University of Stuttgart
Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW)

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Digital Twins

And the Asset Administration Shell

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We were Confused about the Asset Administration Shell (AAS)

And how this modeling technology relates to digital twins

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1. Zhang, J., Ellwein, C., Heithoff, M., Michael, J., & Wortmann, A. (2025). Digital twin and the asset administration shell. Software and Systems Modeling, 24(3), 771-793.

The AAS aims to Locate all Relevant Information About an Asset Centrally

Submodels are the main content of asset administration shells

Capabilities

- End milling
- Drilling

Maintenance

- Cutting time
- Latest service

Operational Data

- Sensor data
- Energy consumption

Technical Data

- Max. spindle speed
- Axis count

Digital Nameplate

- Contact data
- Serial number

3-axis milling machine

Number of our submodels: 99

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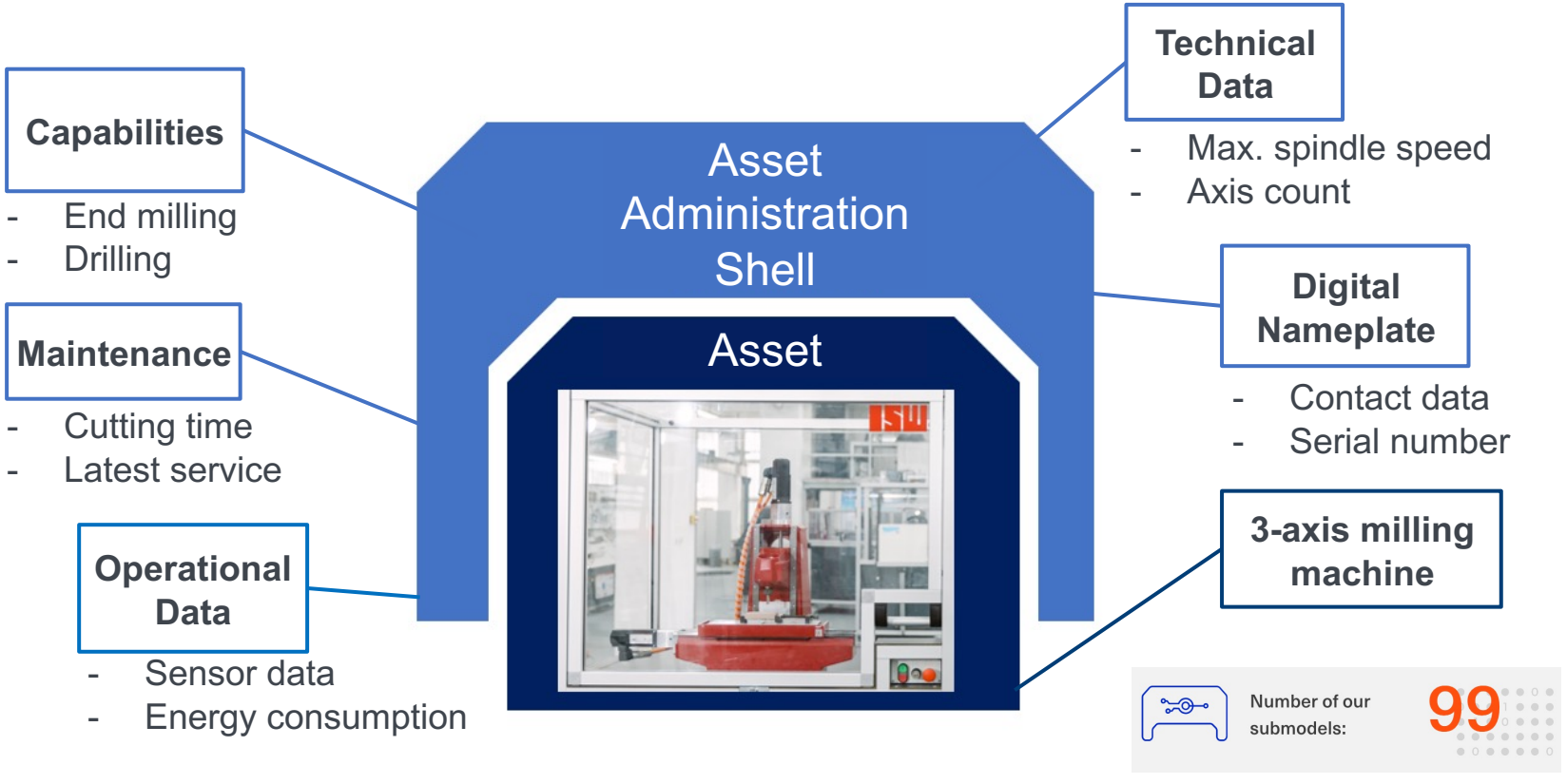
Submodels are the main content of asset administration shells



