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Agriculture Information Model as semantic interoperability enabler in data spaces

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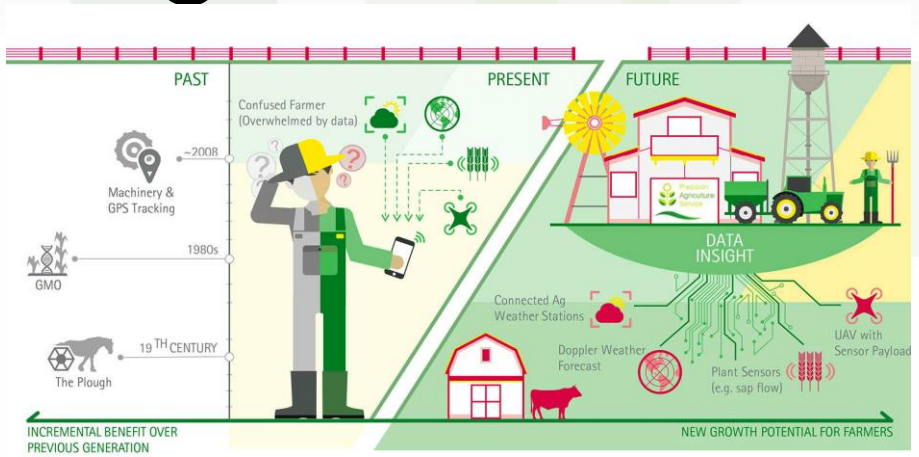
Interoperability challenges in AgTech sector

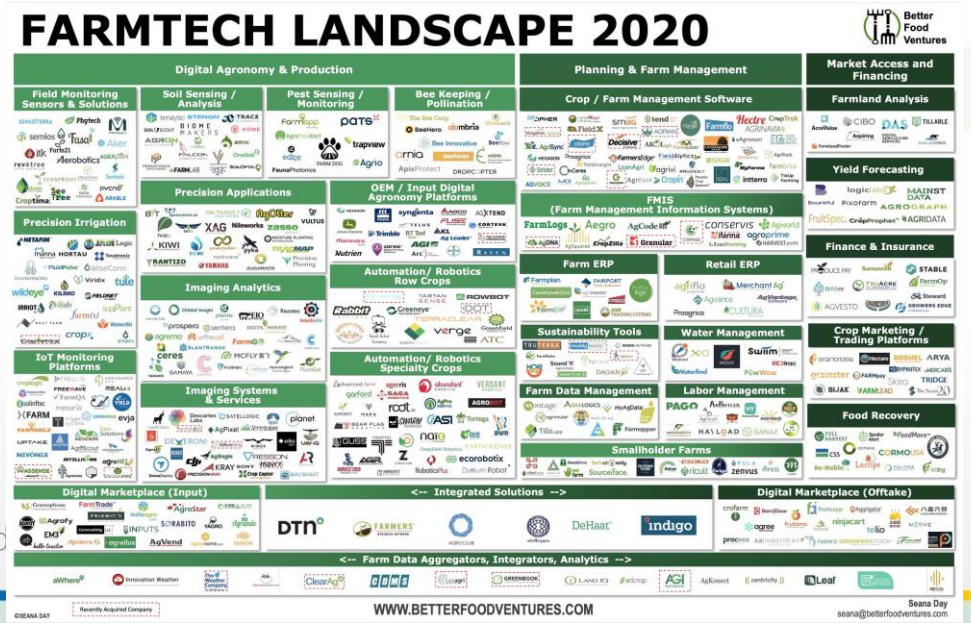
The rapid advances of IoT technologies, AI and Big Data, among others, have boosted the adoption of smart farming practices.

This, however, has led to an explosion of data, generated by a wide range of different systems and platforms that rarely interoperate.

Some of the key challenges hampering the seamless exchange and integration of the data produced or collected by those systems include:

- Availability of data in different formats and represented according to different models
  - heterogeneity of data models and semantics used to represent data
  - lack of related standards dominating this space
- Insufficient interoperability mechanisms that enable the connection of existing agri-food data models





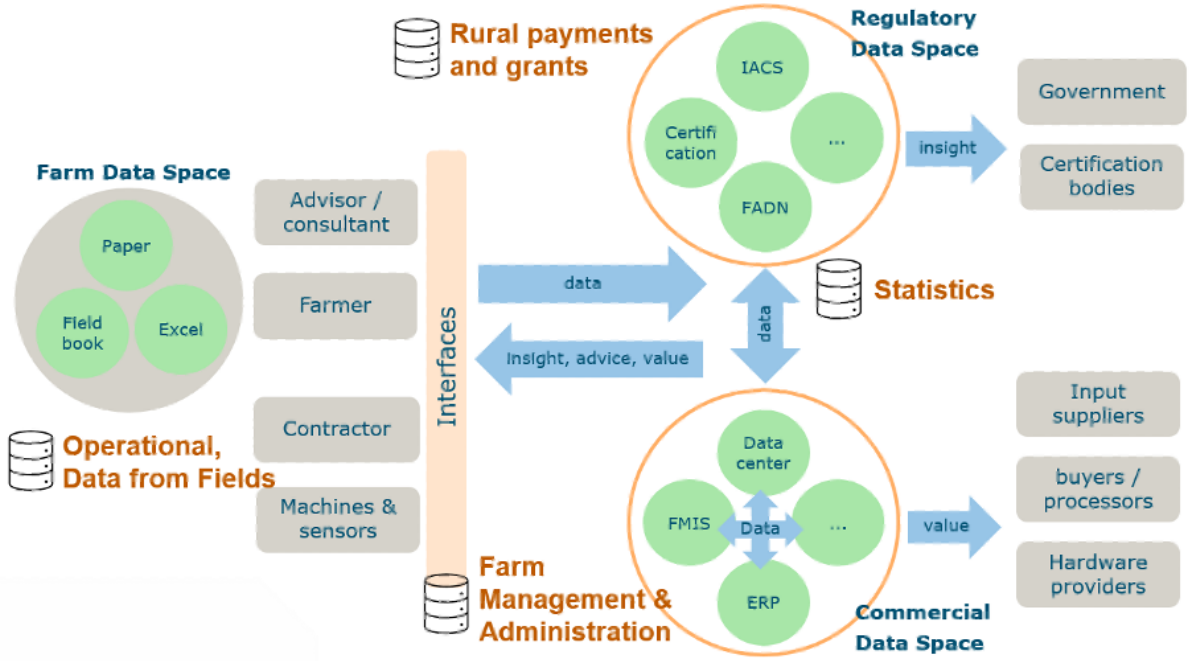
The current use of data systems in agriculture

Broad existing categories

- Operational, Data from Fields
- Farm Management and Admin
- Rural Payments and Grants

