CATENA-X
STANDARD

CX - 0003 SAMM Semantic Aspect Meta Model v.1.0.2

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ABOUT THIS DOCUMENT & MOTIVATION

Catena-X is the first open and collaborative data ecosystem. The goal is to provide an environment for the creation, operation, and joint use of end-to-end data chains along the entire automotive value chain. All partners are on an equal ground, have sovereign control over their data and no lock-in effects occur. This situation provides a sustainable solution for the digitalization of supply chains, especially for medium-sized and small companies, and supports the cooperation and collaboration of market participants and competitors.

The ever-growing Catena-X ecosystem will enable enormous amounts of data to be integrated and collaboratively harnessed. To ensure that these complex data volumes can be sent, received, and processed smoothly across all stages of the value chain, one language for all players: common standards. The standards of the Catena-X data ecosystem define how the exchange of data and information in our network works. They are the basis for ensuring that the technologies, components, and processes used are developed and operated according to uniform rules.

Common standards create added value for all partners: Within our network, data flows more smoothly through interfaces. In addition, we avoid cumbersome individual IT solutions for sharing data with other partners. In the field of international standardization, Catena-X follows the proven international standardization institutions: ISO/IEC/ITU and CEN-CENELC/ETSI.

For users and data providers, implementation of standards will reduce the costs that would arise from adapting different systems. In addition, no important data is lost. On the contrary, it even becomes easier to collect data across companies. For operators and developers, standards will create a framework that provides reliable orientation and planning security.

The following document describes one of the standards used in the Catena-X ecosystem and the requirements needed to implement it. Here, it serves as main resource to illustrate the following data model. It contains information starting from the format of the model, up to the conceptual and physical model. The standardisation of the data model will enable faster information sharing and homogeneity throughout the entire Catena-X ecosystem.

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ABSTRACT

The Semantic Aspect Meta Model (SAMM), an open standard, shall be used for defining the semantics of the different aspects of an asset that is represented via a digital twin. Aspect models are machine readable and other artifacts can be derived from it. The aspect model is the common basis for the http/REST API for accessing data via the standardized digital twin API of the Asset Administration Shell.

1 Introduction

1.2 Audience & Scope

This section is non-normative

This standard is relevant for the following roles:

- Business Application Provider
- Data Provider / Consumer
- Core Service Provider
- Enablement Service Provider
- Onboarding Service Provider
- Consulting Service Provider

The standard needs to be applied in the following cases for the following roles:

- Business Application Providers who want to request or create proprietary new aspect models
- Data Providers who need to create digital twins offering data conformant to a specific aspect model and want to understand the underlying metamodel
- Data Consumers who need to understand the data offered by a digital twin and want to understand the underlying metamodel of the corresponding aspect model

Core, enablement and onboarding service providers who offer services in the context of the Semantic Hub or for tooling based on aspect models

Consulting service providers who offer consulting for data consumers and data providers

1.2 Context

This section is non-normative

In Catena-X, along with GAIA-X, Digital Twins are to be considered as a core concept to exchange data in the data space. The Digital Twin Registry and the Semantic Hub are classified as core services, Section B, see [Catena-X Operating Model Whitepaper].

The Digital Twin Architecture Pattern focuses on ensuring (semantic) inter-operability via Digital Twins and Semantic Models in a federated system.

A Digital Twin System forms the basis for comprehensive digitization of production and logistics by gradually creating consistent data homogeneity and interoperability. Since not everyone needs the same set of information, a Digital Twin is a collection of various aspects of an asset. An aspect can, for example, bundle all information about machine malfunctions. Such aspects are characterized by concrete aspect models that describe formally how an aspect is structured. Aspect models describe things like the units of measurement and possible value range for a temperature sensor in a way that is readable by machines. This allows for faster, more automated responses to the data as it is received. Here, a meta model is a model that defines the constructs and properties used by aspect models. Expressing this aspect's semantics to consumers of the data can open up completely new possibilities. In other words, an aspect meta model provides the machine-readable language or semantics used across an entire system of aspect models. Hence, the Semantic Aspect Meta Model (SAMM) allows the creation of meta models to describe the semantics of digital twins by defining their domain-specific aspects, containing information about both the runtime data structure (e.g., that there is a property in the data called "temperature", and that it has a numeric value) and information that is not part of the runtime data (e.g., the unit or range). It does not, however, contain actual runtime data (e.g., a numeric value representing the current temperature), as this will be delivered by an Aspect conforming to this Aspect model. The combination of raw runtime data and its corresponding Aspect model yields information. Moreover, the SAMM allows to reuse semantic descriptions across different aspect models.

