

Intelligent Manufacturing Engineering:
Digital & Smart Factory
DigitalTwin, PLM, Planning, Simulation, Optimization

智能制造工程专业:
数字化与智能工厂
数字孪生、产品生命周期管理、规划、仿真、优化

Dr.-Ing. Dipl.-Math. Klaus Schröer

1. Digital Twin & Asset Administration Shell (AAS)

- With Basics: Unified Modeling Language - UML.

数字孪生与资产管理壳 (AAS)

基础篇：统一建模语言 - UML。

2. Survey on Modeling, Simulation & Optimization in Automotive Manufacturing.

汽车制造建模、仿真和优化综述。

3. Product Lifecycle Management (PLM).

- PLM [TC-Connect] – ERP – ALM.
- With Basics: Databases.

产品生命周期管理 (PLM) 。

4. Digital Planning Process (DPIP).

- PMI – MBD – MBE – MBSE.
- Example: EasyPlan.
- With Basics: Tolerance Engineering.
- With Basics: Curves & Surfaces for Visualization.

基础篇：数据库。

数字化规划流程 (DPIP) 。

示例：EasyPlan.

基础篇：公差工程。

基础篇：曲线与曲面在可视化中的应用。

5. Plant & Logistics Simulation & Optimization.

- With Basics: Mathematical Optimization.

植物与物流模拟与优化。

基础篇：数学优化。

6. Process Simulation & Optimization.

- With Basics: Kinematics & Control Technology & Robotics.

过程模拟与优化。

基础篇：运动学与控制技术及机器人学。

7. Finite Element & Volume Methods (FEM & FVM) governed by partial differential equations (PDE).

有限元与体积方法 (FEM & FVM)

由偏微分方程控制 (PDE) 。

8. Manufacturing Plant IT-Infrastructure (IT-IS)

制造工厂IT基础设施 (IT-IS)

1. Digital Twin – Asset Administration Shell (AAS) 数字孪生 – 资产管理壳 (AAS)

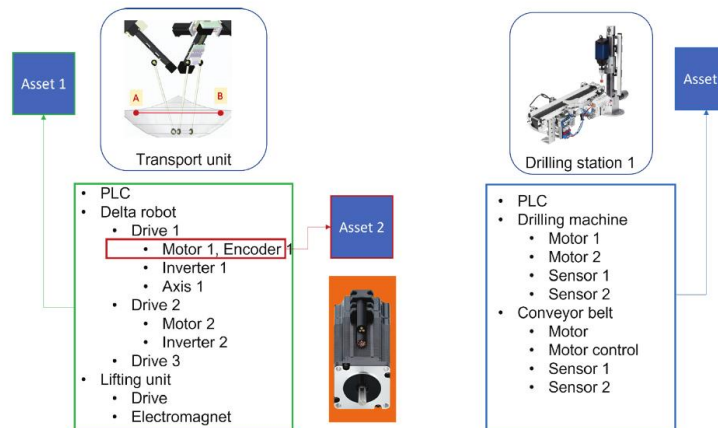
Standard to manage Digital Twins of Assets (Components, Machines, Lines, ...):

- provides data of the asset and its sub-assets (e.g., dig. nameplate, documentation, simulation models, ...),
- uses standardized dictionaries and ontologies to define the common vocabulary as basis for interoperability,
- provides APIs to access the information of an asset,
- provides interfaces to the asset,
- lists submodels and their data (e.g., for simulation),
- can provide submodels which reference asset services provided for an asset (from supplier or service provider e.g., for maintenance).

→ **Manufacturer-Independent.**



An Asset's AAS is "an instance of a data structure":



管理资产（组件、机器、生产线.....）数字孪生的标准：

- 提供资产及其子资产的数据（如铭牌、文档、仿真模型等）、
- 使用标准化字典和本体来定义通用词汇，作为互操作性的基础、
- 提供获取资产信息的应用程序接口、
- 提供资产接口、
- 列出子模型及其数据（如用于模拟）、
- 可提供子模型，参考为资产提供的资产服务（来自供应商或服务提供商，如用于维护）。

→ **制造商独立。**

1. Digital Twin – AAS – Seen by the Package Explorer

数字孪生 – AAS – 软件包资源管理器查看



▶ Exemplary implementation of an Administration Shell that has to be exchanged



Papierkorb



Dieser PC



sample-admin-shell.aasx

▶ Exemplary Browser and Editor

▶ Companies can develop their own solutions based on their own business use case.

