Semantic PEA Datasheets
for digitalised modular plant documentation

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REUNION
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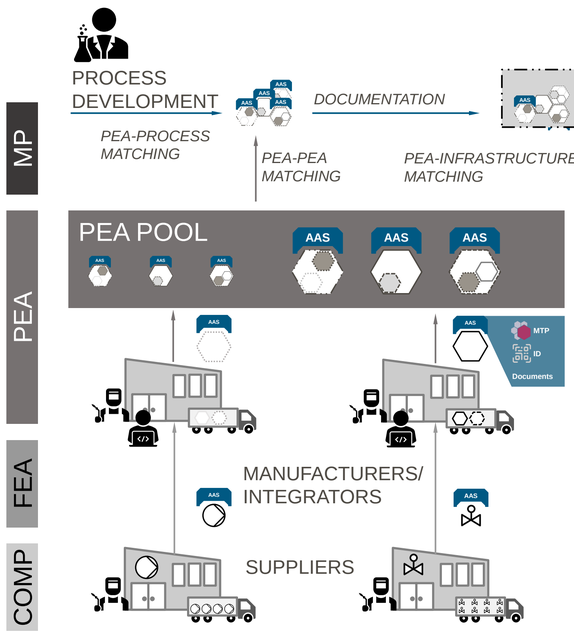


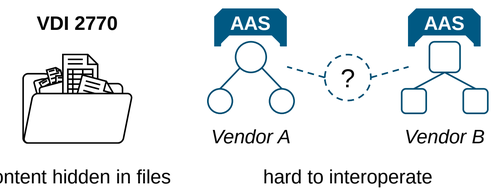
Figure 1: Modular plants according to VDI 2776-1[1] in an Asset Administration Shell (AAS)[2] based ecosystem. Components are aggregated into Functional Equipment Assemblies (FEAs) and further into Process Equipment Assemblies (PEAs), which are matched and assembled into a modular plant within a non-modular infrastructure. PEA automation relies on MTP[3], with individual MTP files orchestrated at plant level via a POL. Documentation accumulated in the AAS at each level forms the basis for plant approval, providing a vendor-independent, standardized method for knowledge aggregation and reuse.

[1] Verein Deutscher Ingenieure e.V. (VDI), "VDI 2776-1, Process engineering plants – Modular plants – Fundamentals and planning modular plants", DIN Media, 2020.
[2] Industrial Digital Twin Association e.V. (IDTA), "AAS Specification", 2026. url: https://industrialdigitaltwin.org/en/content-hub/aasspecifications, accessed June 3rd, 2026.

REQUIREMENTS & CONCEPT

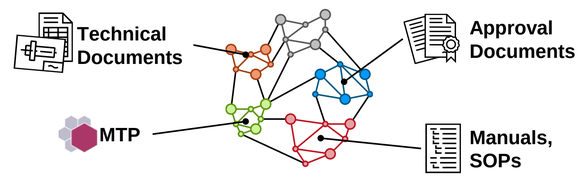
Documentation standards & guidelines

- AAS provides a vendor-independent format for the description and provision of information on industrial assets, sectioned into submodels
- Guideline VDI 2770[4] provides format for machine-readable documentation through minimum requirements (also available as an AAS submodel)
- No specification on what specific information on PEAs including their semantics exist → ambiguity of data limits usability



Semantic PEA Datasheet Concept

- single point of truth for documentation
- FAIRification of documentation
- human- and machine-readable across domains
- coverage of critical data: operational, capabilities, interfaces, design, safety



- interoperability through use of existing ontologies and vocabularies
- linking data to documentation sources
- related data model standards: OntoCAPE[5], DEXPI 2.0 specifications[6]