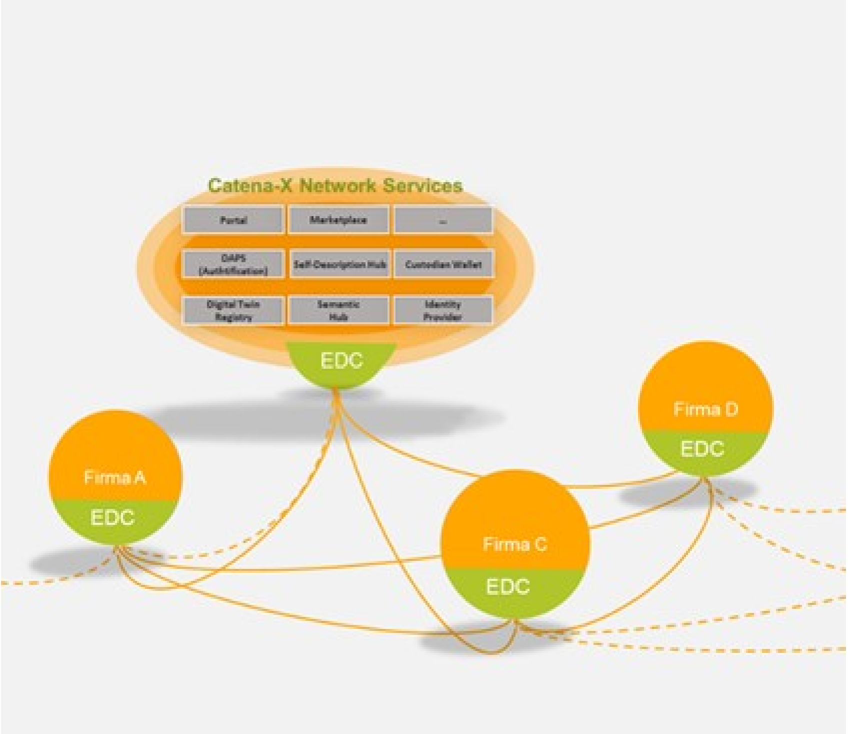
1.3 Architecture Overview

This section is non-normative

This chapter just gives a rough overview of the architecture. Up to Catena-X Release 3 the architectural components "Semantic Hub" and "Digital Twin Registry" are considered core services, Section B. Core services Section B lists services that can only be operated once in the Catena-X data space due to business reasons or technical limitations and are therefore tendered via the nomination process of the association", see Catena-X Operating Model Whitepaper.

The Semantic Hub is a database containing aspect models released in Catena-X. These aspect models are accessible via a UI in the Catena-X Portal. The database is synchronized with the public github (see Proof of conformity) containing the machine-readable specification of the aspect models that shall be conformant to the Semantic Aspect Meta Model as specified in this document. Every aspect model has a unique ID and this is why it can be referenced. Up to Release 3 there is a central Semantic Hub for the complete data space. This makes sense for the standardized and released aspect models. In the future also proprietary aspect models might be defined. So also decentralized Semantic Hubs will be possible.

A Digital Twin Registry contains the digital twins of a data provider together with access information for the single aspects associated with a digital twin. Additionally, every aspect of a digital twin contains information about its semantics. The semantics is described via an aspect model conformant to the Semantic Aspect Meta Model as specified in this document. Up to Release 3 there is a central digital twin registry for the complete data space. In future releases there will be decentralized digital registries. However, this specification is not affected by these different architecture patterns.



The Eclipse Data Space Connector (EDC) (see standard CX-0018) defines access and usage policies for the different digital twins and aspects of the digital twins.

1.4 Conformance

As well as sections marked as non-normative, all authoring guidelines, diagrams, examples, and notes in this specification are non-normative. Everything else in this specification is normative.

The key words MAY, MUST, MUST NOT, OPTIONAL, RECOMMENDED, REQUIRED, SHOULD and SHOULD NOT in this document are to be interpreted as described in [BCP 14], [RFC2119], [RFC8174] when, and only when, they appear in all capitals, as shown here.

1.5 Proof of Conformity

This section is non-normative

All participants and their solutions will need to prove that they conform to the Catena-X standards. To validate that the standards are applied correctly, Catena-X employs Conformity Assessment Bodies (CABs).