AASX Package Explorer - Example_AAS_ServoDCMotor - Extended.aasx

File Workspace Help

Submodel

Submodel element

Submodel element

http://customer.com/assets/KHB VZISQIV



▲ AAS "ExampleMotor" [URI, http://customer.com/aas/9175_7013_7091_9168] of [UR

▲ Sub "Identification" [URI, http://i40.customer.com/type/1/1/F13E8576F648B34;

Prop "Manufacturer" = CUSTOMER GmbH

Prop "GLN" = 10101010

Prop "ProductDesignation" = I40 Capable Servo Motor (EN)

Prop "SerialNumber" = P12345678I40

▲ Sub "TechnicalData" [URI, http://i40.customer.com/type/1/1/7A71048DAB57E1

Prop "MaxRotationSpeed" = 5000 [1/min]

Prop "MaxTorque" = 200 [Nm]

Prop "CoolingType" = BAB657

▲ Sub "OperationalData" [URI, http://i40.customer.com/instance/1/1/AC69B1CB4

Prop "RotationSpeed" = 4370 [1/min]

Prop "Torque" = 117.4 [Nm]

▲ Sub "Documentation" [URI, http://i40.customer.com/type/1/1/1A7B62B529F19

▲ Coll "OperatingManual" (10 elements)

Prop "DocumentId" = 3 608 870 A47

Prop "DocumentClassId" = 03-02

Prop "DocumentClassName" = Operation (EN) Bedienung (DE)

Prop "DocumentClassificationSystem" = VDI2770:2018

Prop "OrganizationName" = CUSTOMER

Prop "OrganizationOfficialName" = CUSTOMER GmbH

Prop "Title" = Operating Manual

Prop "Language" = en-US

File "DigitalFile_PDF" -> /aasx/OperatingManual.pdf

Ref "ReferencedObject" -> [Asset, Local, URI, http://customer.com/aas

▲ View "SafetyView" (1 elements)

http://i40.customer.com/instance/1/1/AC69B1CB44F07935/ RotationSp

Element Content

Referable members:

IdShort: MaxRotationSpeed

category: PARAMETER

Kind:

kind: Instance

Semantic ID

semanticId: (ConceptDescription) (Local) [IRDI] 0173-1#02-BAA120#008

Qualifier

ConceptDescription

Referable members:

idShort: MaxRotationSpeed

category: PROPERTY

Identifiable members:

IdType: IRDI

id: 0173-1#02-BAA120#008

version:

revision: 2

IsCaseOf

HasDataSpecification

hasDataSpecificati (GlobalReference) (no-Local) [URI] www.admin-shell.io/DataSpecificat

DataSpecificationContent

Data Specification Content | EC61360

preferredName: [de] max. Drehzahl

[en] Max. rotation speed

shortName:

unit: 1/min

unitId: (GlobalReference) (no-Local) [IRDI] 0173-1#05-AA650#002

dataType: INTEGER_MEASURE

definition: [de] Höchste zulässige Drehzahl, mit welcher der Motor oder die Spe

[en] Greatest permissible rotation speed with which the motor or fee

Property

valueType: integer

value: 5000

Reload

Drag from here!