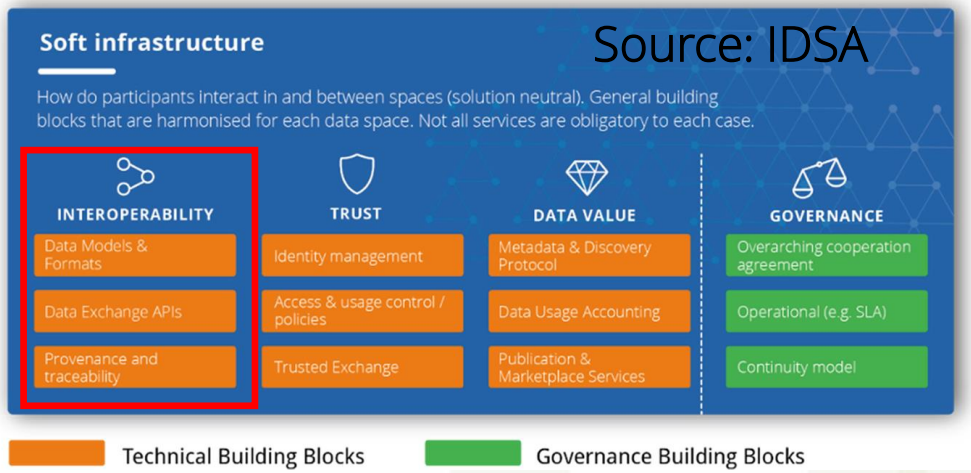
Current situation

- Highly fragmented
- Little, to no interoperability
- Short-sighted, siloed, data-ownership based business models



Plus: Lot of legacy to deal with...

Architectural Building Blocks - Data Plane



Basic integration (communication protocols)

foundational interoperability (i.e. MQTT, REST/HTTP)

Intermediate (machine-readability)

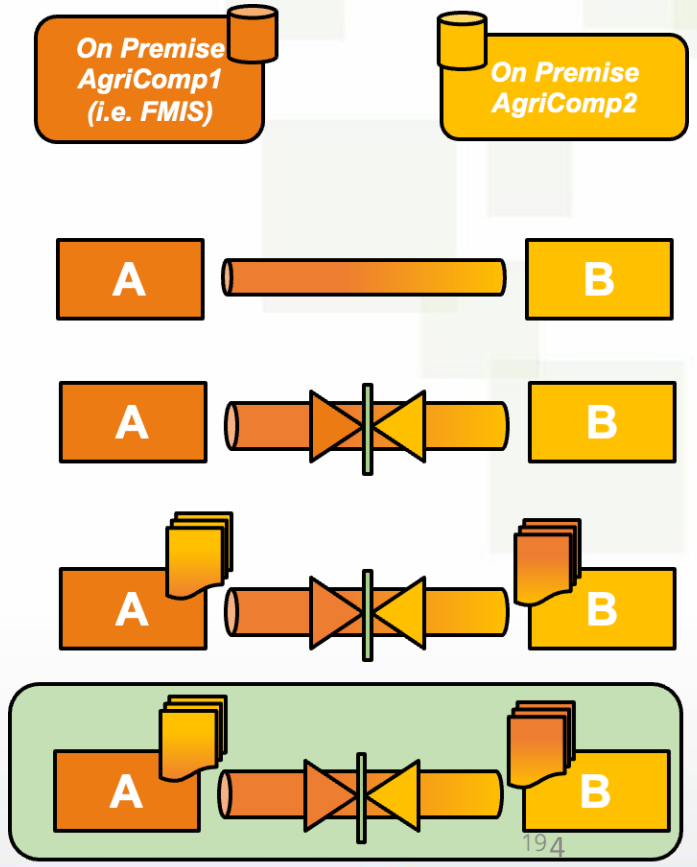
interface interoperability (i.e. JSON, metadata)

Advanced (data models)

syntactic interoperability (i.e. structured APIs)

Full (common ontologies, vocabularies)

semantic interoperability (i.e. AIM, AGROVOC)



Agriculture Information Model - AIM

AIM aims to establish the basis of a common agricultural data space, enable the interoperation of different systems, and the analysis of data produced by those systems in an integrated manner

AIM follows a modular approach in a layered architecture:

- realized as a *suite of* ***ontologies*** and associated ***JSON-LD contexts*** enabling both the specification of formal semantics, and a simple adoption and implementation by tech providers, plus a set of ***SHACL shapes*** enabling validation of data at the semantic level.
- implemented in line with best practices, ***reusing*** existing ***standards*** and well-scoped ***models***
- establishes ***alignments*** between base models to enable their ***interoperability*** and the ***integration*** of existing data

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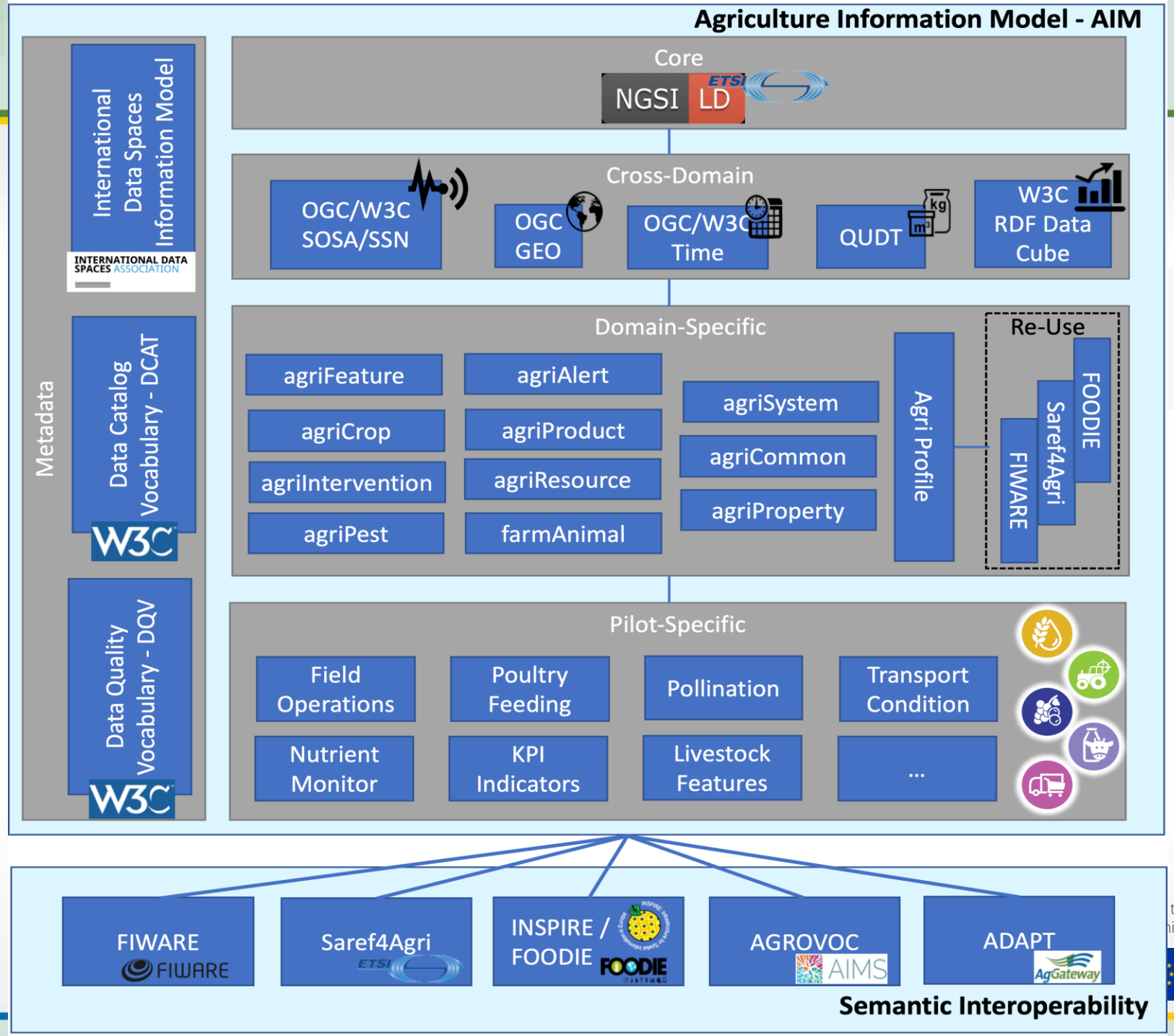
AIM layers