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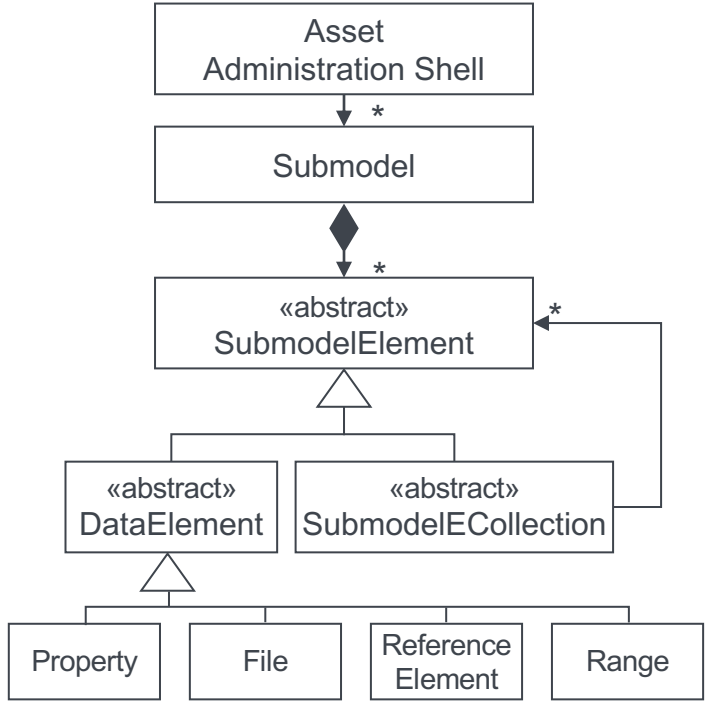
The Asset Administration Shell is an Industrial Modelling Success Story

Every information about an asset in a single place

- Essentially a metamodeling framework for asset information (including data, models, and more)
- Standardized by Industrial Digital Twin Association (IDTA)[1]
- 129 members, incl. ABB, Bosch, Danfoss, Dassault, Hitachi, Huawei, Mitsubishi, PTC; Siemens, SAP, Trumpf, VW, …
- Core metamodel[2] building on industry standards
  - Data model based on ISO 13584-42, IEC 61360
  - ECLASS[1] ISO/IEC compatible data modeling standard
- Goal: Standard for Digital Twins in Industry
- Eclipse BaSyx for implementation (among others)