Every aspect model released or standardized in Catena-X MUST be maintained in Tractus-X - SLDT Semantic Models.

For validation of aspect models open-source tool support is available as part of the ESMF SDK.

Every aspect model in Tractus-X - SLDT Semantic Models that has the status "released" or "standardized" MUST be validated without errors against the Semantic Aspect Meta Model. For the current version of the Semantic Aspect Meta Model under consideration see normative references. For the currently used version of the Validator see information in Readme. Newer versions of the validator can be used but need an explicit decision and – if needed – a migration path of all existing and released aspect models to do so.

For more information on the governance process for new, updated or deprecated aspect models see standard CX-0004. The governance process is described directly in the github project.

Every aspect of a digital twin registered in a digital twin registry (see standard CX-0002) accessible in the Catena-X data space MUST have a semantic description (semantic ID) that is conformant to the unique identifier of the SAMM aspect model associated to it.

1.6 Examples

Example would be an aspect models to exchange information about the carbon footprint (PCF) of a product. This aspect model would specify that the following information is mandatory to be transferred: the footprint itself but also the product footprint identifier, the product footprint specification version and the product category. Optionally also land use emissions may be provided.

An extract from a corresponding machine-readable specification of the aspect model conformant to the Semantic Aspect Meta Model could look like this:

```
    :ProductFootprintVersionCharacteristic a samm:Characteristic;

        samm:name "ProductFootprintVersionCharacteristic";

        samm:preferredName "Product Footprint Version Characteristic"@en;

        samm:description "Characteristic for defining a product footprint version as specified by
the WBCSD (World Business Council for Sustainable Development) Pathfinder initiative."@en;

        samm:see <https://wbcsd.github.io/introduction/>;

        samm:dataType xsd:positiveInteger.
```

For more examples of aspect models conformant to the Semantic Aspect Meta Model see https://github.com/eclipse-tractusx/sldt-semantic-models.

1.7 Terminology

This section is non-normative

Aspect

> *a domain-specific view on information and functionality associated with a specific Digital Twin with a reference to a concrete Aspect Model.*

Note 1 to entry: An Aspect is a software service to retrieve the actual runtime data of a Digital Twin (current or aggregated) from a data source or to trigger operations. Thus, an aspect is built with an implementation that ensures that the exchanged data is compliant to the specification of the referenced Aspect Model via a defined interface.

Note 2 to entry: Aspects are registered (incl. their "API endpoint" information) with the Digital Twin to which they belong in the Digital Twin Registry.

Note 3 to entry: an aspect corresponds to a *Submodel* in the *Asset Administration Shell*

[SOURCE: Eclipse Semantic Modeling Framework (ESMF), editorial changes and notes added]

Aspect Model

> *a formal, machine-readable semantic description (expressed with RDF/turtle) of data accessible from an Aspect.*

Note 1 to entry: An Aspect Model must adhere to the Semantic Aspect Meta Model (SAMM), i.e., it utilizes elements and relations defined in the Semantic Aspect Meta Model and is compliant with the validity rules defined by the Semantic Aspect

Meta Model.

Note 2 to entry: Aspect models are logical data models which can be used to detail a conceptual model in order to describe the semantics of runtime data related to a concept. Further, elements of an Aspect model can/should refer to terms of a standardized Business Glossary (if existing).

Note 3 to entry: An Aspect Model describes the semantics of a *Submodel*.

[SOURCE: Eclipse Semantic Modeling Framework (ESMF), editorial changes and notes added]

Asset Administration Shell

> *standardized digital representation of an asset*

Note 1 to entry: Asset Administration Shell and Administration Shell are used synonymously.

[SOURCE: IEC 63278-1, note added]

Submodel Template

> *guides the creation of a Submodel conformant to the Aspect Model and the Asset Administration Shell.*

[SOURCE: IEC 63278-1, extracted from text plus correlation with aspect model added]

Digital Twin

> *digital representation, sufficient to meet the requirements of a set of use cases*

Note 1 to entry: in this context, the entity in the definition of digital representation is typically an asset.

[SOURCE: IIC Vocabulary IIC:IIVOC:V2.3:20201025, adapted (an asset, process, or system was changed to an asset)]

Digital representation

> *information and services representing an entity from a given viewpoint*

EXAMPLE 1: examples of information are properties (e.g., maximum temperature), actual parameters (e.g., actual velocity), events (e.g., notification of status change), schematics (electrical), and visualization information (2D and 3D drawings).