[3] Verein Deutscher Ingenieure e.V. (VDI), "VDI/VDE/NAMUR 2658-1, Automation engineering of modular systems in the process industry – General concept and interfaces", DIN Media, 2022.
[4] Verein Deutscher Ingenieure e.V. (VDI), "VDI 2770-1, Minimum requirements for digital manufacturer information for the process industry – Fundamentals", DIN Media, 2020.
[5] Marquardt et al., "OntoCAPE – A Re-Usable ontology for Chemical Process Engineering", Springer Berlin Heidelberg, 2010. doi: 10.1007/978-3-642-04655-1
[6] DEXPI e.V., "DEXPI Specification 2.0.0", 2025. URL: https://dexpi.org/static/ea_dexpi_spec_2.0/

SEMANTIC PEA DATASHEET (SPEAD)

MODELLING

Approach

- Modelled using the case- and competency question-based method by KENDALL and MCGUINNESS[7]
- Competency Questions (CQ) derived from representative use cases define requirements that must be fulfilled by the information model
- 12 CQs: eight content related questions, four terminology and provenance related questions
- Adherance to OWL 2 RL profile to retain tractability in reasoning and validation

Use-Case: Exchange of PEAs in a modular plant

A service technician is charged with replacing the reactor PEA from an existing plant with a new one from a pool of available reactor PEAs. To do this, they require information about the operating conditions, structure, and available MTP services of all PEAs in the pool.

CQ #	Competency Question	Expected Answer
1	What is the maximum operating temperature of this PEA?	The maximum operating temperature of this PEA is X °C.
2	Which FEAs and components does this PEA contain?	A list of FEAs and components of this PEA.
…	…	…

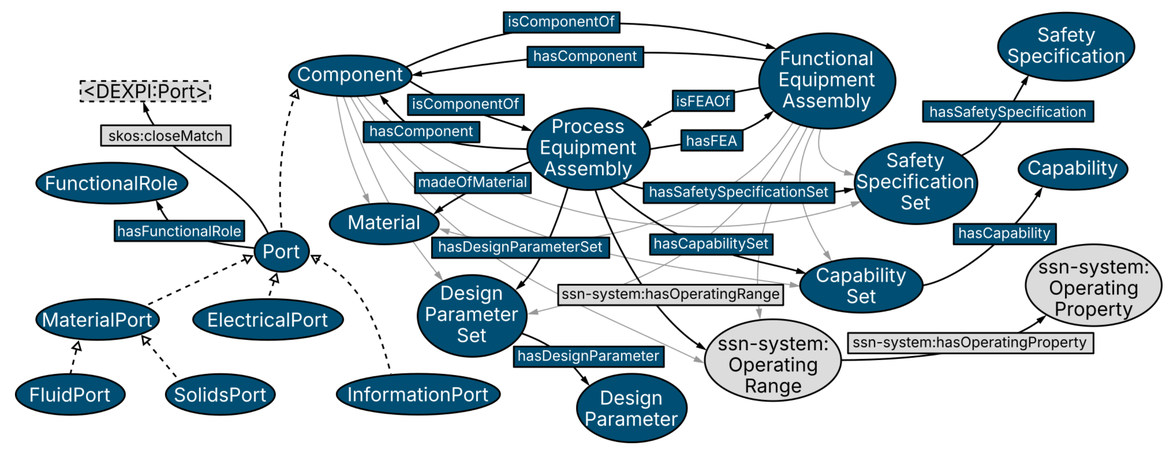


Figure 1: Core classes and properties from the SPEAD ontology. Thin grey lines depict relationships between the Component and FEA class and other core classes that are only labeled between the PEA class and other core classes. Dashed lines indicate that the subject is a subclass of the object. SPEAD definitions in dark blue, external definitions in light grey.

