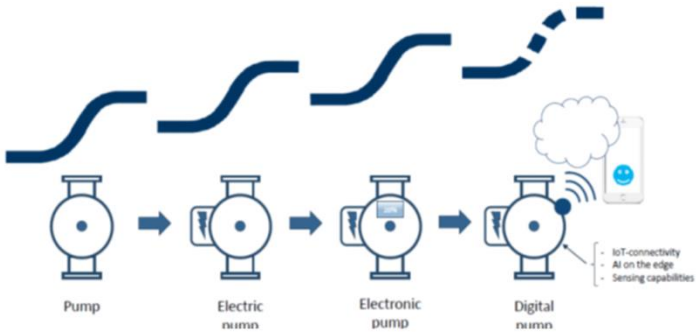


Image source: Grundfos

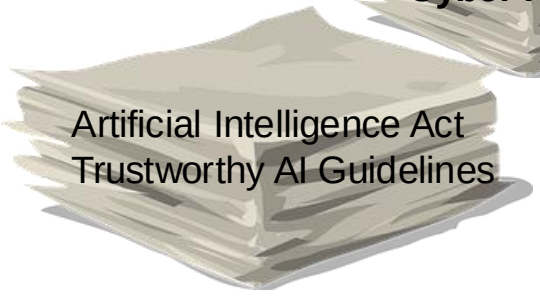
[https://iot.telenor.com/iot-case/grundfos/]

EN 809:1998 + A1:2009
Pumps and pump units for liquids – Common safety requirements

ISO 12100: 2010 -Safety of machinery- General principles for design — Risk assessment and risk reduction

Machine Directive
2006/42/EC

Machine Regulation



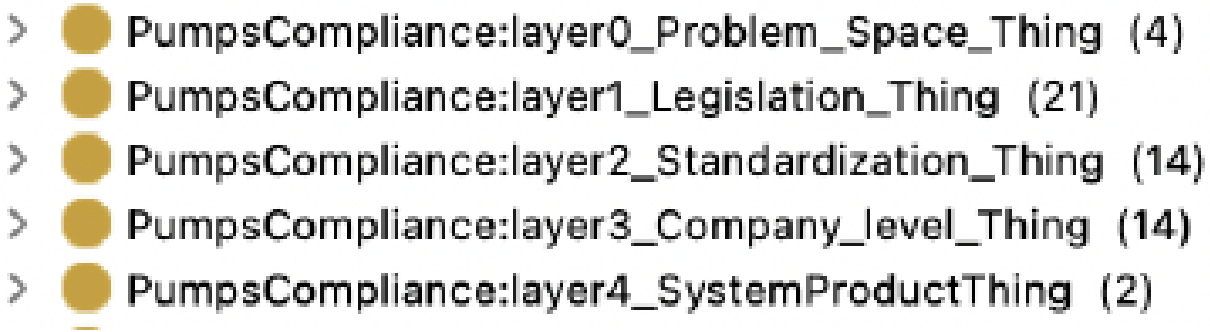
Artificial Intelligence Act
Trustworthy AI Guidelines

Cybersecurity Act
Cyber Resilience Act

Pieces of solution towards the ontology-based representation

A layered ontology-based representation of the socio-technical system

[Gallina et al.2024c]