demeter

agridataspace-csa.eu

Example data types represented via AIM

- Farm data (e.g., field data, field status, soil data, Crops/treatment/fertilisation data, farm input data, energy consumption data, …)
- Earth Observation Data (e.g., satellite data, remote sensing imagery, soil maps, vegetation indices, such as NDVI, EVI, NDRE, NDMI)
- Meteorological data (e.g., temperature, humidity, wind speed/direction, solar radiation, pressure, etc.)
- Agricultural machinery data (e.g., engine data, fuel consumption, emissions, exhaust gas, NOx-conversion, exhaust temperatures, …)
- Representation of data quality metrics
- Field Operations data (irrigation, fertilisation, soil tillage)
- Livestock data
- Traceability data (transport)
- Financial farm data, benchmarking data and KPIs
- Farmer information
- …

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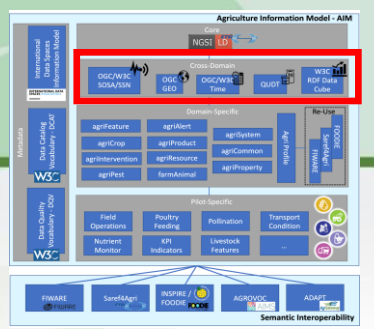

AIM cross-domain layer

- Generic model re-used by various domain-specific models
  - Define concepts and terms that are generic and applicable to various domains
  - Avoids conflicting/redundant definitions of the same concept in different domain specific models
  - Provides basis for interoperability with information systems and tooling that are aligned
- Specified by reusing concepts from a number of ontologies and vocabularies:
  - **W3C OWL Time** concepts of temporal properties and time values
  - **OGC GeoSPARQL** and associated definitions for geographical and geometrical properties
  - Concepts from **W3C/OGC** recommendation **SOSA/SSN** regarding sensor and actuator data, including observations, observation collections, observed properties, systems and platforms
  - **QUDT** regarding units of measurement, and concepts to represent quantities and quanity kinds
  - Concepts from the **RDF data cube** vocabulary to represent statistical data, including datasets, data structures, slices, measure properties, dimension properties, etc.
  - Basic terms from other standard or widely used vocabularies like skos, foaf, schema.org.
  - Alignment with **ISO geographic technology standards** , including features (domain and sampling feature), and observations
  - Alignment with core meta-model layer (**NGSI-LD**)

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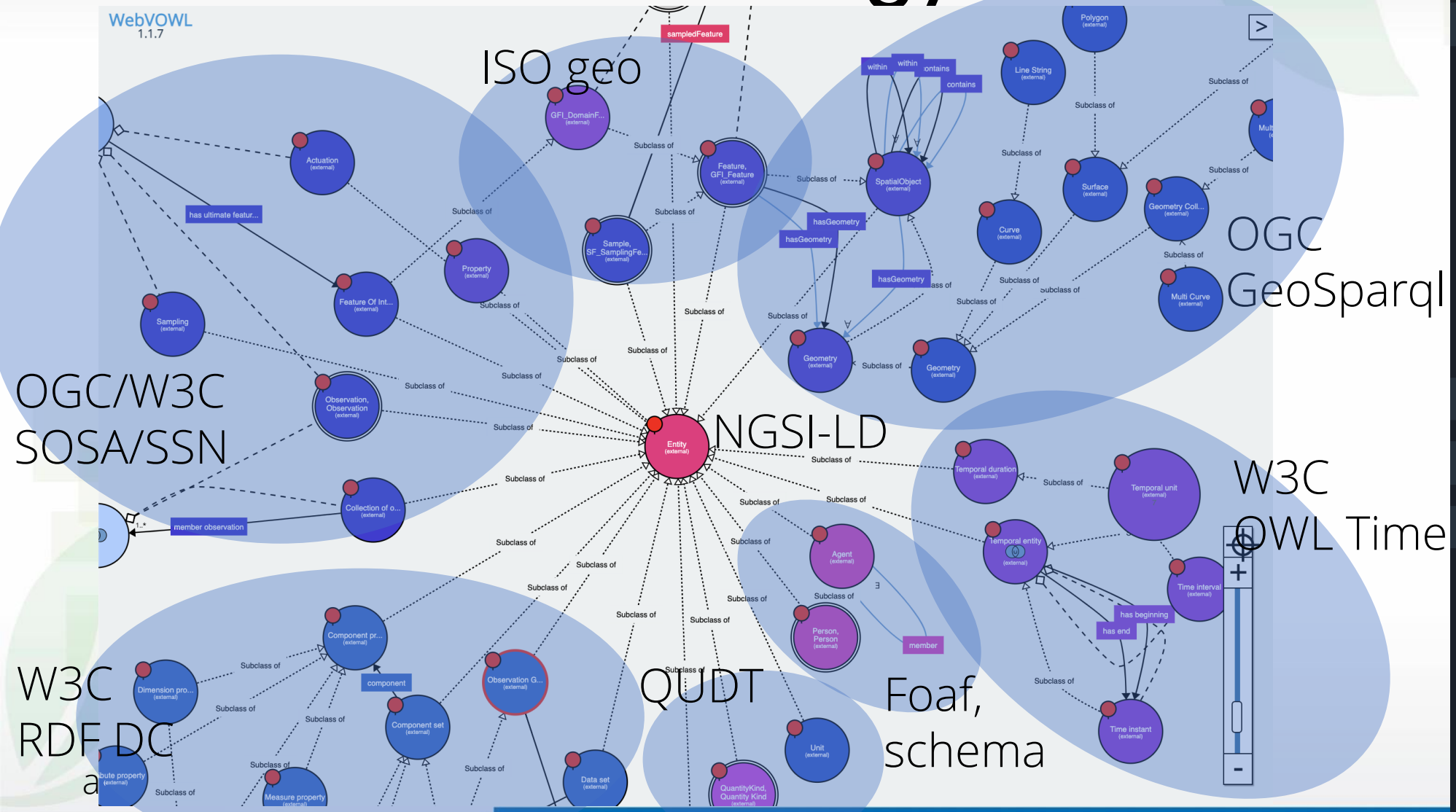
AGRI DATASPACE

Cross domain ontology overview



DEMETER Cross-Domain

https://w3id.org/demeter/crossDomain

Version: 1.0

Author(s): _:genid249385

Language: en

▼ Description

The DEMETER cross domain ontology i) defines concepts and terms that are generic and applicable to various domains; ii) avoids conflicting or redundant definitions of the same concept in different domain specific models; iii) provides the basis for interoperability. The ontology is specified by reusing concepts and terms from a number of standard ontologies and vocabularies including OGC/W3C SOSA/SSN, OGC GeoSparql, W3C RDF data cube, QUDT, FOAF, schema.org and others. It includes alignment to ISO standards and with DEMETER core meta-model (NGSI-LD).

