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# BIG DATA VALUE FORUM

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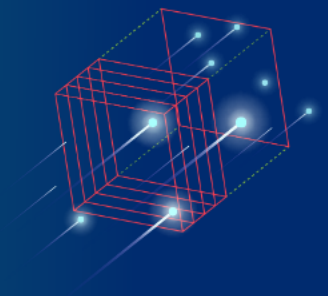

**EMPOWERING**
**EUROPE'S FUTURE**
**WITH AI AND DATA**

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# COMPLIANCE TRACK

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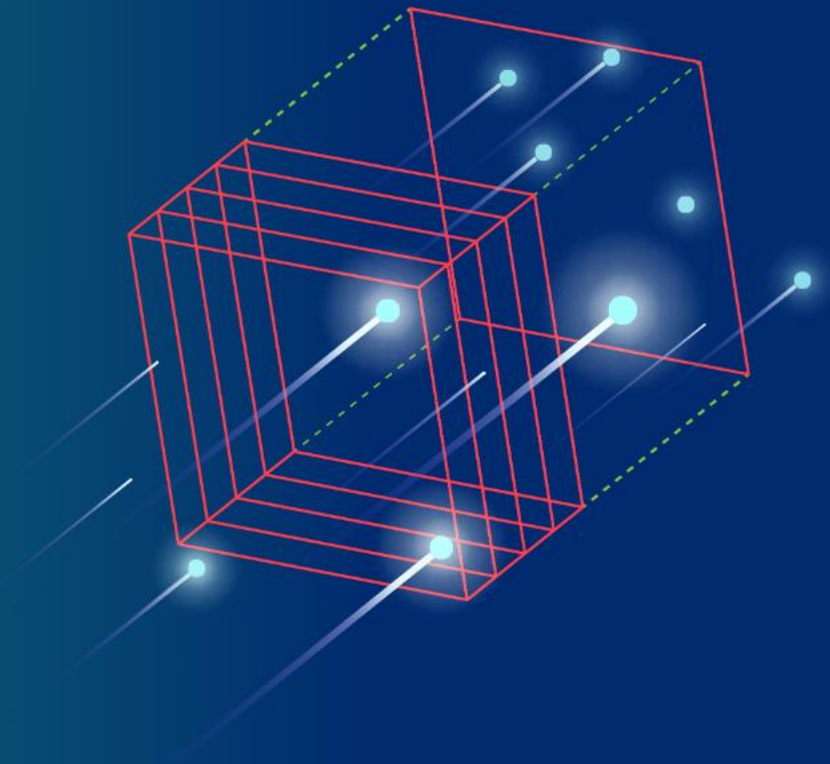

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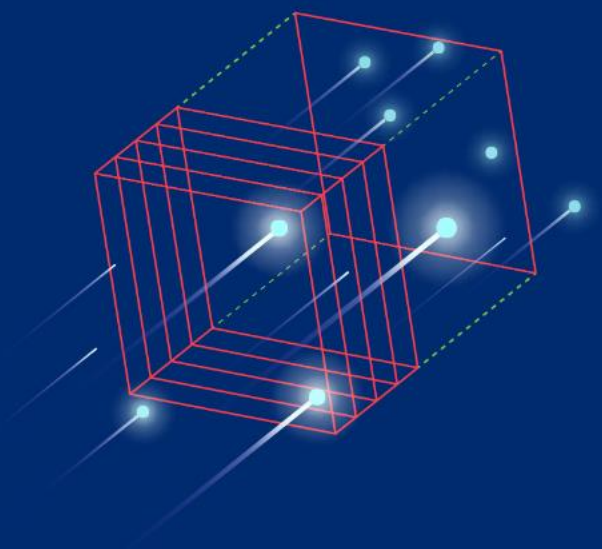

**14 November, 09:00 - 10:30 CET**

# Semantics & Compliance: Enabling Trustworthy Data/AI in European Data Spaces

**Mark Dietrich**
SAGE
BLOODSTONE CONSULTING

**Christoph Mertens**
IDSA

**Dumitru Roman**
SINTEF

**Fenareti Lampathaki**
SUITE5 DATA INTELLIGENCE SOLUTIONS

**George Konstantinidis**
SOUTHAMPTON UNIVERSITY

**Rafael Rodriguez**
DIGITAL FOR PLANET

**Silvia Colella**
PNO INNOVATION

**Parul Chaudhary**
EIT DIGITAL

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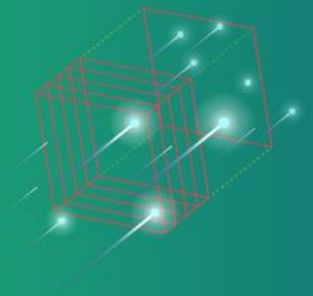

Semantics & Compliance

# DataPACT

Dr. Dumitru Roman
Senior Research Scientist, SINTEF Digital

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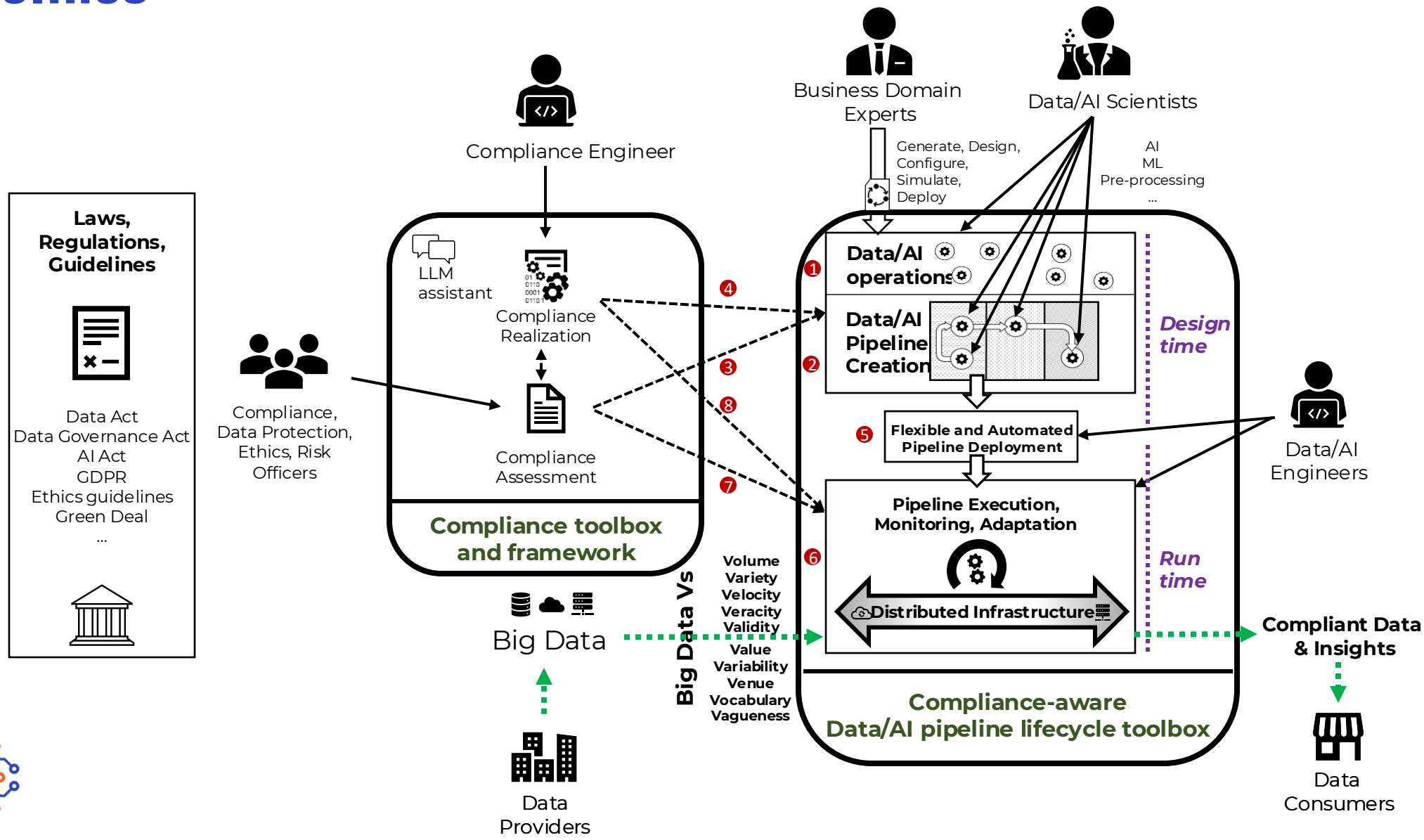
DATAPACT