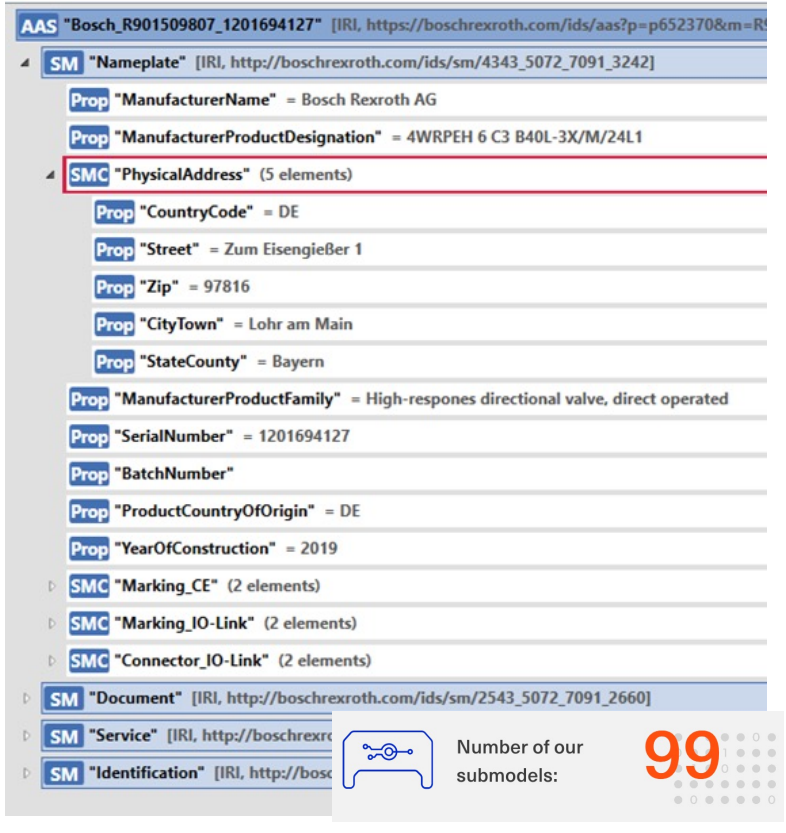
ECLASS IEC

1. https://industrialdigitaltwin.org
2. https://industrialdigitaltwin.org/wp-content/uploads/2023/04/IDTA-01001-3-0_SpecificationAssetAdministrationShell_Part1_Metamodel.pdf

AAS Submodel Templates Facilitate Structuring Asset Information

Standardizable data models within the IDTA

- 40 submodel templates official released, incl.
  - Digital Nameplate
  - Provision of Simulation Models
  - Handover Documentation
  - Bill of Material
  - Asset Interfaces Description
- Rest under development, incl.
  - Software Bill of Materials
  - Nameplate for Software in Manufacturing
  - Digital Battery Passport
- Or build your own submodel templates



1. https://industrialdigitaltwin.org/en/content-hub/submodels

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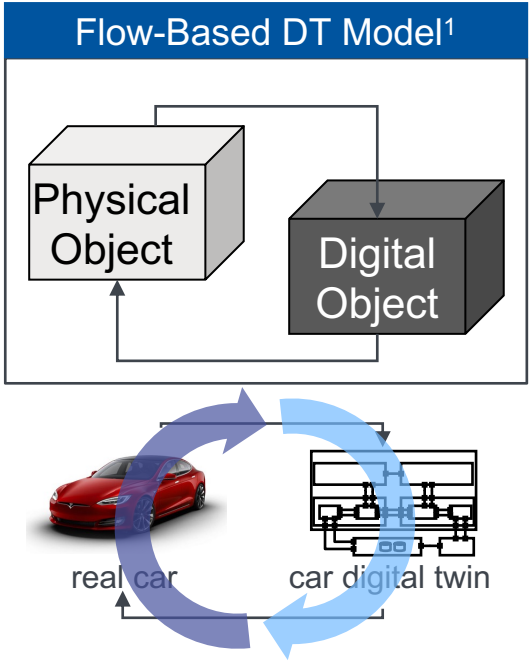
Question

Is the Asset Administration Shell a Digital Twin?

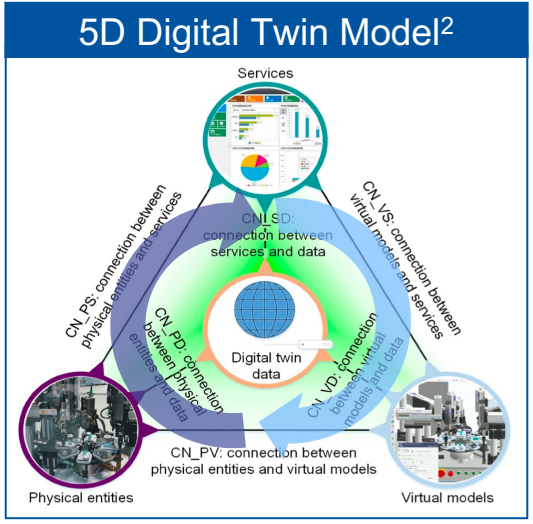
A Digital Twin is a Software System using Data, Models, and Services

That can represent and control its (cyber-physical) counterpart

Flow-Based DT Model[1]