▶ Metadata

▶ Statistics

▼ Selection Details

Name: *Observation*

Type: *owl:equivalentClass*

Equiv.: *Observation*

Charac.: *equivalent, external*

Comment: *If values are not provided for the following Observation properties, they may be provided by the ObservationCollection of which it is a member: - hasFeatureOfInterest - hasUltimateFeatureOfInterest - madeBySensor - observedProperty - phenomenonTime - resultTime - usedProcedure*

AIM domain layer

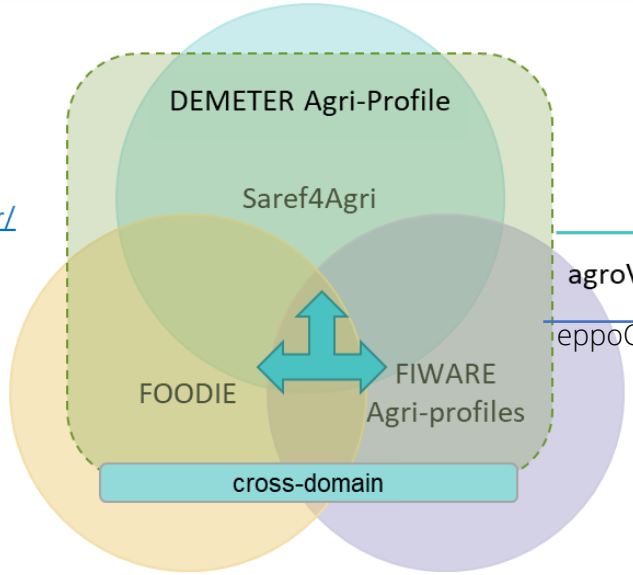
- Defines agricultre-specific concepts and properties covering different aspects of interest of agri related applications and data sources
- Aligns relevant vocabularies in the sector allowing interoperability and integration of existing data sources

W3id
W3C Permanent Identifier Community Group
https://w3id.org/demeter/

JSON-LD

SHACL

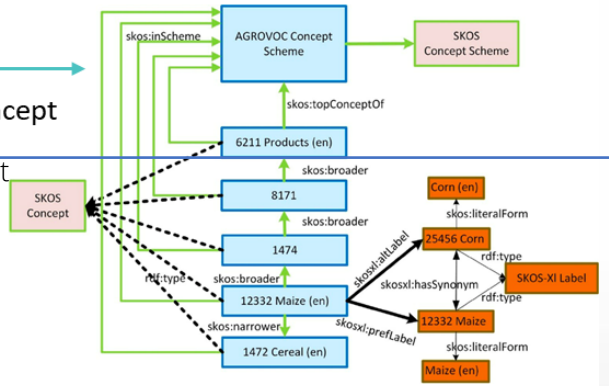
- Resolvable
- Persistent
- Content-negotiation
- Versioning



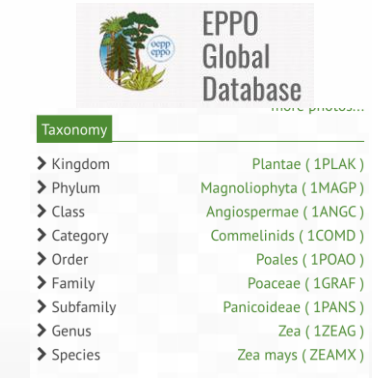
agroVocConcept

eppoConcept

AGROVOC Concept Scheme



EPPO Global Database



Full context:
https://w3id.org/demeter/agri-context.jsonld

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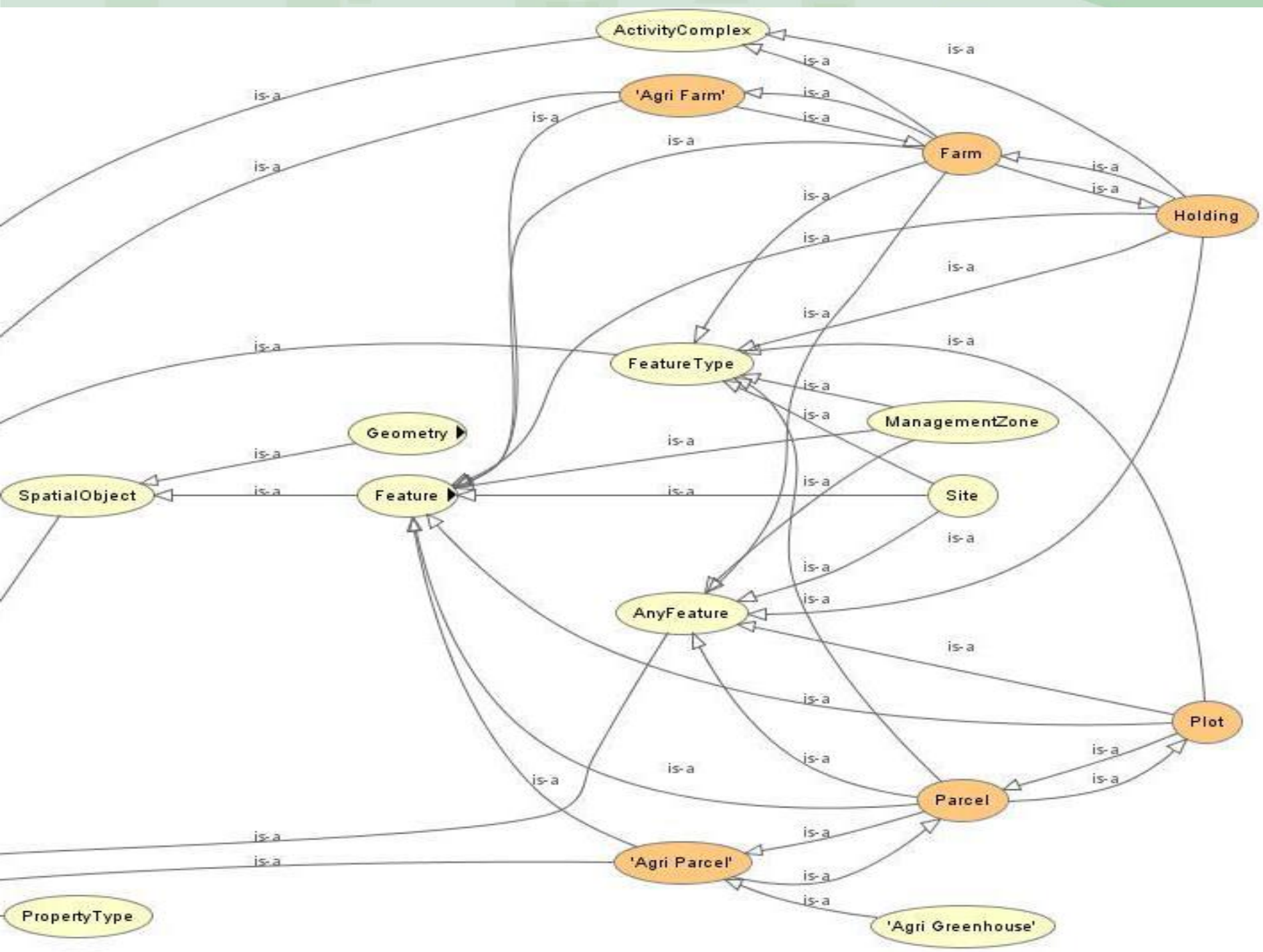