SPEAD Ontology

- Aggregation of modular plants derived from guideline VDI 2776-1
- Grouping classes which can carry their own metadata and simplify querying
- Interface structure derived from DEXPI 2.0
- Schematic description of quantifiable properties based on QUDT to ensure interoperability

Provenance module

- SPEAD is modularised to enable (re-)use of individual parts of the ontology
- Provenance tracking of information based on guideline VDI 2770, adapted to the PROV ontology

Data Quality Assurance

- Ontology level: extensive metadata on class and property definitions including labels, definitions, examples, sources (where applicable)
- Aligned with foundational ontology BFO as a framework for fundamental distinctions enables integration of other domain-specific ontologies
- Instance level: SHACL shapes validate structural conformance at different levels (plant aggregation, quantifiables schema, …)

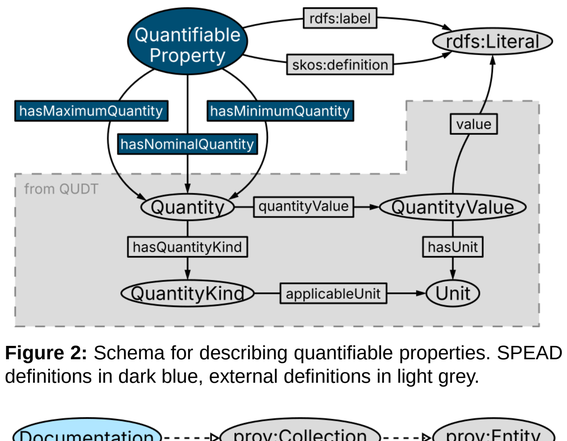


Figure 2: Schema for describing quantifiable properties. SPEAD definitions in dark blue, external definitions in light grey.

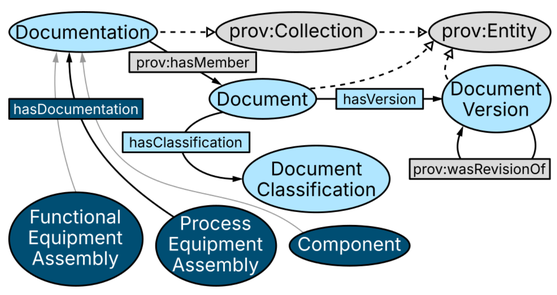


Figure 3: Excerpt from the provenance module based on guideline VDI 2770 and the PROV-O ontology. SPEAD definitions in dark blue, definitions adapted from VDI 2770 in light blue, external definitions in light grey.

APPLICATION: CASE STUDIES

- Two PEAs developed within the project REUNION are used as case studies: CSTR PEA (shown in Figure 4) with 358 triples and a dosing PEA with 214 triples
- Evaluation against our own CQs as well as eight of eleven CQs developed by KOCH ET AL.[8], e.g.:
  - CQ1: The maximum operating temperature of the CSTR PEA is 150 °C.
  - CQ2: The CSTR PEA contains these components: MR01R1 (Class: Vessel), …
  - CQ9: The source of the maximum operating temperature is the file Technical_Datasheet.pdf.