# Semantics in DataPACT
## Compliance for Data/AI Pipelines

**Dumitru Roman**
dumitru.roman@sintef.no
SINTEF AS, Norway

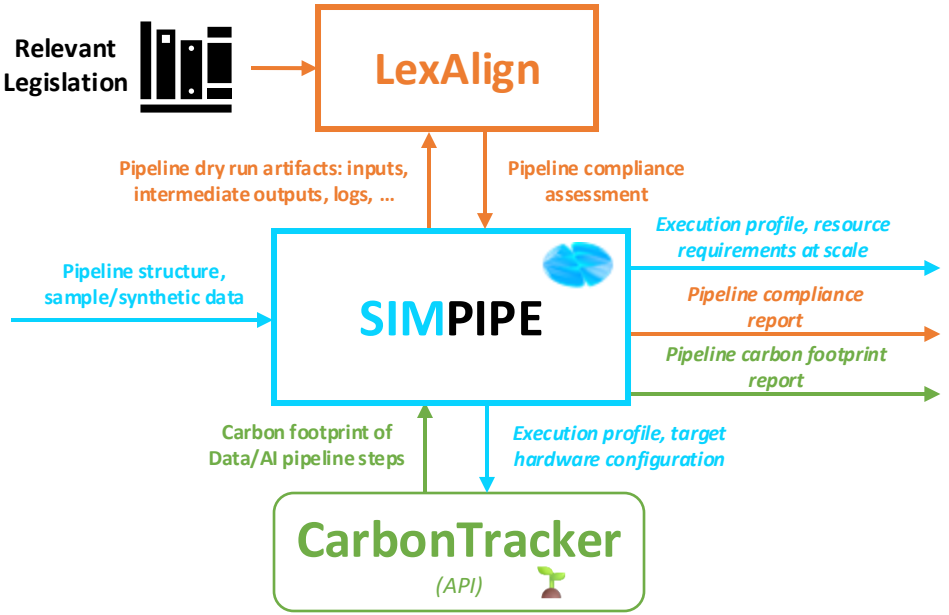
14.11.2025 @EBDVF2025

# DataPACT envisioned ecosystem for Compliance-by-Design data/AI pipelines



# Example Tools for Data/AI Pipeline Compliance Sandboxing

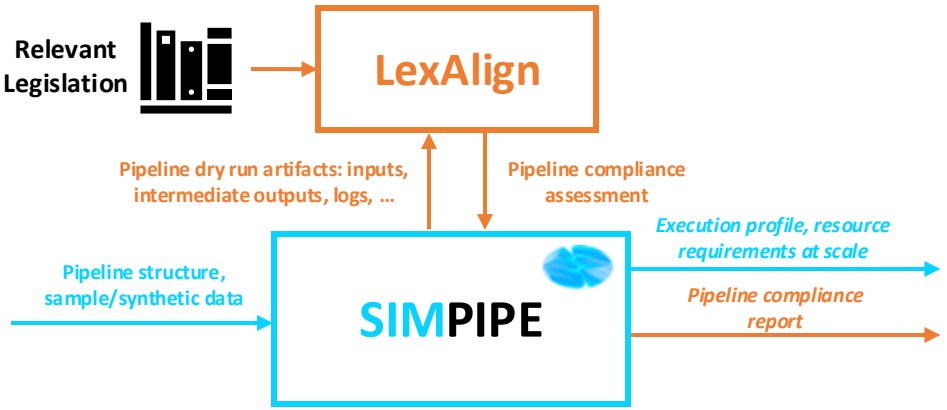
- Data/AI pipeline profiling
  - Emulation of target infrastructure
  - Duration and resource requirements measurements (CPU, memory)
  - Estimations for scaled deployments
- Carbon footprint estimation
  - $CO_2$ and *energy* use estimation
- Regulatory compliance assessment
  - EU regulations (AI Act, Data Act, GDPR, …)
  - Industry-specific legislation



# Semantics in DataPACT

## Context engineering for LLMs reasoning about compliance – using legal flows

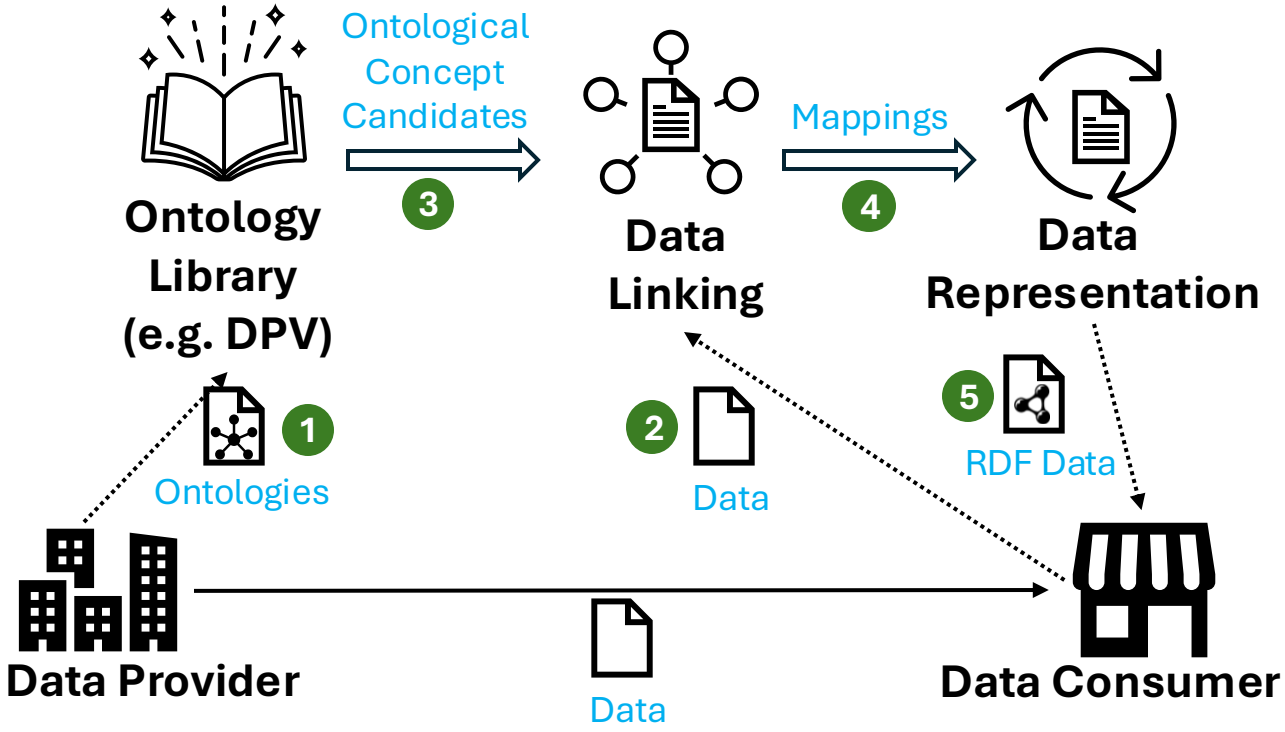
- Use ontologies to model regulations and relationships between articles in regulations/definitions
- Encode legal knowhow (what are the relevant aspects of the law needed to answer accurately) by associating semantically annotated parts of the law
- Considering to use semantic technology to model facts about pipeline
- Use in RAG to create accurate context for LLM reasoning