agriCommon

- Agent
- Person
- Farmer

- code
- description
- createdAt
- hasTimestamp

agriSystem

- Actuator
- Platform
- Sensor

- in deployment

agriPest

- hasAgriProductType

- name
- description

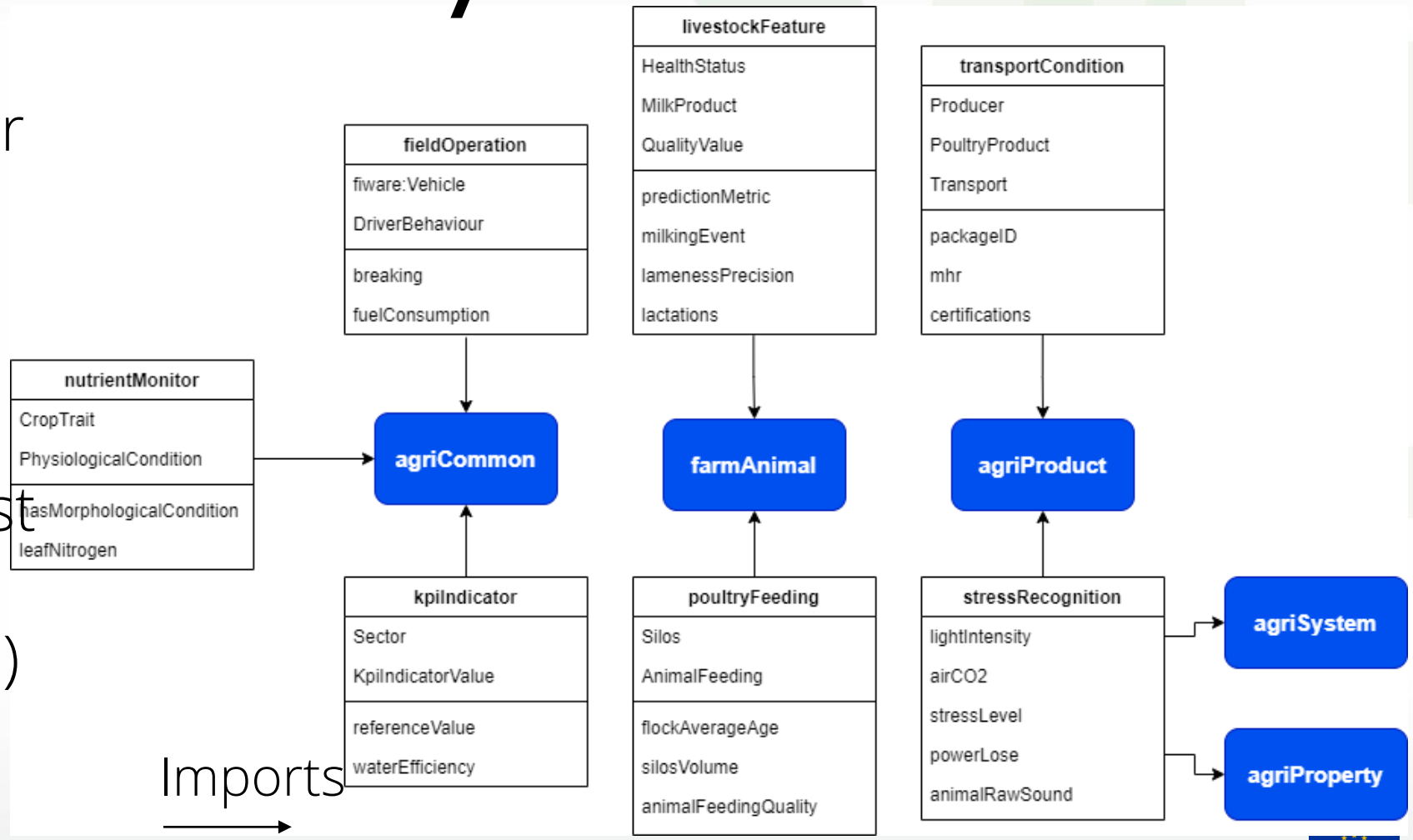
agriFeature

- Farm
- Parcel
- Site
- Building
- Geometry

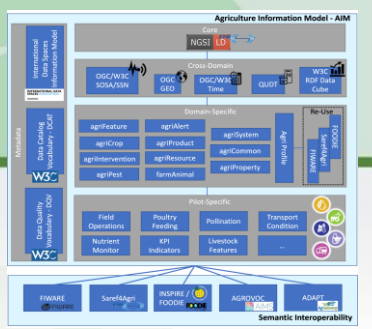
- area
- has serialization

AIM Pilot-Specific Layer

- Extend the domain layer to cover pilot specific needs and/or to extend AIM coverage.
- Each pilot-specific ontology imports at least one domain module (and thus cross-domain)



AIM alignments



FIWARE term	Type	AIM mapping	mapping_type	AIM module
fiware:AgriCrop	class	saref4agri:Crop	equivalentClass	agriCrop
fiware:AgriFarm	class	saref4agri:Farm	equivalentClass	agriFeature
fiware:Ag				
fiware:Ag				