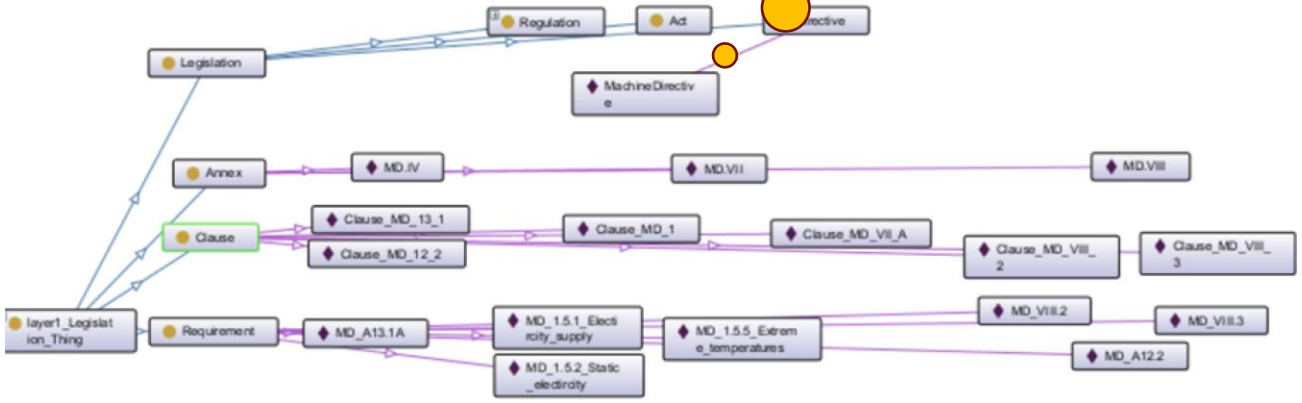


A layered ontology-based representation of the socio-technical system –Legislation layer

[Gallina et al.2024c]

- PumpsCompliance:layer0_Problem_Space_Thing (4)
- PumpsCompliance:layer1_Legislation_Thing (21)
- PumpsCompliance:layer2_Standardization_Thing (14)
- PumpsCompliance:layer3_Company_level_Thing (14)
- PumpsCompliance:layer4_SystemProductThing (2)

Formalisation after specification, conceptualisation
A legislation has a preamble, which in turns is constituted by
a set of citations
a set of recitals
- a set of articles
- a set of annexes

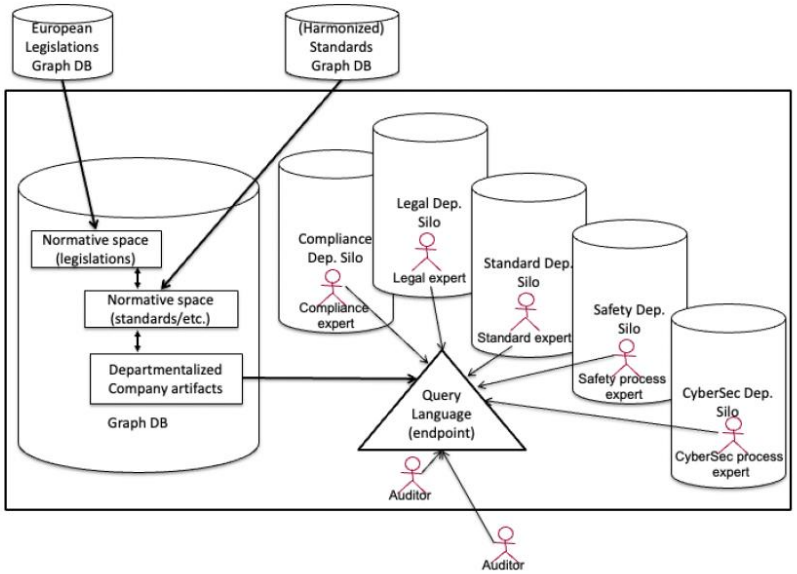


A layered ontology-based representation of the socio-technical system –Legislation layer

[Gallina et al.2024c]

Which are the safety-related legislations?