EXAMPLE 2: examples of services are providing the history of the configuration data, providing the actual velocity, and providing a simulation.

EXAMPLE 3: examples of viewpoints are mechanical, electrical, or commercial characteristics.

[SOURCE: IEC 63278-1, editorial changes]

Submodel

> *container of SubmodelElements defining a hierarchical structure consisting of SubmodelElements*

[SOURCE: IEC 63278-1]

SubmodelElement

> *elements in a Submodel*

[SOURCE: IEC 63278-1]

Submodel template

> *container of Submodel template elements defining a hierarchical structure consisting of Submodel template elements*

[SOURCE: IEC 63278-1, note removed]

Additional terminology used in this standard can be looked up in the glossary on the association homepage.

2 Semantic Aspect Meta Model (SAMM)

2.1 Eclipse Semantic Modeling Framework

The Semantic Aspect Meta Model (SAMM) is specified as an open standard as integral part of the Eclipse Semantic Modeling Framework (ESMF). This part again is part of the Top-Level Project Eclipse Digital Twin. The Eclipse Digital Twin Top-Level Project is a collaborative, open-source initiative at the Eclipse Foundation fostering the development of reference implementations for the activities driven by the Industrial Digital Twin Association (IDTA).

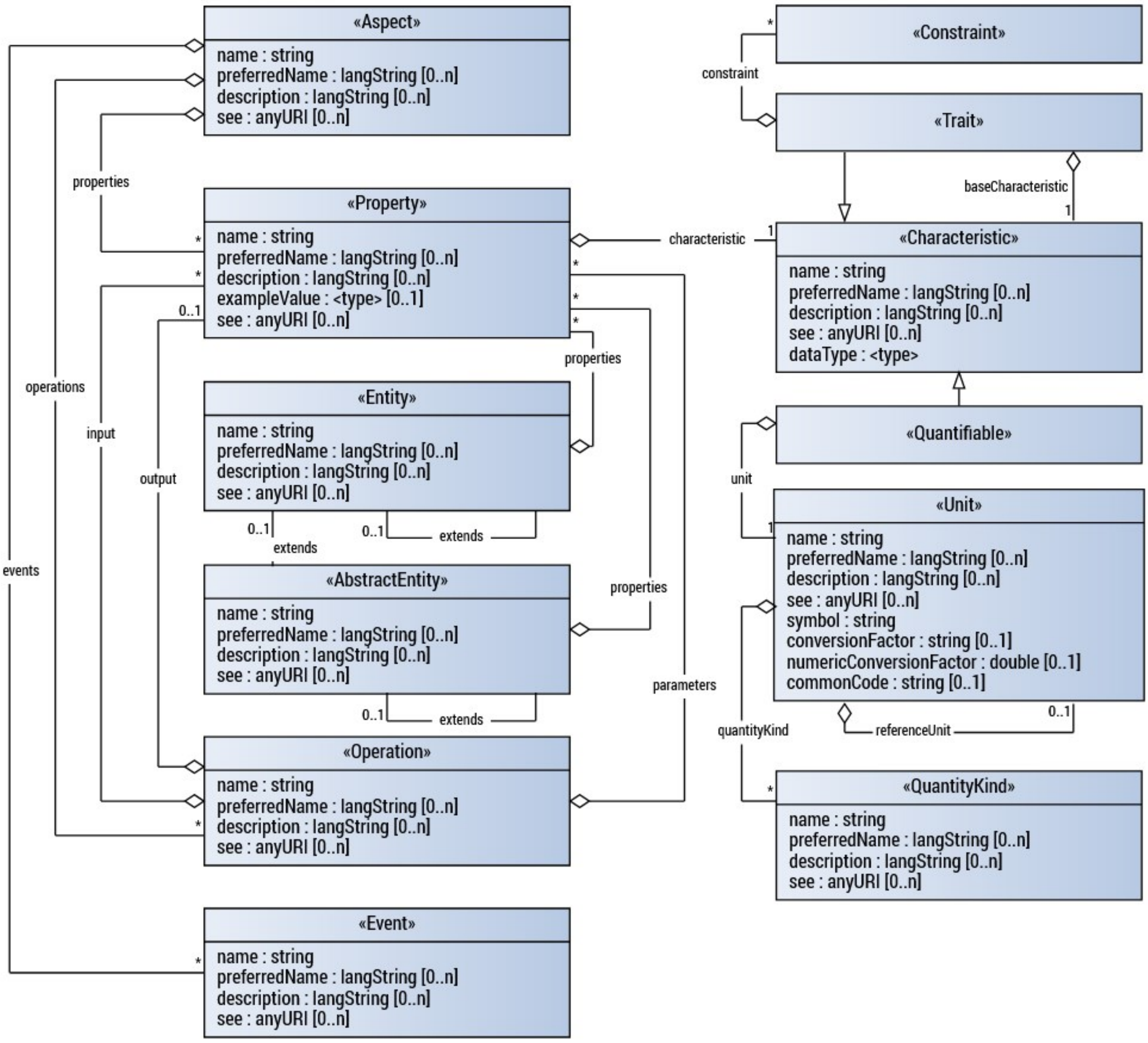
The core of the Eclipse Semantic Modeling Framework is the development of the Semantic Aspect Meta Model (SAMM). Besides the SAMM specifying the language to define the semantics of a submodel in an "Aspect Model", the ESMF also includes an editor, SDKs in different programming languages, a command line tool for validation, generating documentation and different serializations and other functionality easing its usage and implementation in digital twin projects. Also, aasx generators for support of Asset Administration Shell are in scope.