# Semantics in DataPACT

## Data enrichment for compliance

- Identify key data aspects in designing and running pipelines
  - E.g., identification of the existence of personal data in running pipelines by annotating using DPV vocabulary
- Compliant publication of datasets in data spaces – ontologies such as DCAT / Schema.org
  - Semantic data enrichment services that are able to automatically classify a dataset or fill in datasets descriptions according to DCAT / Schema.org



# Semantics in DataPACT

## Policy specification

- Expressing policies on data/AI pipelines (ODRL and related ontologies)
  - Encoding compliance requirements using semantic technologies

*DataPACT is funded by the European Comission under the grant number 101189771 (HORIZON-CL4-2024-DATA-01). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.*

*Website: https://datapact.eu*

*Contact: dumitru.roman@sintef.no*

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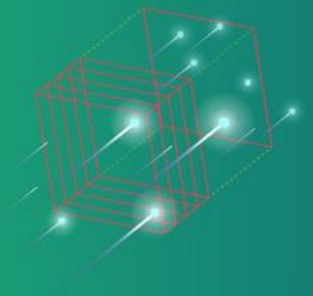

## Semantics & Compliance

# ACCOMPLISH

Dr. Fenareti Lampathaki (Suite5)
Technical Coordinator - ACCOMPLISH

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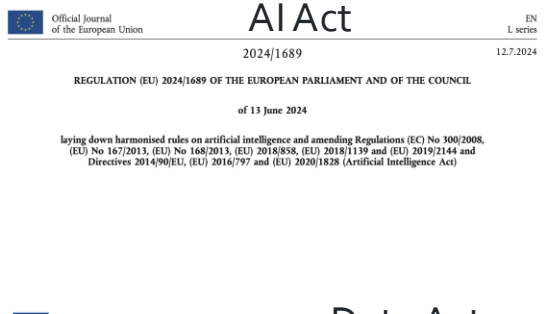
Scope

I. Automated Compliance Assessment, Recommendation Generation & Certification

II. Trustworthy Digital Enablers for Data/AI Ops

# accomplish & Semantics: How and What?


Official Journal of the European Union — EN L series — 12.7.2024

2024/1689

REGULATION (EU) 2024/1689 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 13 June 2024

laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act)

AI Act

Official Journal of the European Union — EN L series — 22.12.2023

2023/2854

REGULATION (EU) 2023/2854 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 13 December 2023

on harmonised rules on fair access to and use of data and amending Regulation (EU) 2017/2394 and Directive (EU) 2020/1828 (Data Act)

Data Act

4.5.2016 — EN — Official Journal of the European Union — L 119/1

I

(Legislative acts)

REGULATIONS

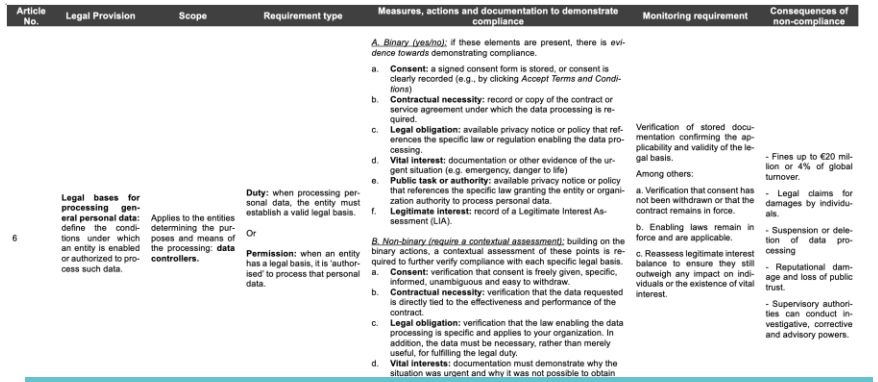
REGULATION (EU) 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 27 April 2016

on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation)

GDPR

From EU Acts....



| Article No. | Legal Provision | Scope | Requirement type | Measures, actions and documentation to demonstrate compliance | Monitoring requirement | Consequences of non-compliance |
|---|---|---|---|---|---|---|
| 6 | **Legal bases for processing general personal data:** define the conditions under which an entity is enabled or authorized to process such data. | Applies to the entities determining the purposes and means of the processing: **data controllers.** | **Duty:** when processing personal data, the entity must establish a valid legal basis.<br>Or<br>**Permission:** when an entity has a legal basis, it is 'authorised' to process that personal data. | *A. Binary (yes/no):* if these elements are present, there is *evidence towards* demonstrating compliance.<br>a. **Consent:** a signed consent form is stored, or consent is clearly recorded (e.g., by clicking *Accept Terms and Conditions*)<br>b. **Contractual necessity:** record or copy of the contract or service agreement under which the data processing is required.<br>c. **Legal obligation:** available privacy notice or policy that references the specific law or regulation enabling the data processing.<br>d. **Vital interest:** documentation or other evidence of the urgent situation (e.g. emergency, danger to life)<br>e. **Public task or authority:** available privacy notice or policy that references the specific law granting the entity or organization authority to process personal data.<br>f. **Legitimate interest:** record of a Legitimate Interest Assessment (LIA).<br>*B. Non-binary (require a contextual assessment):* building on the binary actions, a contextual assessment of these points is required to further verify compliance with each specific legal basis.<br>a. **Consent:** verification that consent is freely given, specific, informed, unambiguous and easy to withdraw.<br>b. **Contractual necessity:** verification that the data requested is directly tied to the effectiveness and performance of the contract.<br>c. **Legal obligation:** verification that the law enabling the data processing is specific and applies to your organization. In addition, the data must be necessary, rather than merely useful, for fulfilling the legal duty.<br>d. **Vital interests:** documentation must demonstrate why the situation was urgent and why it was not possible to obtain | Verification of stored documentation confirming the applicability and validity of the legal basis.<br>Among others:<br>a. Verification that consent has not been withdrawn or that the contract remains in force.<br>b. Enabling laws remain in force and are applicable.<br>c. Reassess legitimate interest balance to ensure they still outweigh any impact on individuals or the existence of vital interest. | - Fines up to €20 million or 4% of global turnover.<br>- Legal claims for damages by individuals.<br>- Suspension or deletion of data processing<br>- Reputational damage and loss of public trust.<br>- Supervisory authorities can conduct investigative, corrective and advisory powers. |

Compliance Requirements Elicitation

**GDPR Certification Controls**

Controls focus on data minimization, consent management, and safeguards against profiling to meet GDPR requirements.

**AI Act Evaluation Criteria**

Controls include risk classification, human oversight, and robustness to ensure ethical AI operation.

**NIS2 Cybersecurity Controls**

Focus on cybersecurity governance, incident response, and mandatory reporting to secure digital infrastructures.