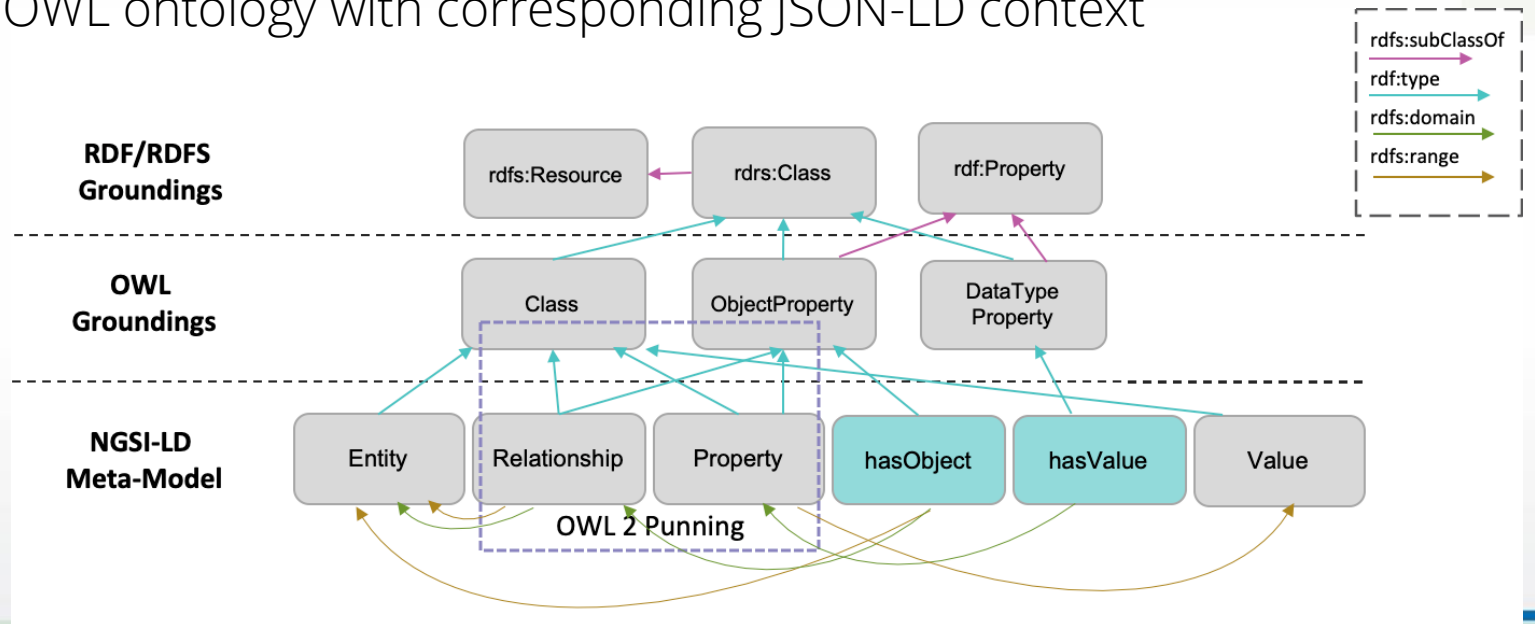
Saref4Agri/Saref term	type	AIM mapping	mapping_type	AIM module
saref4agri:Animal	class	inspire-af:FarmAnimalSpecies	equivalentClass	farmAnimal
saref4				
saref4				

ADAPT term	Type	AIM mapping	mapping_type	ADAPT module
adapt:Farm	class	saref4agri:Farm	equivalentClass	Grower
adapt:Field	class	saref4agri:Parcel	equivalentClass	Grower
ad				

FOODIE/INSPIRE term	type	AIM mapping	mapping_type	AIM module
foodie:Alert	class	fiware:Alert	equivalentClass	agriAlert
foodie:CropSpecies	class	saref4agri:Crop	equivalentClass	agriCrop
foodie:Plot	class	saref4agri:Parcel	equivalentClass	agriFeature
foodie:Product	class	fiware:AgriProductType	equivalentClass	agriProduct

AIM alignments: meta-model layer

- AIM can be aligned with high level meta-models
- Current alignment with *NGSI-LD meta-model*, which provides the formal basis for representing "*property graphs*" using *RDF(S)/OWL, thus allowing AIM to*
  - obtain the best of two worlds, i.e., enabling the conversion between datasets based on the property graph model and linked data datasets that rely on the RDF framework
  - be compliant and easily integrated with NGSI-LD data and models
  - Implemented an OWL ontology with corresponding JSON-LD context



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AIM-based JSON-LD content

- Context links terms in a JSON file to elements in an ontology
- @context needs to be defined and include AIM context(s) as reference
- Main AIM context contains all AIM terms (upper image), but also individual contexts -equivalent to modules- may be used (lower image)

Simple farm example


```
{
  "@context": [
      "https://w3id.org/demeter/agri-context.jsonld"
  ],
  "@id": "urn:ngsi-ld:farm:72d9fb43-53f8-4ec8-a33c-fa931360259a",
  "@type": "Farm",
  "name": "Wheat farm",
  "description": "A farm producing wheat",
  "hasGeometry": {
    "@id": "urn:ngsi-ld:AgriFarm:geo:72d9fb43-53f8-4ec8-a33c-fa931360259x",
    "@type": "Point",
    "asWKT": "POINT(11.3 44.12)"
  },
  "containsPlot":[
    {
      "@id": "urn:ngsi-ld:plot:72d9fb43-53f8-4ec8-a33c-fa931360259a",
      "@type": "Plot",
      "hasGeometry": {
        "@id": "urn:ngsi-ld:plot:geo:72d9fb43-53f8-4ec8-a33c-fa931360259y",
        "@type": "Polygon",
        "asWKT": "POLYGON (100 0, 101 0, 101 1, 100 1, 100 0)"
      },
      "area": 2012120,
      "description": "Spring wheat parcel",
      "category": "arable",
      "crop": {
        "@id": "urn:ngsi-ld:crop:df72dc57-1eb9-42a3-88a9-8647ecc954b4",
        "@type": "Crop",
        "cropSpecies":{
          "@id": "urn:demeter:croptype:df72dc57-1eb9-42a3-88a9-8647ecc954b4",
          "@type": "CropType",
          "name": "Wheat",
          "alternateName": "Triticum aestivum",
          "agroVocConcept": "http://aims.fao.org/aos/agrovoc/c_7951",
          "description": "Spring wheat"
        },
        "cropStatus": "seeded",
        "lastPlantedAt": "2016-08-23T10:18:16Z"
      }
    },
```

Farm related observations example


```
{
  "@id": "urn:demeter:plot:72d9fb43-53f8-4ec8-a33c-fa931360259a",
  "@type": "Plot",
  "hasGeometry": {
    "@id": "urn:demeter:plot:geo:72d9fb43-53f8-4ec8-a33c-fa931360259y",
    "@type": "Polygon",
    "asWKT": "POLYGON (100 0, 101 0, 101 1, 100 1, 100 0)"
  },
  "area": 2012120,
  "description": "Spring wheat plot",
  "category": "arable",
  "crop": {
    "@id": "urn:demeter:crop:df72dc57-1eb9-42a3-88a9-8647ecc954b4",
    "@type": "Crop",
    "cropSpecies": "urn:demeter:croptype:df72dc57-1eb9-42a3-88a9-8647ecc954b4",
    "cropStatus": "seeded",
    "lastPlantedAt": "2016-08-23T10:18:16Z"
  }
},
{
  "@id": "urn:demeter:croptype:df72dc57-1eb9-
  "@type": "CropType",
  "name": "Wheat",
  "alternateName": "Triticum aestivum",
  "agroVocConcept": "http://aims.fao.org/aos/
  "eppoConcept": "https://gd.eppo.int/taxon/T
  "description": "Spring wheat"
},
```

```
{
  "@id": "urn:demeter:observation-20180101",
  "@type": "ObservationCollection",
  "observedProperty": "http://purl.oclc.org/NET/ssnx/cf/cf-property#normalized_difference_vegetation_index",
  "hasFeatureOfInterest": "urn:demeter:plot:72d9fb43-53f8-4ec8-a33c-fa931360259a",
  "madeBySensor": "sensor/35-207306-844818-0/BMP282",
  "resultTime": "2018-01-01T12:36:12Z" ,
  "hasMember": ["urn:demeter:observation/20180101/q10", "urn:demeter:observation/20180101/q50","urn:demeter:observation/20180101/q90"]
},
{
  "@id": "urn:demeter:observation/20180101/q10",
  "@type": "Observation",
  "identifier": "q10",
  "hasSimpleResult": "0.27121272683143616"
},
{
  "@id": "urn:demeter:observation/20180101/q50",
  "@type": "Observation",
  "identifier": "q50",
  "hasResult": {
    "@id": "urn:demeter:observation/20180101/q50/result",
    "@type": "QuantityValue",
    "numericValue": "0.3173256516456604",
    "unit": "qudt-unit:UNITLESS"
  }
},
```

AIM value proposition

- AIM harmonizes and aligns relevant cross-domain standards with domain models, bridging various views on the agriculture data and providing a formal representation enabling unambiguous translations between them, establishing the basis to enable a semantic interoperability data space

- Benefits for farmers
  - use the best suited solution for their needs, including systems and components from different technology providers that will be able to seamlessly interoperate and exchange data (avoid vendor lock-in)
  - support their decision making processes (exploiting full value of available data)
- Benefits for tech providers
  - allow systems and components to interoperate with other existing solutions (focus on main expertise, reduce costs, times, efforts)
  - allow providers, especially smaller (e.g., SMEs, start-ups), to enter in otherwise monopolized farming solutions.
  - ensure future interoperation with other components, as long as they will produce/consume AIM-compliant data.