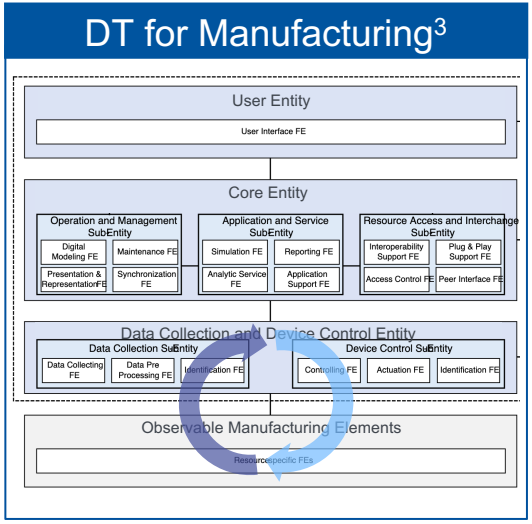
5D Digital Twin Model[2]



5 Dimensions

(1) CPS, (2) Data, (3) Models, (4) Services, (5) Connections

DT for Manufacturing[3]



Observable Manufacturing Elements:

Physical, biological, chemical, virtual, …

1 Kritzinger, W., Karner, M., Traar, G., Henjes, J., & Sihn, W: Digital Twin in manufacturing: A categorical literature review and classification. IFAC-PapersOnLine, 2018.
2. Qi et al.: Enabling technologies and tools for digital twin. In: Journal of Manufacturing Systems, Elsevier, 2019
3. ISO 23247. Digital Twin Framework for Manufacturing, 2021.

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There are Three Types of Asset Administration Shells

At different levels of maturity

Type 1 AAS

- Shells are serialized files
- Contain static information
- Data model governed by AAS meta model
- Describe types and instances of assets as-designed
- No automated dataflows from/to asset

Type 2 AAS

- Runtime instances: may contain static and dynamic information from asset
- Interact w. other components
- Ex: frontend for device services, live sensor data, …
- Properties, operations, events via generic runtime interface
- Automated dataflows only from asset

Type 3 AAS

- Extend type 2 AAS
- Have active behavior
- Can start to communicate & to negotiate on their own
- Well-defined language and message structures (VDI/VDE 2193)
- Automated dataflows from/to asset

Question

How Much Digital Twin do the Three Asset Administration Shell Types Support?

We opted to Analyze very Popular and Important Digital Twin Definitions

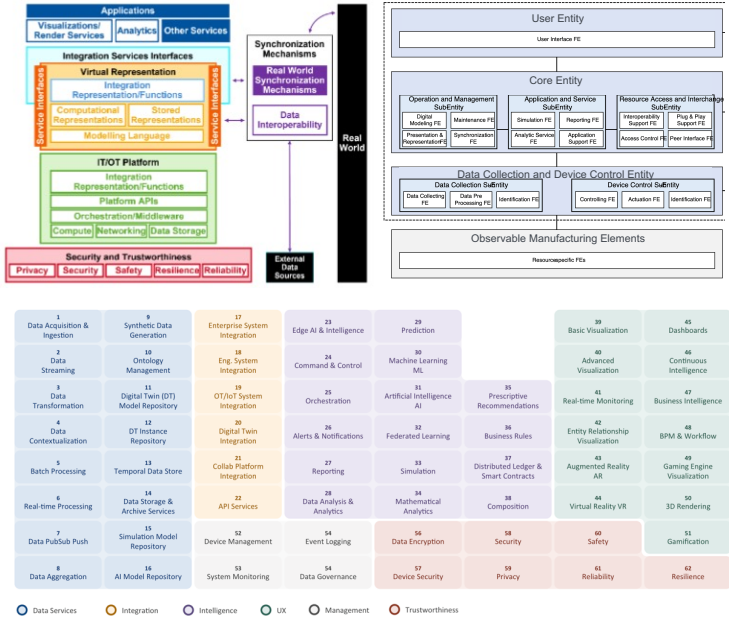
Omitted many less useful defintions[1]

ACADEMIC DEFINITIONS

- Based on data flows[2] (Kritzinger et. al)
- Based on dimensions[3] (Qi et. al)

INDUSTRIAL DEFINITIONS

- ISO DT framework for manufacturing[4]
- Digital Twin Consortium (DTC) platform stack architecture for digital twins[5]
- DTC digital twin capability periodic table[6]