- PumpsCompliance:layer0_Problem_Space_Thing (4)
- PumpsCompliance:layer1_Legislation_Thing (21)
- PumpsCompliance:layer2_Standardization_Thing (14)
- PumpsCompliance:layer3_Company_level_Thing (14)
- PumpsCompliance:layer4_SystemProductThing (2)



Imports | Instances | Inheritance | Domain | Relevant Properties | Error Log | SPARQL | SPARQL | Text Search

Query Editor | Query Library

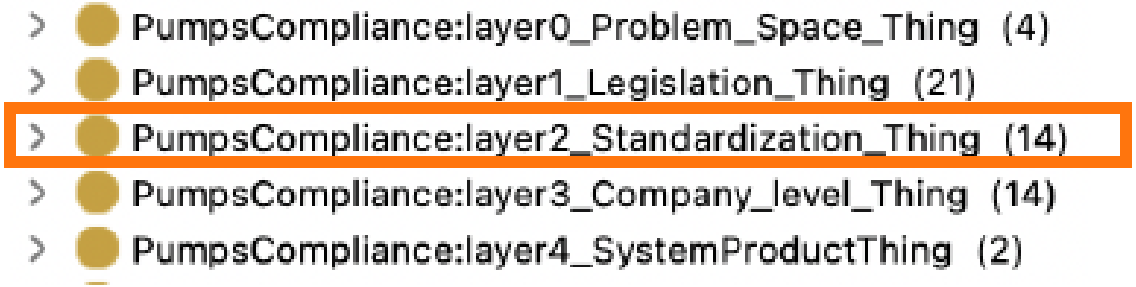
```
SELECT ?Legislation
WHERE {
  ?Legislation PumpsCompliance:SubjectsOfApproval ?Subject .
  ?Legislation a ?L .
  ?L rdfs:subClassOf* PumpsCompliance:Legislation .
  Filter (?Subject = PumpsCompliance:FunctionalSafety)

}
```

[Legislation]

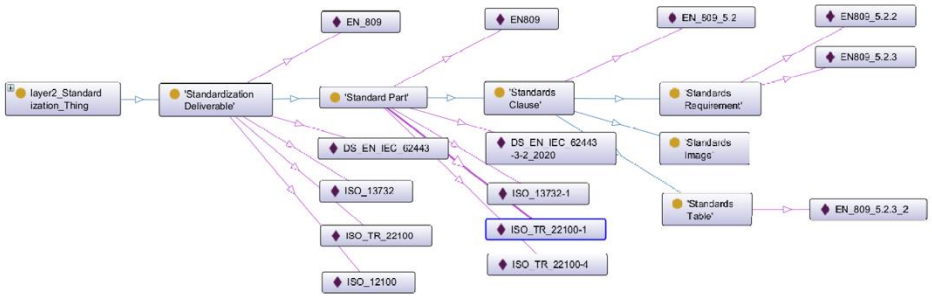
- PumpsCompliance:MachineDirective
- PumpsCompliance:MachinearyRegulation

A layered ontology-based representation of the socio-technical system –Standardization layer

[Gallina et al.2024c]



- a set of parts. Each part in turns is constituted by:
  - set of clauses, Each clause in turns is constituted by:
    - set of requirements
    - set of images
    - set of tables
- a set of associated standards
- a set of associated legislations

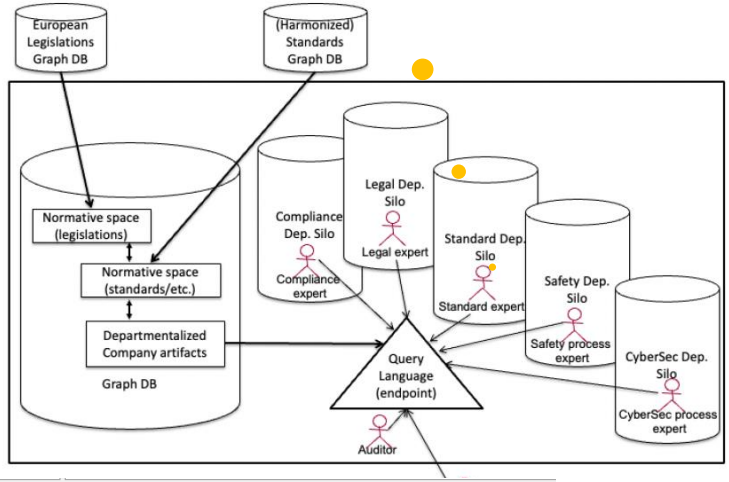


A layered ontology-based representation of the socio-technical system –Standardization layer

[Gallina et al.2024c]

Which are the safety-related standards?