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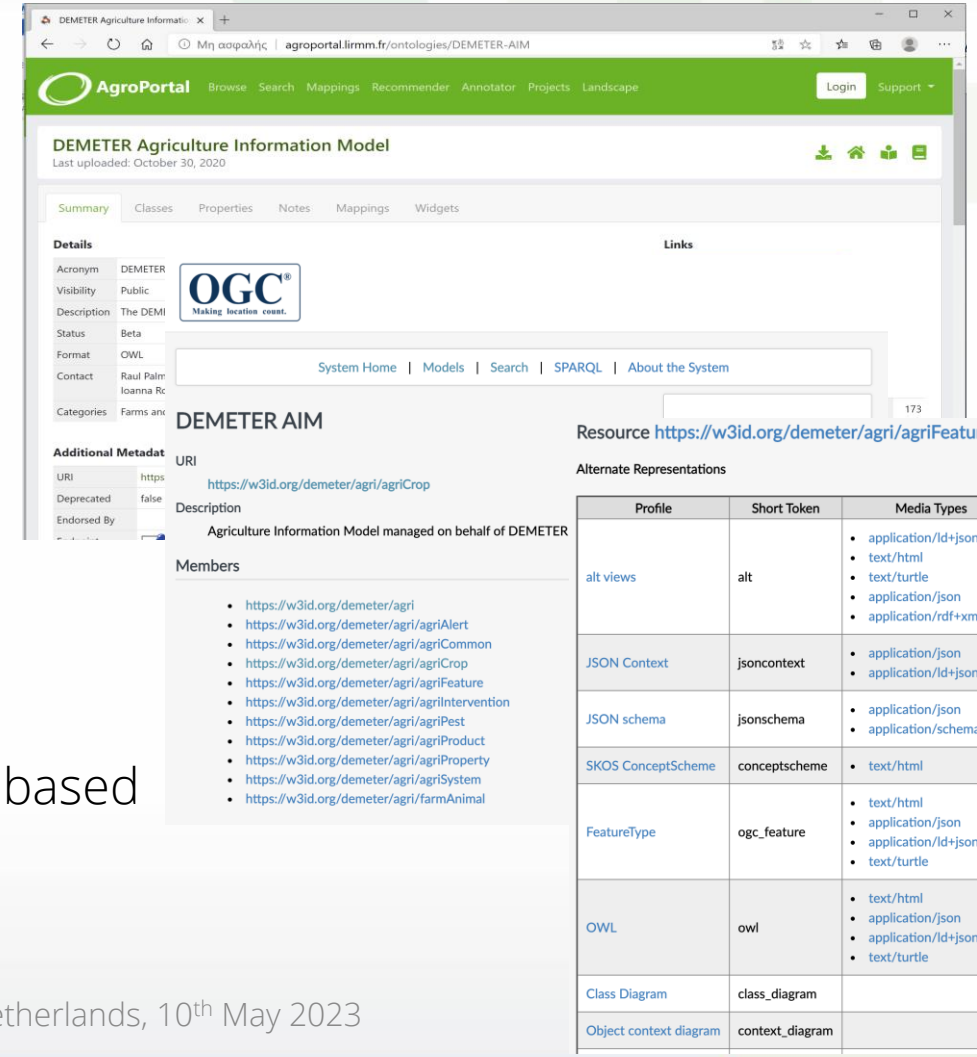
AIM adoption and evolution

- DEMETER pilots have all adopted AIM
  - Still on-going development of extensions
  - Issue Tracker: used to report and request for AIM changes.
- Examples of how to represent AIM compliant data
  - Recommended terms
- Usage guidelines – AIM adoption
  - How to find terms and retrieving annotations (reference terms)
  - How to create JSON-LD content using AIM
  - How to validate data is AIM compliant
- Profiling methodology by OGC
  - From a domain model to multiple implementation patterns
- Implementation of (linked) data pipelines for data integration based on AIM
  - Data Preparation & Integration enabler/service



AIM as a candidate OGC standard

- OGC Agriculture Information Model (AIM) SWG Charter, proposed via the OGC agriculture DWG, to specify:
  - Purpose of the standard
  - Business value proposition
  - Scope of work
  - Description of deliverables
  - IPR Policy for this SWG
  - Anticipated Audience / Participants
  - Domain Working Group Endorsement
  - Other informative information about the work of this SWG

Open Geospatial Consortium Key topics ↓ About ↓ Innova

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Standards working groups

Standards Working Groups (SWG) have specific charter of working on a candidate standard prior to approval as an OGC standard or on making revisions to an existing OGC s

Agriculture Information Model SWG
(AIM.SWG)

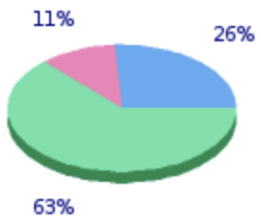
The Agriculture Information Model SWG will develop, publish and maintain an Agriculture Information Model (AIM) to support interoperability of information in the Agriculture Domain, with emphasis on the re-use of generic OGC standards as appropriate.