**Data Act Sharing Standards**

Certification Controls Definition

```
{
  "@context": http://www.w3.org/ns/odrl.jsonld,
   "@type": "Set"
  "uid": "http://example.com/policy: lawful_processing_of_personal_data",
  "profile": http://example.com/odrl:profile:ACCOMPLISH,
  "permission": [{
    "target": http://fokus.fraunhofer.de/asset:personal_data,
    "action": "processing"
    "assignee": "http://fokus.fraunhofer.de/data_controller"
"predicateConstraint": {
  "leftOperand": "legalBasis",
       "operator": "isAnyOf",
       "rightOperand": {
         "@list": [
           { "@id": "Consent"},
           { "@id": "Contract"},
           { "@id": "LegalObligation"},
           {"@id": "VitalInterest"},
           { "@id": "PublicInterest" },
           { "@id": "ExerciseOfOfficialAuthority" },
           { "@id": "LegitimateInterest" }
         ]
       } }]
"prohibition": [{
       "legalBasis": "LegitimateInterest",
       "predicateConstraint": [{
"leftOperand": "action",
"operator": "isA",
"rightOperand": "ProcessingEffectingFundamentalRightsAndFreedomsOfTheDataSubject"
```


ODRL Policy Models Design *(ODRL Regulatory Compliance Profile)*

Compliance Inference Engine Design

LLM-based Compliance Assessment Recommendations Engine Design

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## Semantics & Compliance

# Achilles

Silvia Colella
Project Manager - PNO Innovation Digital

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# About me and PNO Digital

## Silvia Colella

**Project Manager**

- Expertise in **EU-funded projects, innovation strategy, and digital transformation**
- Passionate about connecting **technology, ethics, and real-world impact**

## PNO Digital

- Supports research and innovation projects across Europe
- Focus on data, AI, and digital transformation
- Helps bridge the gap between technology, compliance, and sustainability
- Active in several Horizon Europe projects, including ACHILLES

# ACHILLES

**The Challenge: AI Has Its Achilles' Heel**

- Artificial Intelligence is powerful - but not invincible.
- It faces vulnerabilities: lack of transparency, high energy use, privacy concerns, and ethical risks.
- Like the mythic hero, AI has its own *"Achilles' heel"* - trust and reliability.

# ACHILLES: our ambition

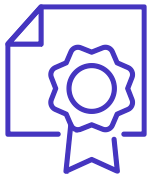
We aim to make AI:

**LIGHTER**

more efficient,
less energy-hungry

**CLEARER**

more transparent
and explainable

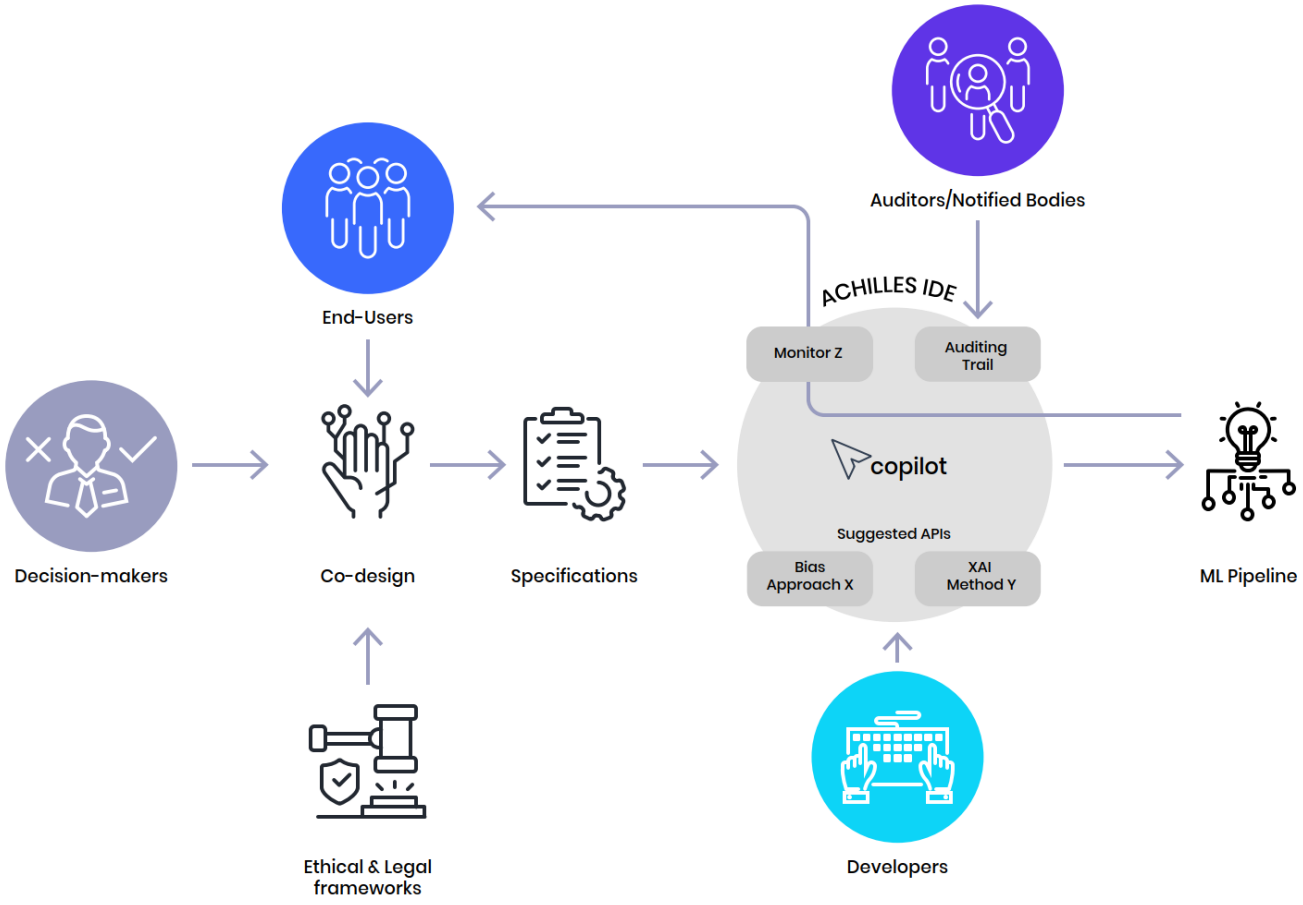


**SAFER**

more robust, reliable,
and compliant

# How we do it – ACHILLES IDE

- IDEs should not be only for developers
  - Bridge the gap between stakeholders
  - Controllable workflows (SOPLang)
- Copilot – a Multi-agent system
  - Specialised agents capable of interacting with
    - Legal/ethical specifications
    - Technical APIs (e.g., bias, privacy-checks)



# From semantics to compliance: the ACHILLES semantic stack

| | | |
|---|---|---|
| **Specification Layer** | **SOP Lang**<br>Structured language to express *intent, ethical principles, and regulatory conditions* in machine-readable form. | **"Ontology for action":** rules, roles, and workflows share a common vocabulary. |
| **Reasoning Layer** | **Multi-Agent Copilot**<br>Agents interpret the SOP Lang specs and perform *bias checks, GDPR validation, energy efficiency*, etc. | Implements **neurosymbolic reasoning** (expert-defined rules + LLM interpretation).. |
| **Documentation Layer** | **Model Card API**<br>Standardized, semantic documentation of models: *intended use, risks, compliance status*. | **"Compliance as data"** — accessible to humans and machines. |
| **Governance Layer** | **Audit & Traceability Framework**<br>Links specifications, datasets, models, and evaluations into an *evidence graph*. | Supports explainability, provenance, and certification. |

# Interoperable Trust: ACHILLES for European Data Spaces

## Interoperable Metadata

- **Model Cards & SOP Lang** make compliance **machine-readable** (AI Act, GDPR, ISO/IEC 42001).
- **Structured and interoperable metadata** describe data, models, and rules.
- Shareable across federated nodes via **standard APIs** or **Linked Data**.

## Provenance & Auditability

- Every step (data → model → deployment) is **logged, signed, and versioned**.
- Builds an **evidence graph** linking datasets, models, and results.
- Ensures **traceability**, **accountability**, and **explainability** across organizations.

## Policy-aware Agents

- Semantic agents perform **"compliance checks as services."**
- Validate **lawful basis**, **consent**, **AI Act risk class**, and **privacy constraints** *before* execution.
- Combine **expert-defined rules** and **neurosymbolic reasoning** for automated policy enforcement.

## Federated-by-Design

- With **AssistOS + Ploinky**, each organization operates in a **secure, containerized environment**.
- Shares **proofs, not data** — exchanging verifiable evidence instead of raw datasets.
- Fully aligned with **data sovereignty**, **privacy-preserving AI**, and **trust interoperability** principles.