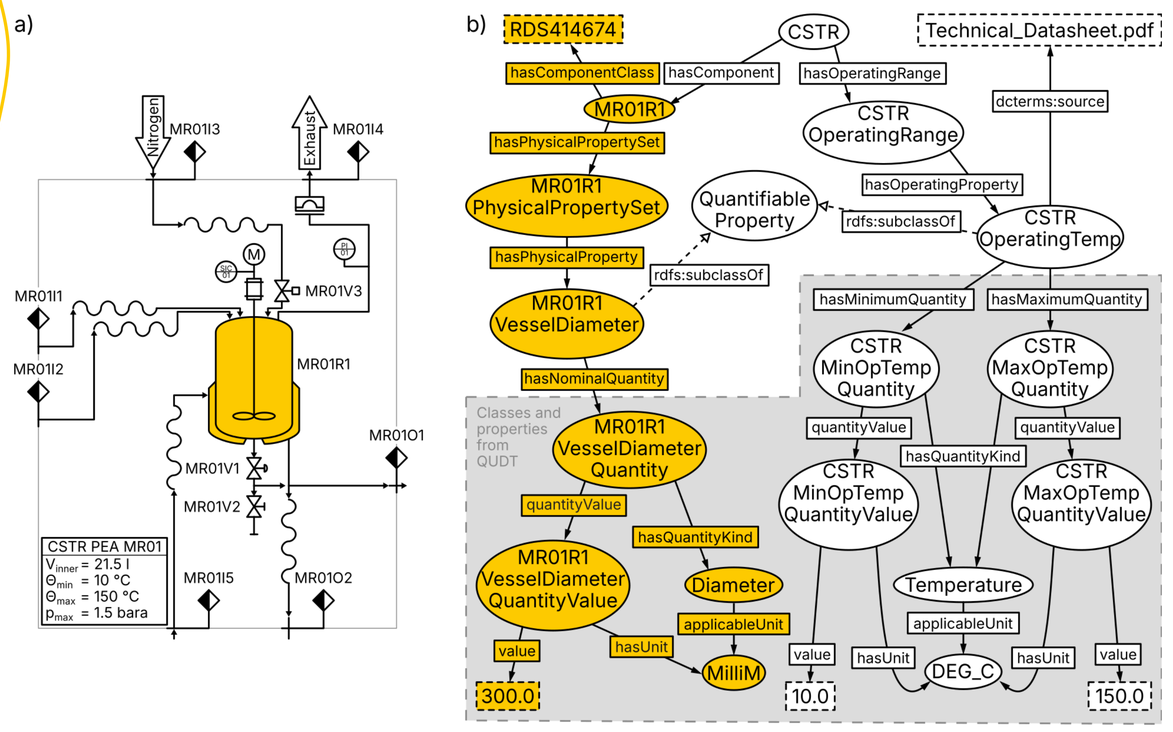


Figure 4: a) Simplified P&ID of a Continuous Stirred-Tank Reactor (CSTR) PEA developed within the project REUNION. The reactor component is highlighted in yellow. B) Excerpt from the SPEAD representing the CSTR PEA. Highlighted in yellow are nodes and properties relating to the reactor component in a). Boxes with dashed outlines indicate literal values.

Results

- Full coverage of developed CQs, partial coverage of CQs from the literature
- Improved tracability of information compared to OntoCAPE and DEXPI through provenance module.
- Current implementation of Capability and Safety modules limit expressiveness
- Data availability was limited. In the final implementation, we expect SPEADs to reach the order of 10^4 triples, retaining tractability of reasoning and validation.

OUTLOOK

Coverage Expansion

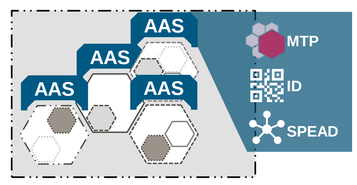
- Adaptation of Capability ontology module to align more closely with MTP[3] guidelines
- Expansion of Safety ontology module and introduction of controlled vocabularies to cover common safety-related information (ATEX certification, IP rating, …)
- Improved alignment with other key standards (OntoCAPE[5], DEXPI 2.0[6], …)
- Integration of infrastructure-related information to improve PEA-Infrastructure matching

Automated Generation

- Development of a pipeline to extract and convert data from existing documentation (technical data sheets, P&IDs, …) into SPEAD instance graphs

Integration with the Asset Administration Shell (AAS)

- SPEAD ontology can serve as a source for semantic identifiers, improving interoperability between vendor and owner/operator
- Alternative: Integration of SPEAD into the AAS as its own submodel



[7] E. F. Kendall and D. L. McGuinness, "Ontology Engineering", Springer Cham, 2019. doi: 10.1007/978-3-031-79486-5
[8] A. Koch, N. Hamedi, L. Furtner, T. Kock, A. Klose, J. Mädler, "Standards for information models considering knowledge distribution in modular plants", IEEE 21st INDIN, 2023. doi: 10.1109/INDIN51400.2023.10218218

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