1. List of 112 definitions of the term digital twin: http://www.wortmann.ac/digital-twin-definitions
2. Kritzinger, W., Karner, M., Traar, G., Henjes, J., & Sihn, W: Digital Twin in manufacturing: A categorical literature review and classification. IFAC-PapersOnLine, 2018.
3. Qi et al.: Enabling technologies and tools for digital twin. In: Journal of Manufacturing Systems, Elsevier, 2019
4. ISO 23247. Digital Twin Framework for Manufacturing, 2021.
5. https://www.digitaltwinconsortium.org/2023/11/understanding-dtcs-digital-twin-platform-stack-architectural-framework/
6. https://www.digitaltwinconsortium.org/initiatives/capabilities-periodic-table/

Common Requirements on Digital Twins

Based on popular definitions, characterizations, and architectures

Req.	The digital twin …	Sources
R1	can **receive data** from twinned counterpart	All
R2	can **send data** to its twinned counterpart	All
R3	has a **user interface**	DTC, ISO
R4	can **represent** its counterpart digitally	All
R5	can **synchronize** (selected) properties with its counterpart.	Flows, ISO
R6	can **report information** to selected recipients aside from the AAS, e.g., by sending a message to the asset's operator	DTC, ISO
R7	can communicate with **other digital twins**	DTC, ISO
R8	can interact with **third-party systems**	DTC, ISO
R9	provides **services** to act on data and models.	5D, DTC, ISO
R10	can **reason** about data from/about the twinned counterpart as well as about data obtained from other systems	DTC, ISO

What IDTA Requires for a Type 1 AAS Based on Various White Papers

Type 1 AAS are serialized files that contain static information

Req.	Evaluation	Eval	Explanation
R1	**receive data**	○	Just an XML file without any activity
R2	**send data**	○	
R3	**user interface**	○	
R4	**represent**	●	Can represent asset information statically
R5	**synchronize**	○	
R6	**report information**	○	
R7	comm. w. **digital twins**	○	
R8	interact w. **3rd-party systems**	○	
R9	**services**	○	
R10	can **reason**	○	

IDTA requires ● suggests ◐ does not require ○ that feature

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What IDTA Requires for a Type 2 AAS Based on Various White Papers

Type 2 AAS are runtime things: may have static/dynamic information from asset

Req.	Evaluation	Eval	Explanation
R1	**receive data**	●	Shall receive asset data via any connection
R2	**send data**	○	
R3	**user interface**	○	
R4	**represent**	●	Can represent system statically and dynamically
R5	**synchronize**	◐	Supports unidirectional, timed synchronization
R6	**report information**	◐	Can use references between submodels to emulate
R7	comm. w. **digital twins**	○	
R8	interact w. **3rd-party systems**	○	
R9	**services**	◐	There is an API for manipulating submodels
R10	can **reason**	◐	There is an API for manipulating submodels

IDTA requires ● suggests ◐ does not require ○ that feature

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What IDTA Requires for a Type 3 AAS Based on Various White Papers

Type 3 AASs encompass Type 2 and yield software modules for added-value

Req.	Evaluation	Eval	Explanation
R1	**receive data**	●	Active bidirectional communication with asset
R2	**send data**	●	Active bidirectional communication with asset
R3	**user interface**	○	
R4	**represent**	●	Can represent system statically and dynamically
R5	**synchronize**	◐	Supports unidirectional, timed synchronization
R6	**report information**	◐	Can use references between submodels to emulate
R7	comm. w. **digital twins**	●	Possible via “Industry 4.0 language”
R8	interact w. **3rd-party systems**	●	Required via “Industry 4.0 language”
R9	**services**	◐	There is an API for manipulating submodels
R10	can **reason**	◐	There is an API for manipulating submodels

IDTA requires ● suggests ◐ does not require ○ that feature

Type 3 Asset Administration Shells are Digital Twins

The others not

Type 1 AAS

- Shells are serialized files
- Contain static information
- Data model governed by AAS meta model
- Describe types and instances of assets as-designed
- No automated dataflows from/to asset

→**Idealized, static, description of an asset**

Digital Model

Type 2 AAS

- Runtime instances: may contain static and dynamic information from asset
- Interact w. other components
- Ex: frontend for device services, live sensor data, …
- Properties, operations, events via generic runtime interface
- Automated dataflows only from asset