# Where we apply it

ACHILLES

Four **real-world use cases** to test the framework:

## HEALTHCARE

ML-based diagnostic tools for eye conditions

## IDENTITY VERIFICATION

Matching people to their official documents

## CREATIVE INDUSTRIES (SCRIPTA)

AI-assisted script writing and adaptation

## PHARMACEUTICALS (HERA)

Improving efficiency and regulatory compliance

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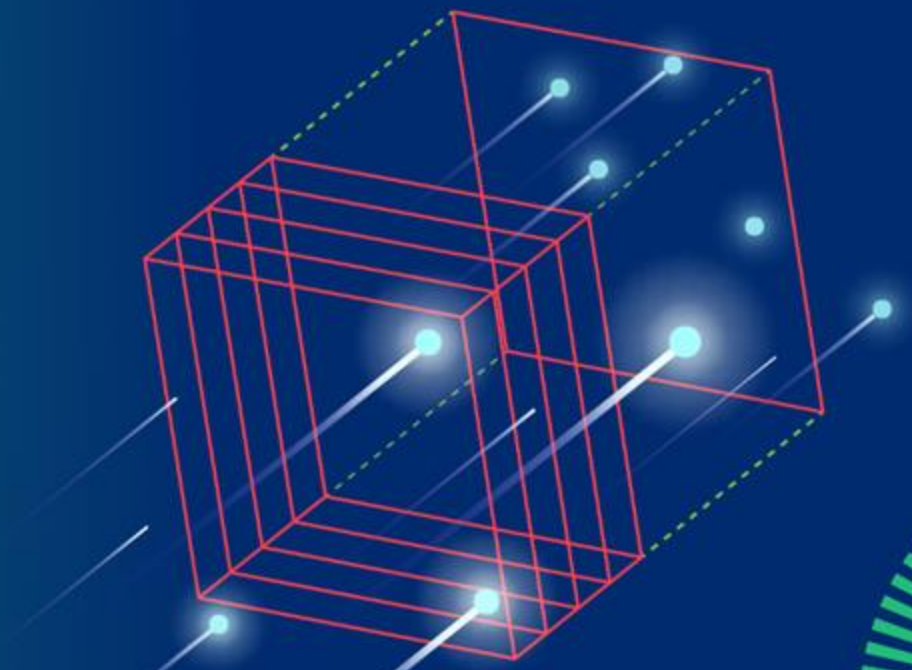

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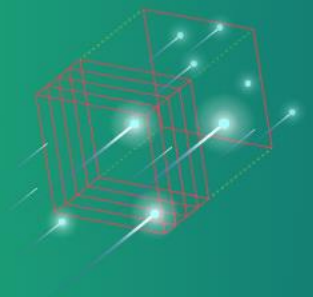

## Semantics & Compliance

# CERTAIN

Rafael Rodrigues
Digital 4 Planet

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# Constructing a Framework for the Ethical and Regulatory Certification of AI Systems


- [1] Rafael Rodrigues, Dimitrios Christodoulou – Digital for Planet (D4P)
- [2] Fabian Kovac, Sebastian Neumaier, Timea Pahi, Torsten Priebe - SPU
- [3] Georgios Pitsiladis, John Soldatos, Petros Zervoudakis - Netcompany

# INTRODUCTION

## Problem Statement

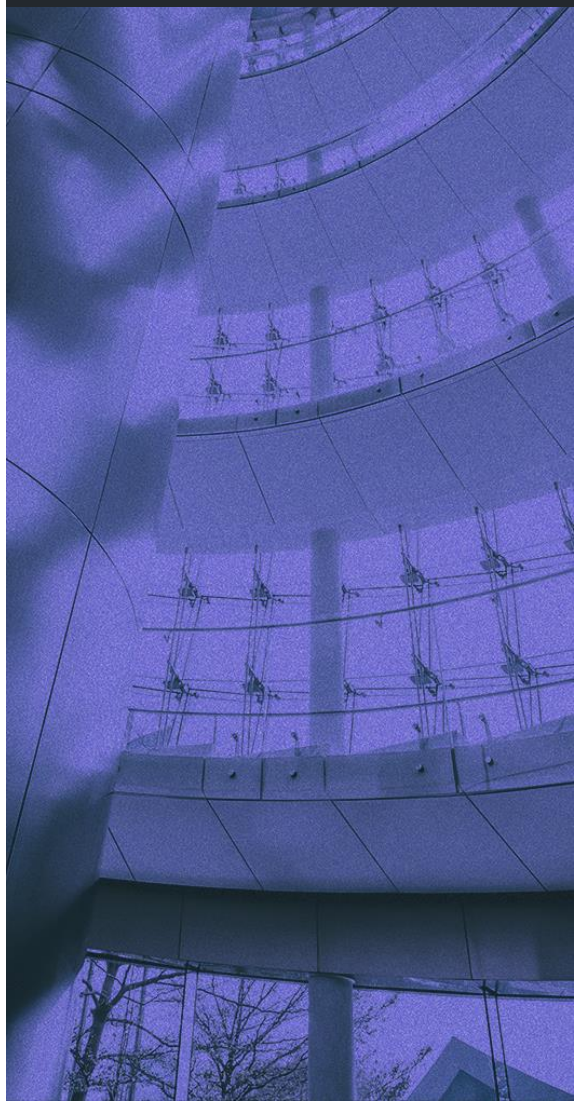
- AI systems are increasingly deployed across critical sectors
- Ensuring transparency, ethics, and regulatory compliance is essential
- New EU regulations broaden the scope

### Challenges

- Regulatory complexity and evolving legal frameworks
- Lack of integrated tools and processes for AI compliance and certification
- Semantic gaps between technical implementations and legal requirements

### Our Mission

- Develop a framework for regulatory transparency, compliance, and “certification”
- Foster trustworthy, sustainable, and responsible AI in line with European values





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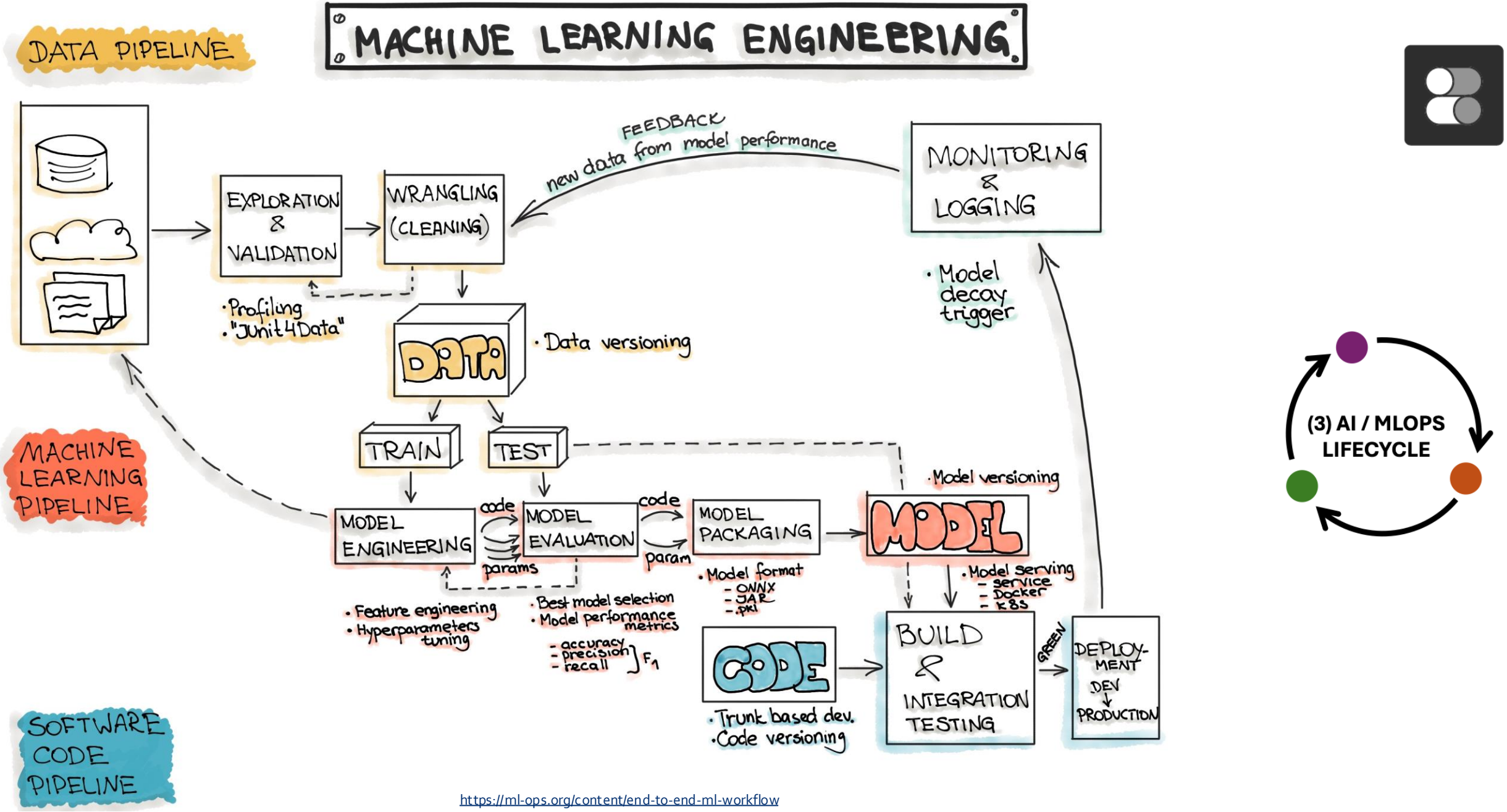