- PumpsCompliance:layer0_Problem_Space_Thing (4)
- PumpsCompliance:layer1_Legislation_Thing (21)
- PumpsCompliance:layer2_Standardization_Thing (14)
- PumpsCompliance:layer3_Company_level_Thing (14)
- PumpsCompliance:layer4_SystemProductThing (2)



Imports | Instances | Inheritance | Domain | Relevant Properties | Error Log | SPARQL | SPARQL | Text Search | Targets | SHACL Validation

Query Editor | Query Library

```
SELECT ?Standard
WHERE {
  ?Standard PumpsCompliance:SubjectsOfApproval ?Subject .
  ?Standard a PumpsCompliance:StandardizationDeliverable .
  Filter (?Subject = PumpsCompliance:FunctionalSafety)

}
```

[Standard]

- PumpsCompliance:EN_809
- PumpsCompliance:ISO_12100
- PumpsCompliance:ISO_TR_22100

A layered ontology-based representation of the socio-technical system –Company layer

[Gallina et al.2024c]

- PumpsCompliance:layer0_Problem_Space_Thing (4)
- PumpsCompliance:layer1_Legislation_Thing (21)
- PumpsCompliance:layer2_Standardization_Thing (14)
- PumpsCompliance:layer3_Company_level_Thing (14)
- PumpsCompliance:layer4_SystemProductThing (2)

- a set of phases, where each phase in turn is constituted by:
  - a set of activities, where each activity in turn is constituted by:
    - a set of tasks, where each task in turn is constituted by:
      - a set of steps, where each step in turn is constituted by:

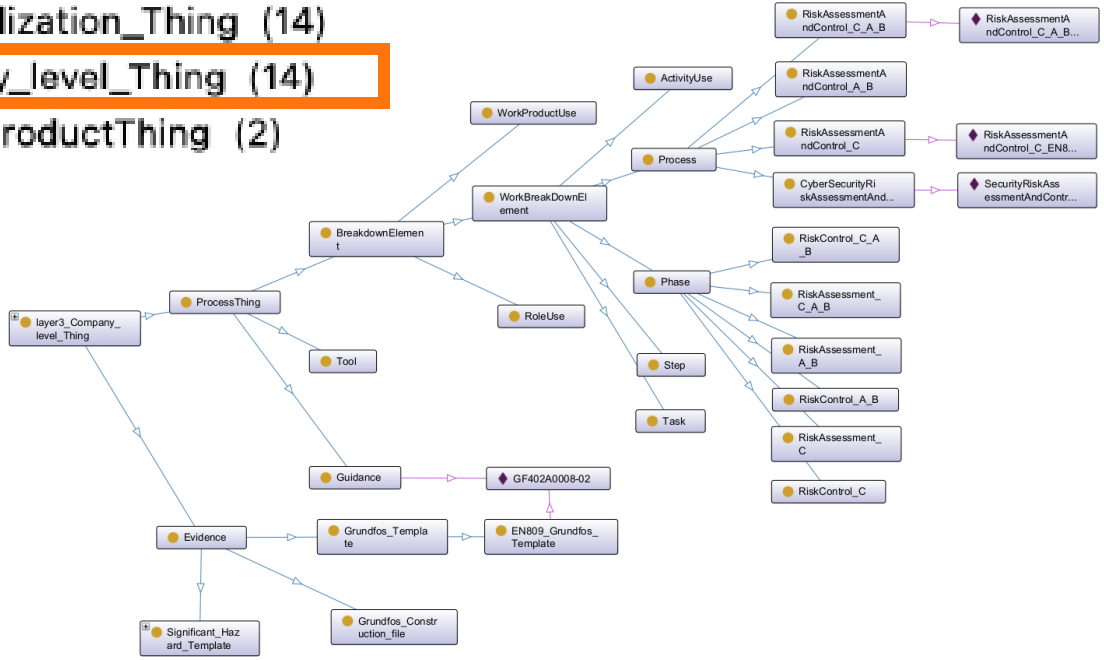
  a set of roles

  a set of tools

  a set of work products in input

  a set of work products in output

  a set of guidelines/templates

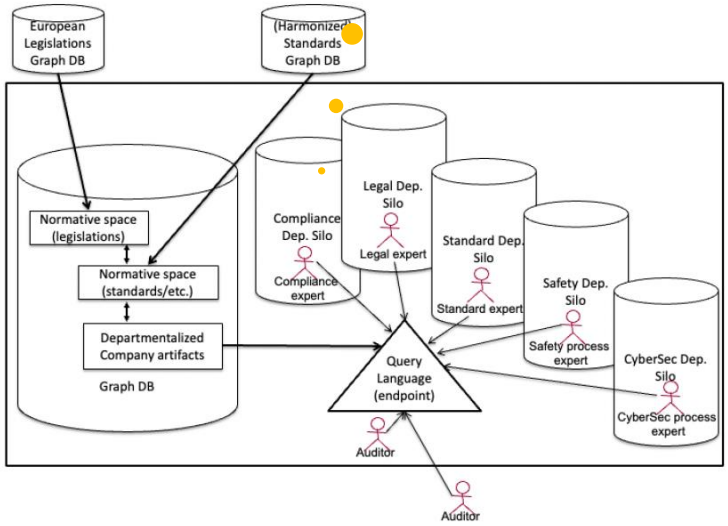


A layered ontology-based representation of the socio-technical system –Company layer

[Gallina et al.2024c]

Which is the process model overview adopted for developing pump CR-1?

- PumpsCompliance:layer0_Problem_Space_Thing (4)
- PumpsCompliance:layer1_Legislation_Thing (21)
- PumpsCompliance:layer2_Standardization_Thing (14)
- PumpsCompliance:layer3_Company_level_Thing (14)
- PumpsCompliance:layer4_SystemProductThing (2)



Imports | Instances | Inheritance | Domain | Relevant Properties | Error Log | SPARQL | SPARQL | SPARQL | SPARQL | Text Search | Targets | SHACL Validation