Aspect Models express a schema with a defined Resource Description Framework (RDF) vocabulary and are validated by a comprehensive set of rules in the Shapes Constraint Language (SHACL). Domain semantics are captured by a combination of structural elements, relations, namespaces and reified named concepts.

The Eclipse Semantic Modeling Framework (ESMF) in combination with the specifications of and open-source solutions for the Asset Administration Shell accelerates the development of digital twin technologies and drives its adoption in ecosystems.

2.2 Semantic Aspect Meta Model

The Semantic Aspect Meta Model (SAMM) provides a set of predefined objects that allow a domain expert to define aspect models and complement a digital twin with a semantic foundation.



The complete specification and further information about its implementation and requirements can be accessed via the Eclipse Semantic Modeling Framework (ESMF).

Every aspect model in https://github.com/eclipse-tractusx/sldt-semantic-models that has status "released" or "standardized" MUST be conformant to the Semantic Aspect Meta Model.

Every new aspect model MUST be conformant to the version of the Semantic Aspect Meta Model as noted in the normative reference SAMM.

2.3 Creation and Maintenance

Every aspect model released or standardized in Catena-X MUST be maintained in Tractus-X: https://github.com/eclipse-tractusx/sldt-semantic-models.

Every semantic model MUST have a unique identifier conformant to the meta model identifiers definition in SAMM. For the semantic models developed in the scope of Catena-X the unique identifier MUST start with

```
urn:samm:io.catenax.
```

Example for a unique identifier for an aspect model "material for recycling":

```
urn:samm:io.catenax.material_for_recycling:1.0.0#MaterialForRecylcing
```

The governance process for new, updated or deprecated aspect models MUST be followed. The governance process is described directly in the github project: https://github.com/eclipse-tractusx/sldt-semantic-models/blob/main/documentation/GOVERNANCE.md.

NOTE: Already released or published version of aspect models MAY start with

```
urn:bamm:io.catenax
```

For migration of older aspect models see the Migration guide.

NOTE: SAMM was named BAMM until end of 2022 (BAMM for BAMM Aspect Meta Model). Renaming was executed in the context of the migration of the corresponding open source projects from Open Manufacturing Platform (OMP), a Linux Foundation project, to Industrial Digital Twin Association (IDTA) and Eclipse Foundation.

2.4 Usage

Every aspect of a digital twin registered in a digital twin registry (see CX-0002) accessible in the Catena-X data space MUST have a semantic description (semantic ID) that is conformant to the unique aspect model ID associated to it (see chapter Creation and Maintenance).

Example for semanticId:

```
urn:samm:io.catenax.material_for_recycling:1.0.0#MaterialForRecycling
```

3 References

3.1 Normative References

SAMM Semantic Aspect Meta Model, Version 2.0.0.

CX - 0002 DIGITAL TWINS IN CATENA-X. Download in Catena-X Standard Library.

Catena-X Operating Model Whitepaper. Release V2 – 21.11.2022.

3.2 Non-Normative References

This section is non-normative

Semantic Data Structuring. Whitepaper. 2021-08-16. Open Manufacturing Platform.

Product Modeling with BAMM. Whitepaper. 2022-11-24. Open Manufacturing Platform.

ESMF Documentation. Eclipse Semantic Modeling Framework.