https://ml-ops.org/content/end-to-end-ml-workflow


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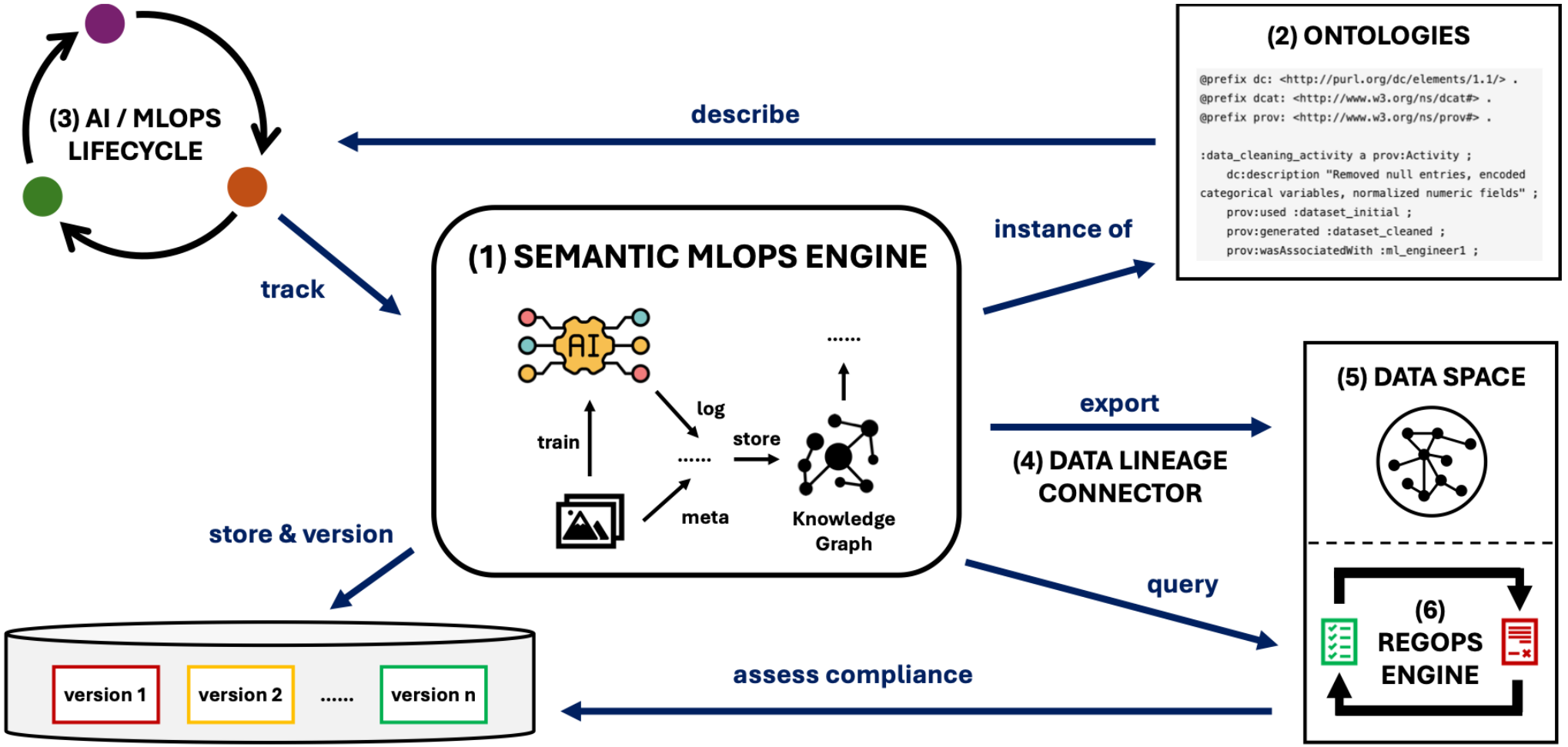
# CERTAIN FRAMEWORK



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# SEMANTIC MLOPS ENGINE – ML LIFECYCLE

```python
# Data Pipeline

def load_data():

def explore_and_validate_data():

def clean_data():

def augmentation_data():

def train_test_split_data():

# Machine Learning

def model_training():

def model_evaluation():

def model_fine_tuning():

# Model Packaging

def model_packaging():

def model_versioning():

# Deployment and Monitorting

def deploy_model():
  # Fast API

def monitor_log_model():

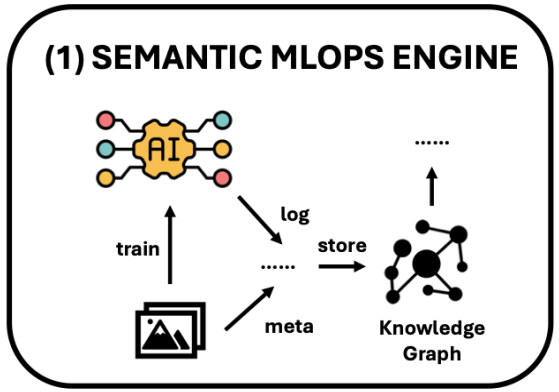
def detect_drift():
```

mlflow

whylogs

CODE CARBON

ZenML





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# SEMANTIC MLOPS ENGINE – DB AND ARTIFACTS

### DATA ANALYSIS

Basic Data Profiling:
- Missing Values.
- Data Types.
- Unique Values.
- Feature Distributions.
- Class Balance.
- Outliers.
- Drifts for each stage.
- Train/Test dataset duration.

- Data Leakage (future values).
- Test/Train Drift.
- Feature Correlation.
- Season Patterns.
- Feature Lags.
- Calendar effects.
- Consumptions / CO2 Emissions

### DATA

- Data Location.
- Timestamp Format.
- Timezone.
- Sampling Frequency.
- Missing data from sensors. (Sampling Failed)
- External Data Sources. (weather provider)
- Data Signature.
- Size.
- Schema.
- Data Sources. (Sensors, database etc)

### DATA TECHNIQUES

Timestamp:
- Timestamp Normalisation.
- Remove Duplicates.