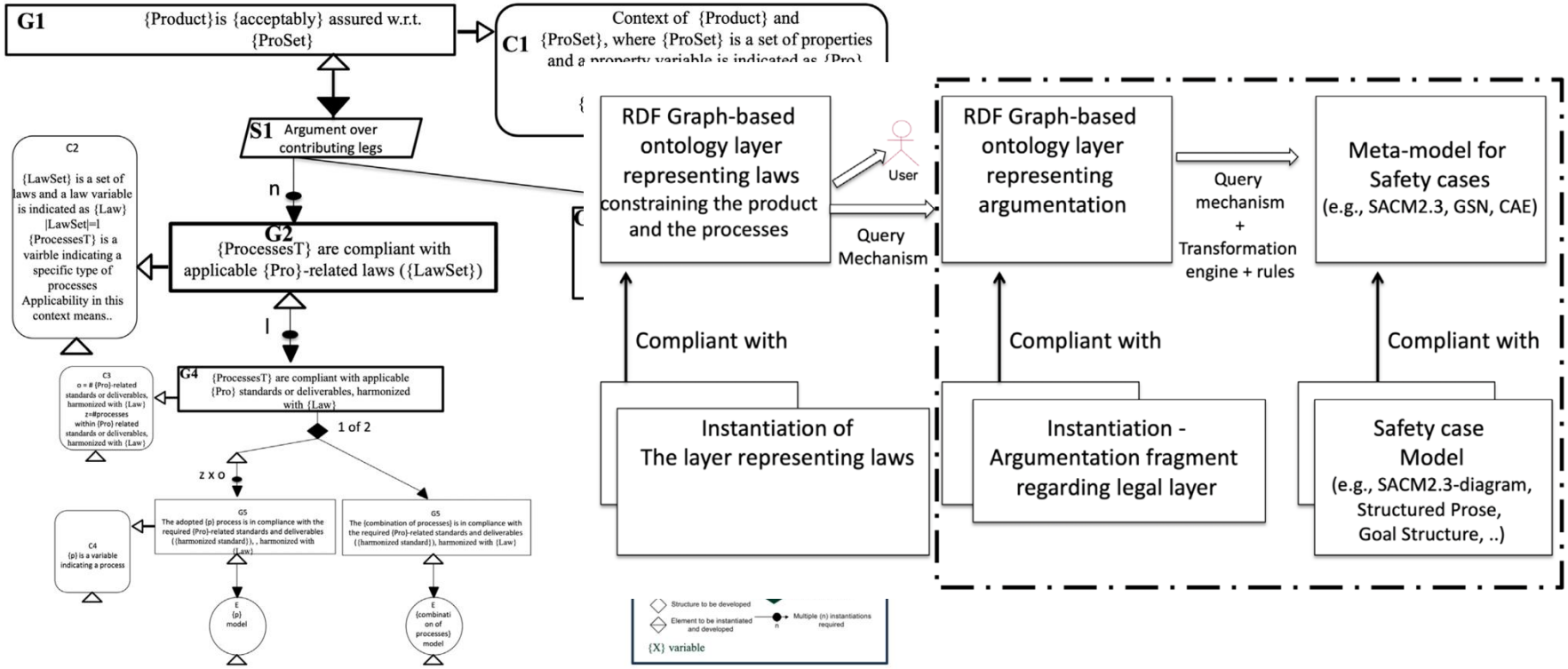
Query Editor | Query Library

```
SELECT ?pump ?PMO
WHERE {
  ?pumpclass rdfs:subClassOf* PumpsCompliance:PumpDriveSystem .
  ?pump a ?pumpclass .
  ?pump PumpsCompliance:AssociatedSetOfProcesses ?process .
  ?process PumpsCompliance:ProcessModelOverview ?PMO
}
```

[pump]	PMO
PumpsCompliance:Pump_CR_1	https://grundfos.sharepoint.com/:i:/r/sites/Project50-ET4CQPPAJ/Shared%20Documents/General/ProcessModelOverview.p...

Automated generation of multi-concern assurance argumentation

[Gallina et al.2024c]



Next?

- More complex case study in cooperation with stakeholders
- Tooling

References

[Gallina et al.2024a] B. Gallina, P. Munk, M. Schweizer. An Extension of the Rasmussen Socio-technical System for Continuous Safety Assurance. Proceedings of 8th International Workshop on Critical Automotive Applications: Robustness & Safety (CARS), Leuven, Belgium, April 8th, 2024. HAL archives ouvertes.fr, <hal-04558510>

[Gallina et al.2024b] B. Gallina, H. Dibowski, M. Schweizer. An Ontology-based Representation for Shaping Product Evolution in Regulated Industries. 21st International Conference on Software and Systems Reuse (ICSR-2024), Lecture Notes in Computer Science, vol 14614. Springer, Cham. DOI: 10.1007/978-3-031-66459-5_6, Limassol, Cyprus, June 19-20, 2024.

[Gallina et al.2024c] B. Gallina, G. L. Steierhoffer, T. Young Olesen, E. Parajdi, M. Aarup. Towards an ontology for process compliance with the (machinery) legislations. Journal of Software Evolution and Process (JSEP). 2024; e2728. DOI; 10.1002/smr.2728

Hope it was interesting!
Thank you very much for your attention!

#49-4DASafeOps – Standards, Assurance Case, Process, Product-Aware SafeOps – focus on variability management
#50-ET4CQPPAJ – Trace Evidence 4 Continuous Quality Product Process Assurance Justification – focus on traceability

Software Center

barbara.gallina@mdu.se