View Options: ☐ Shov

Technical Committee

Charter of the OGC Agriculture Information Model (AIM) SWG

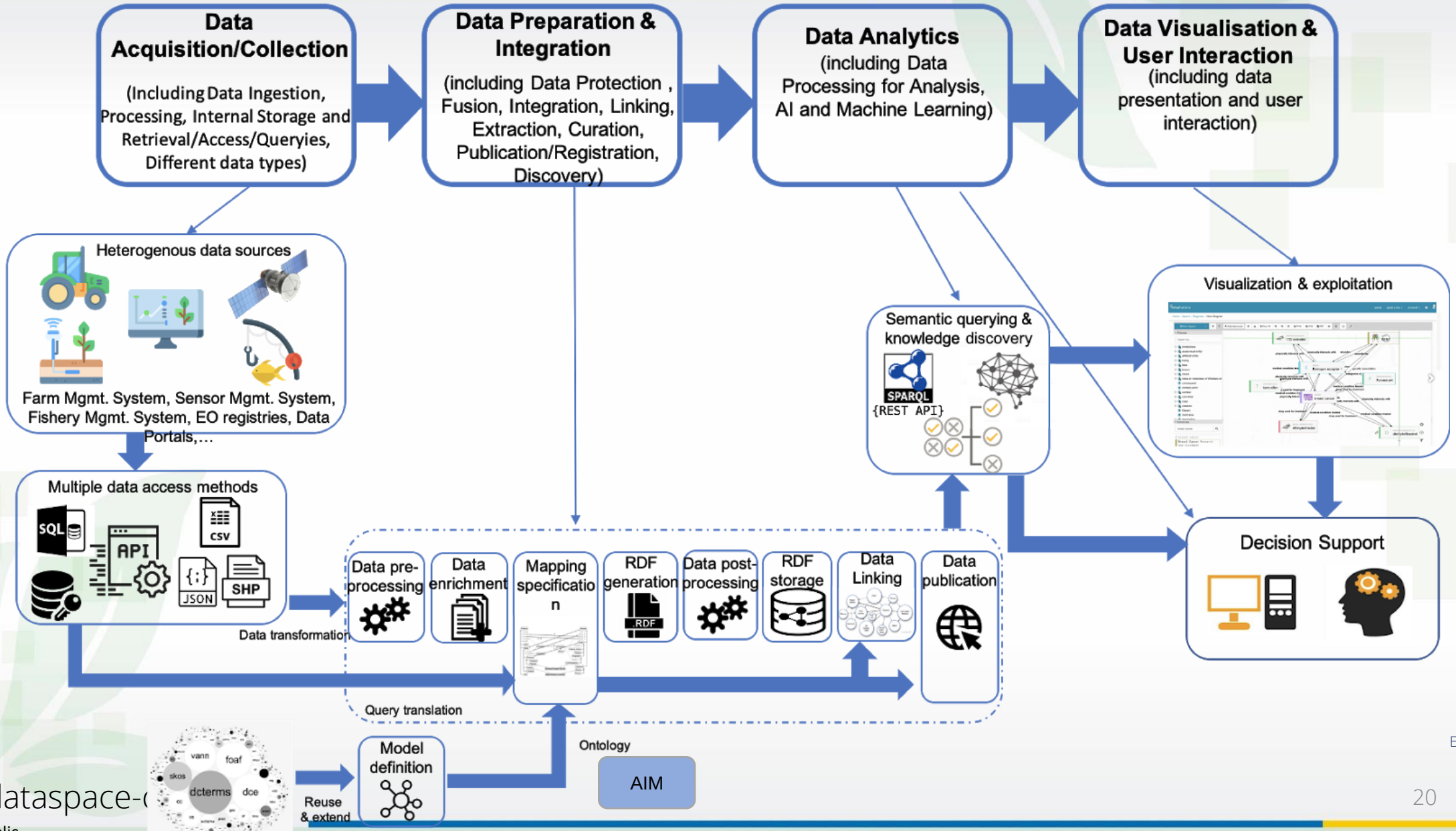
Vote Item	Start	End	Voter Pool (# users / orgs)
1) Charter of the OGC Agriculture Information Model (AIM) SWG	2023-03-07	2023-04-21	Role (183 / 92) 92 Distinct Organizations



Key	#	Vote	%
	24	Yes	26.09%
	10	Abstain	10.87%
	58	Not Voted	63.04%

Statistic	Value
Req. Quorum	33.33%
Current Quorum	36.96%
✓ QUORUM REACHED	

Linked Data Pipelines



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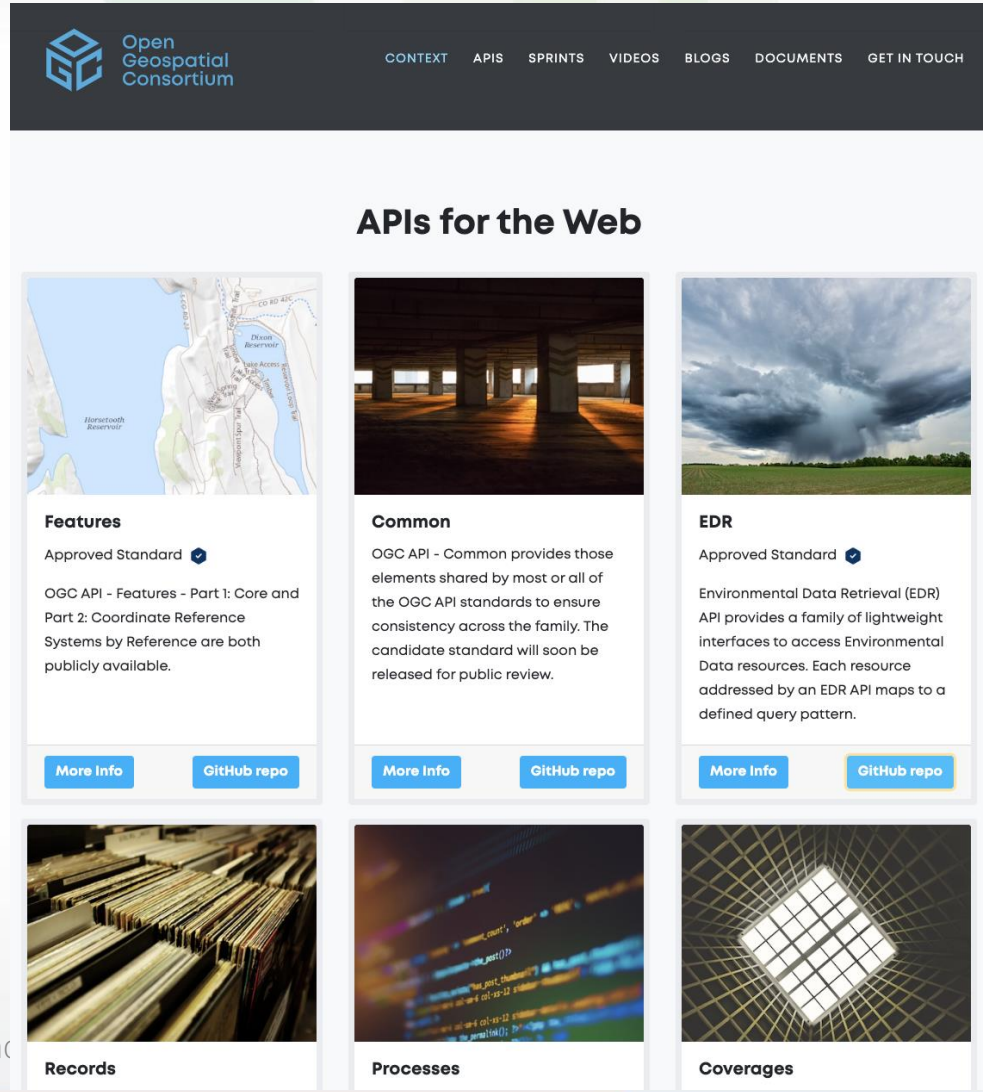
From common semantic data models to standard APIs

- The semantic data models provide the common language (lingua franca) to represent data, with explicit semantics, so that different components can understand and validate it
- The data pipelines allow the harmonization of data according to those models in order to enable an integrated view over different data source
- However, different components normally implement different APIs that expose or consume the data
  - -> need for standardized APIs
  - -> Ongoing efforts to expose harmonized data via OGC API.



Pathway towards a secure and trusted
European data space for agriculture

Thank you