Missing Data:
- Forward/ Backward fill.
- Interpolation.
- Kalman Filter.
- Drop Large Gaps.

Features:
- Features conversion. (categorical -> One-hot)
- Smooth noisy features.

Augmentation:
- External Feature Injection (weather, calendar)
- Jittering. (add noise)
- Scaling.
- Synthetic data generation.

- Consumptions / CO2 Emissions

### MODEL

- Model Signature.
- Model Name.
- Model Version.
- Architecture Params.
- Loss Function.
- Optimizer.
- Regularization.
- Learning Rate.
- Early stopping.
- Training Start/Stop Timestamp.
- Training Time.
- Number Epochs.
- Hardware.
- Random Seed.

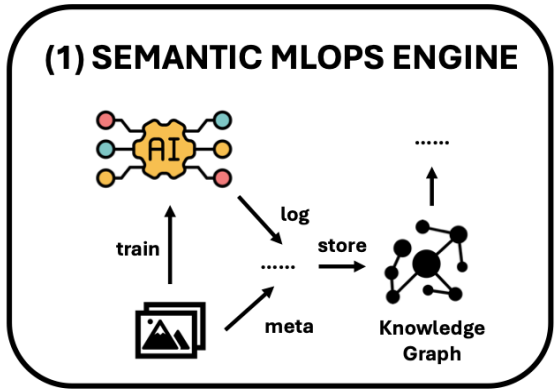
Loss:
- Train Loss.
- Valid Loss.
- Test Loss.

Metrics:
- MAE / RMSE / MAPE.

- Cross Validation Folds.
- Ensembling Methods.
- Consumptions / CO2 Emissions

### DEPLOYMENT

- Deployment ID.
- Model Version.
- Deployment Time.
- Deployed by.
- Environment.
- Infrastructure.
- Hardware Specs.
- Runtime. (Fast API)
- Docker Image Hash.
- Config File Path.
- Input Schema Version.
- Output Schema Version.
- Data Drift.
- Prediction Distribution.
- Consumptions





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# ONTOLOGY – DUAL APPROACH

Dual approach to bridge the gap between high-level compliance requirements and concrete implementations

### Top-Down Approach

**Goal:** Start from *regulatory and legal frameworks* and translate them into actionable technical elements.

- Analyzing the **AI Act** and other legal or ethical guidelines
- Extracting high-level **compliance requirements** and attempting to **map these into the stages of the AI lifecycle**.
- Identifying the **obligations** and **standards** that an AI system must meet throughout its lifecycle (e.g. transparency, traceability, etc.).

➢ Ensuring the resulting framework aligns with **policies, ethical principles, and legal expectations**

### Bottom-Up Approach

**Goal:** Start from *real pilot data and technical processes* to abstract upwards to enrich relevant requirements.

- Focus on **concrete use cases** and **practical workflows** from pilot projects
- Documenting **actual data pipelines, model engineering steps, testing routines, deployment methods**, etc.
- Analyzing what *actually happens* to identify, **which lifecycle stages and requirements are relevant or missing**.

➢ Ensuring that the resulting ontology and questions are **usable in real operational contexts**.


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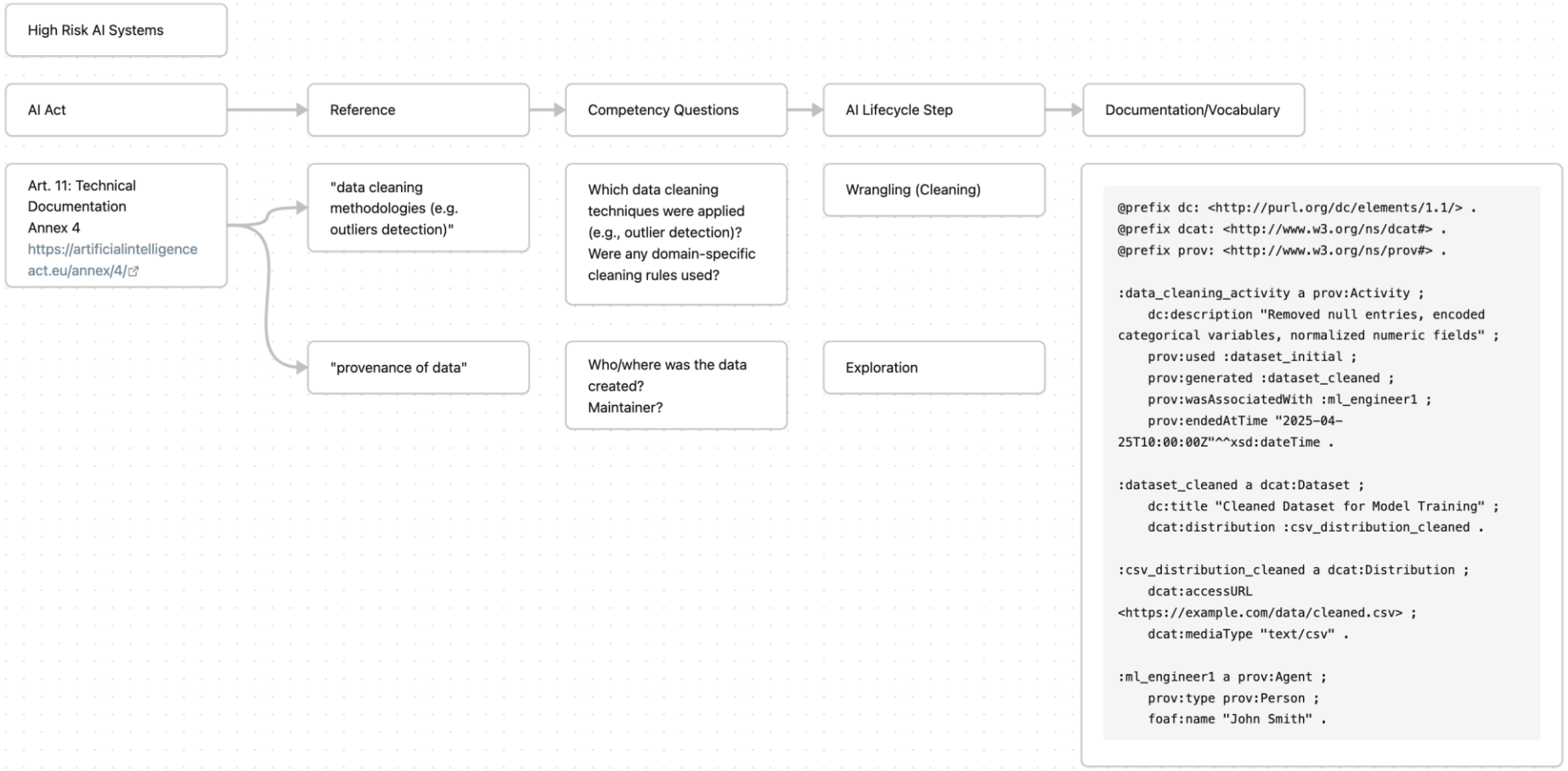
# ONTOLOGY – TOP DOWN APPROACH




**(2) ONTOLOGIES**

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@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix dcat: <http://www.w3.org/ns/dcat#> .
@prefix prov: <http://www.w3.org/ns/prov#> .