→**Well-informed Dashboard**

Digital Shadow

Type 3 AAS

- Extend type 2 AAS
- Have active behavior
- Can start to communicate & to negotiate on their own
- Well-defined language and message structures (VDI/VDE 2193)
- Automated dataflows from/to asset
- **Software interfacing asset**

Digital Twin

Challenges and Opportunities for Future Research

Also exploitation

1. **Deriving Twins.** Engineering models comprise vast asset knowledge,
   - Challenge: Much needs to be re-developed for the digital twins
   - Opportunity: Derive parts of DTs from engineering models
2. **Component Reuse**. DTs process data, models, communication, services
   - Challenge: Reusing their components between DTs hardly possible
   - Opportunity: DT reference architecture w. well-defined component interfaces
3. **Digital Twin Reuse.** Complex DTs should comprise sub-DTs.
   - Challenge: The composition of digital twins is far from solved
   - Opportunity: Systematic method to compose smaller DTs into larger ones.
4. **Low-Code Configuration**. DTs are configured and used by domain experts (DEs)
   - Challenge: Expecting DEs to grasp OO data models or stack traces is futile
   - Opportunity: DSLs to properly configure, represent cross-cutting DT concerns.

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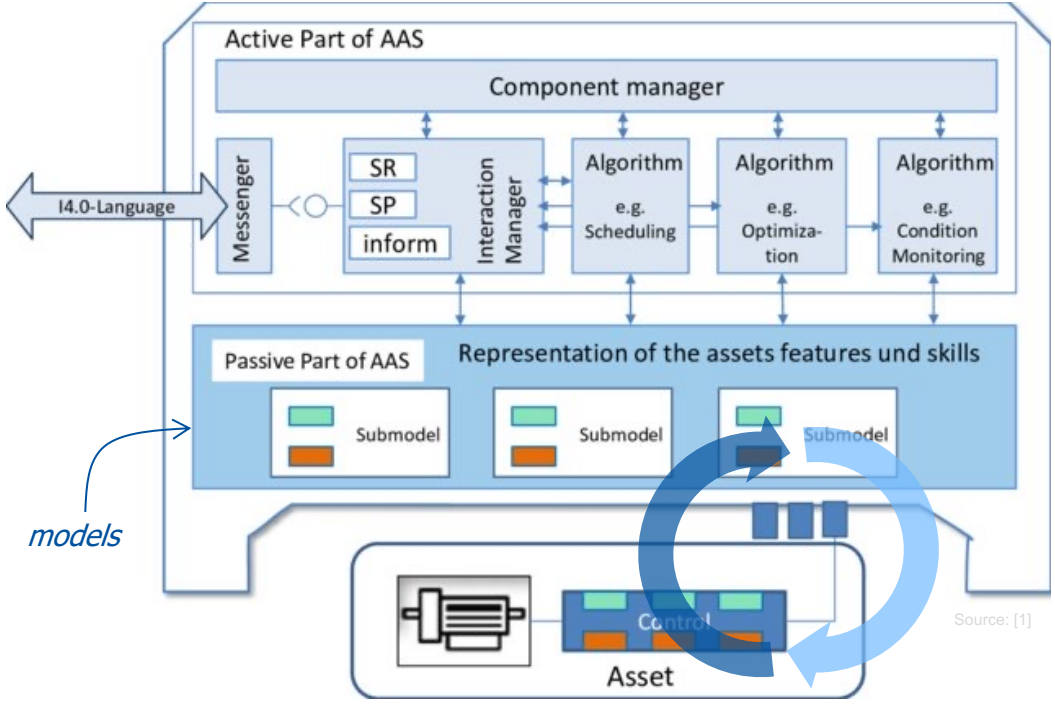
A General Architecture of Type 3 Asset Administration Shells[1]

A potential blueprint for digital twins

- Component manager orchestrates AAS behavior
- Service requester/provider interact with environment
- Algorithms perform computations
- Interact with models and asset
- Reference implementation, e.g., with BaSyx
- A lot of JSON…



1. Belyaev, A., Diedrich, C. (2019). Aktive Verwaltungsschale von Industrie 4.0 Komponenten," in Automationkongress 2019, Baden-Baden.