:data_cleaning_activity a prov:Activity ;
    dc:description "Removed null entries, encoded
categorical variables, normalized numeric fields" ;
    prov:used :dataset_initial ;
    prov:generated :dataset_cleaned ;
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```


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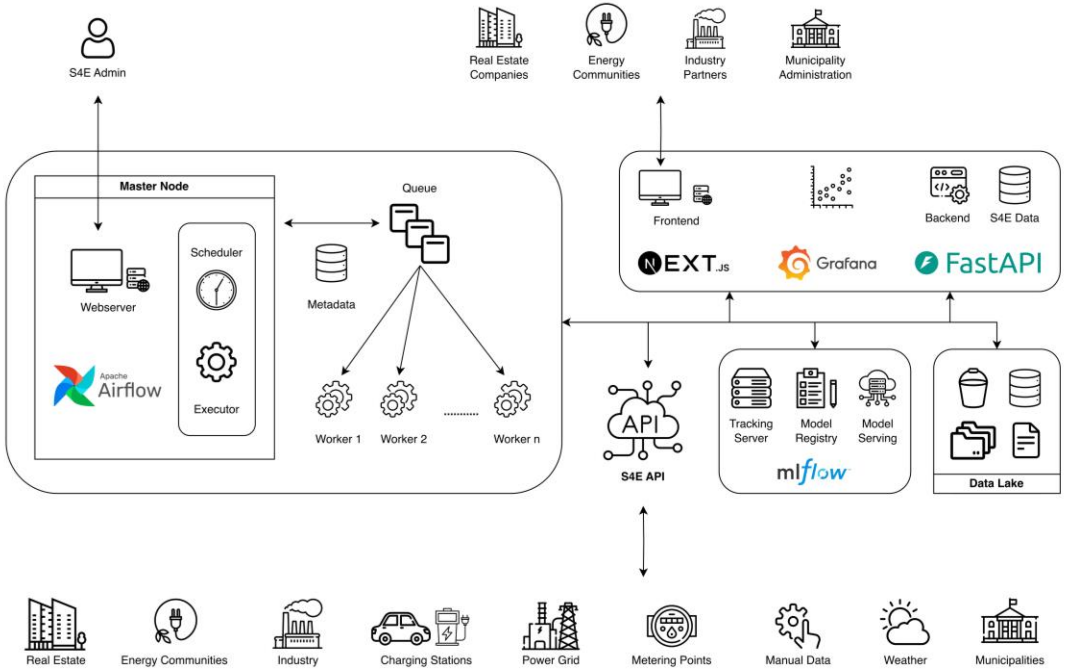
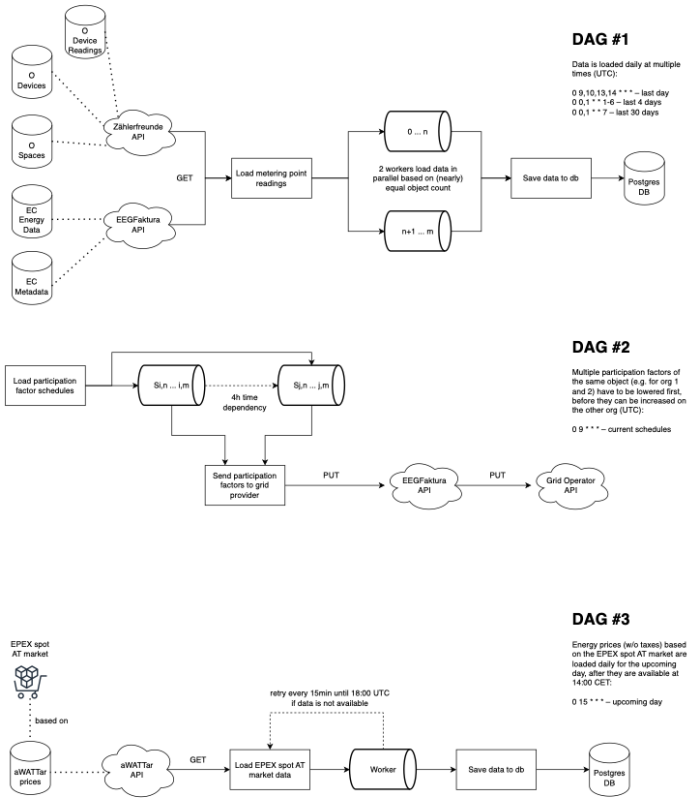
# ONTOLOGY – BOTTOM UP APPROACH

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```

Example: Energy Pilot

Assessment includes architectural overview, sample data, metrics, requirements, accountability information, etc.


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# ONTOLOGY – COMPETENCY QUESTIONS CATALOGUE

| Requirements from AI Act, Annex IV. | Reference | Competency Questions | AI Lifecycle Stages | Reference with Exact Wording |
|---|---|---|---|---|
| **Hardware required for the system** | Annex IV, 1(e) | What hardware does the AI system need to run? | Software Pipeline: Deployment | A description of the hardware on which |
| **Illustrations and markings of the product** | Annex IV, 1(f) | What is the physical form of the product? | Software Pipeline: Deployment | Photographs or illustrations showing th |
| **User interface for the deployer** | Annex IV, 1(g) | What interface is provided for operators or deployers? | Software Pipeline: Deployment | A basic description of the user interfac |
| **Elements of the AI system and development process** | Annex IV, 2(a) | What are the components and steps of development of the software product itself and the AI model(s) used? | ML Pipeline: Model Engineering | A detailed description of the elements |
| **System architecture and algorithms** | Annex IV, 2(b) | What is the architecture and what algorithms are used? | ML Pipeline: Model Engineering | A detailed description of the system ar |
| **Data requirements and processing** | Annex IV, 2(c) | What data is needed and how is it processed? | Data Pipeline: Exploration and Validation | A description of the data requirements |
| **Training, validation, and testing data & provenance** | Annex IV, 2(d) | What data is used? Where does it come from? How was it obtained? | Data Pipeline: Data Training and Testing | A description of the data used for traini |
| **Measures for data quality** | Annex IV, 2(e) | How is the data cleaned, filtered, and validated? | Data Pipeline: Wrangling (Cleaning) | A description of the measures taken to |
| **Training methodologies** | Annex IV, 2(f) | How was the model trained? What techniques were used? | ML Pipeline: Model Engineering | A detailed description of the training m |
| **Testing and validation procedures** | Annex IV, 2(g) | How was the system tested and validated? | ML Pipeline: Model Evaluation | A description of the testing and validat |
| **Risk management system** | Annex IV, 3(a) | What risks were identified and mitigated? How often do get risks (re-)evaluated and checked? | Cross-cutting / All Pipelines | A description of the risk management s |

## (2) ONTOLOGIES

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```


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EUROPEAN BIG DATA VALUE FORUM

## Semantics & Compliance

# Discussion: Ontology, Semantics & Compliance: Tools for Trust

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BDV BIG DATA VALUE ASSOCIATION

IN COLLABORATION WITH

European Commission

DTU

SDU University of Southern Denmark

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#EBDVF25

# Semantics and Compliance

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EUROPEAN BIG DATA VALUE FORUM

## Semantics & Compliance

# Discussion: Semantic Compliance in Data Spaces: Interoperability, Governance & Trust

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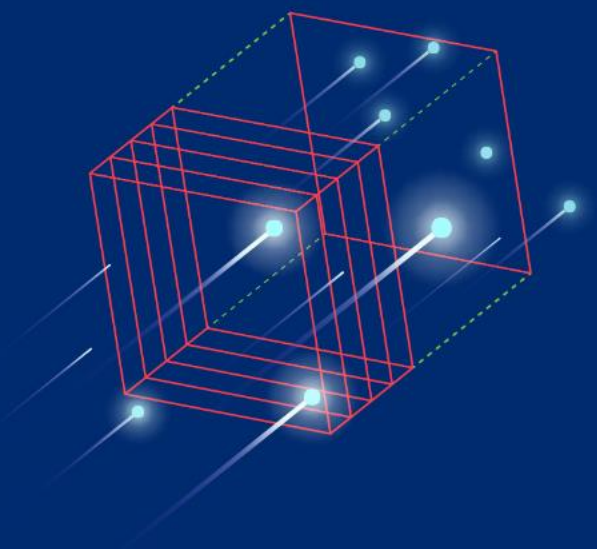

## 14 November, 09:00 - 10:30 CET

# Semantics & Compliance: Enabling Trustworthy Data/AI in European Data Spaces

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