Show Content

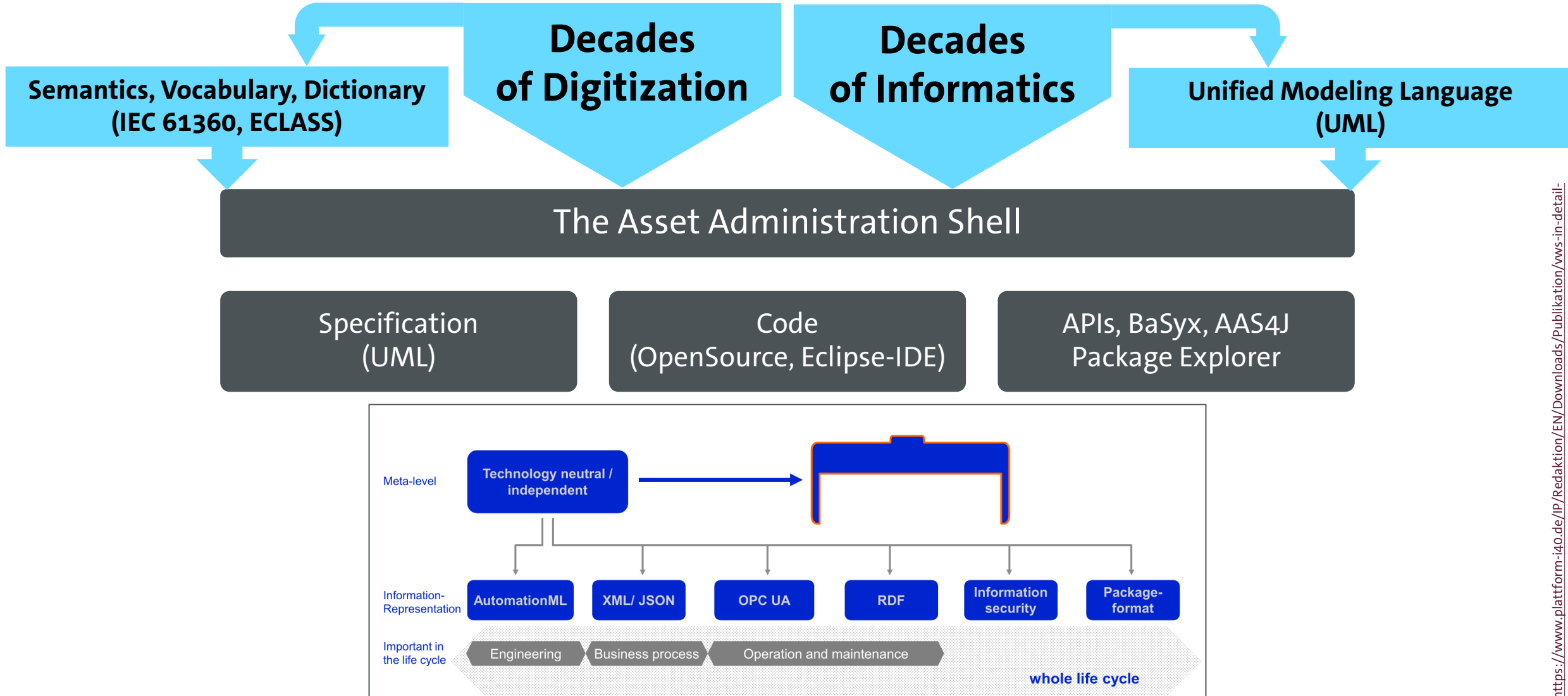
Dr. K. Schröer | 01.07.2026

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https://www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/vws-in-detail-presentation.pdf?__blob=publicationFile&v=1

1. Digital Twin – AAS – Result of Digitization and Informatics

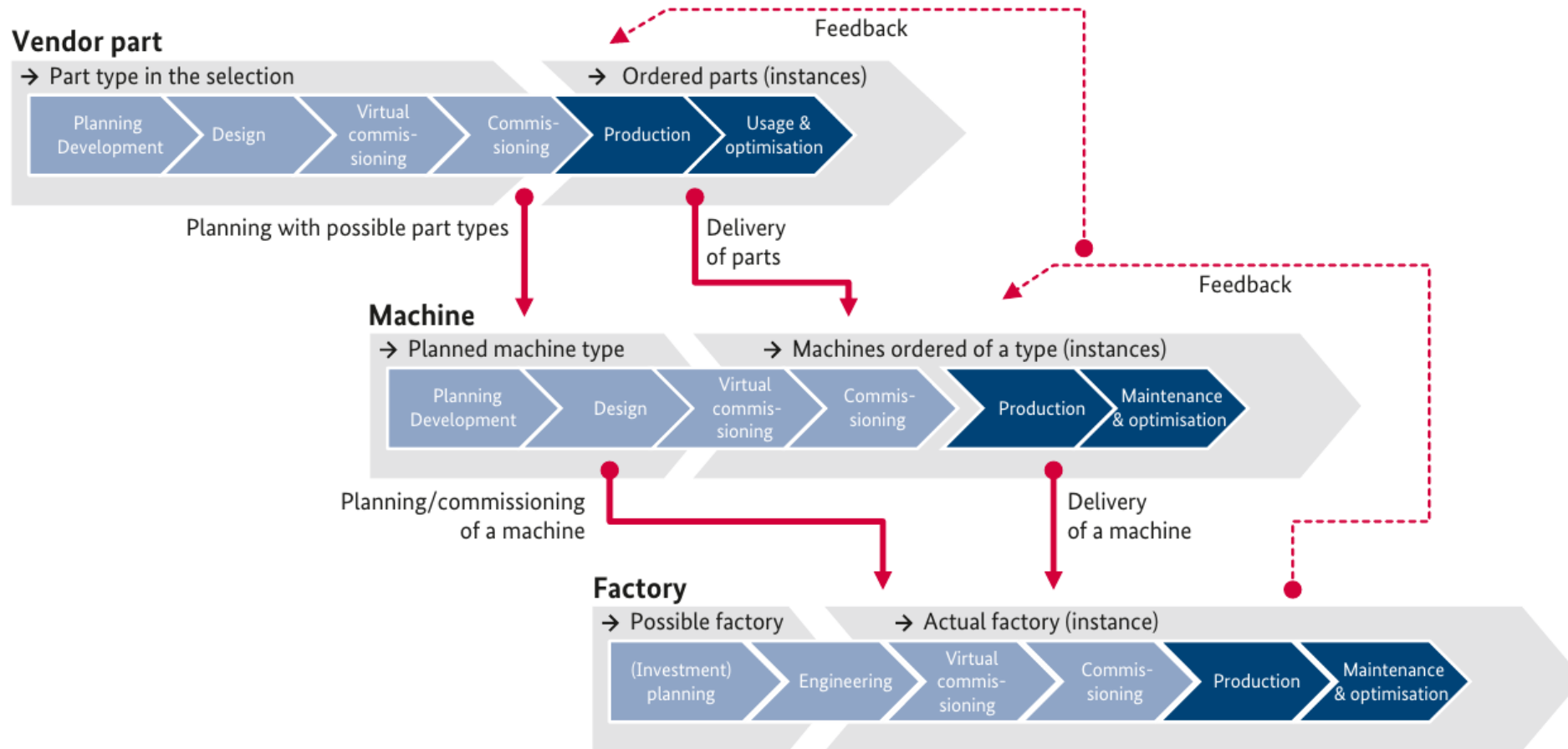
数字孪生 – AAS – 数字化和信息学的成果



1. Digital Twin – AAS – During Lifecycle of a Product, Equipment, ...

数字孪生 – AAS – 在产品、设备和服务的生命周期内, ...

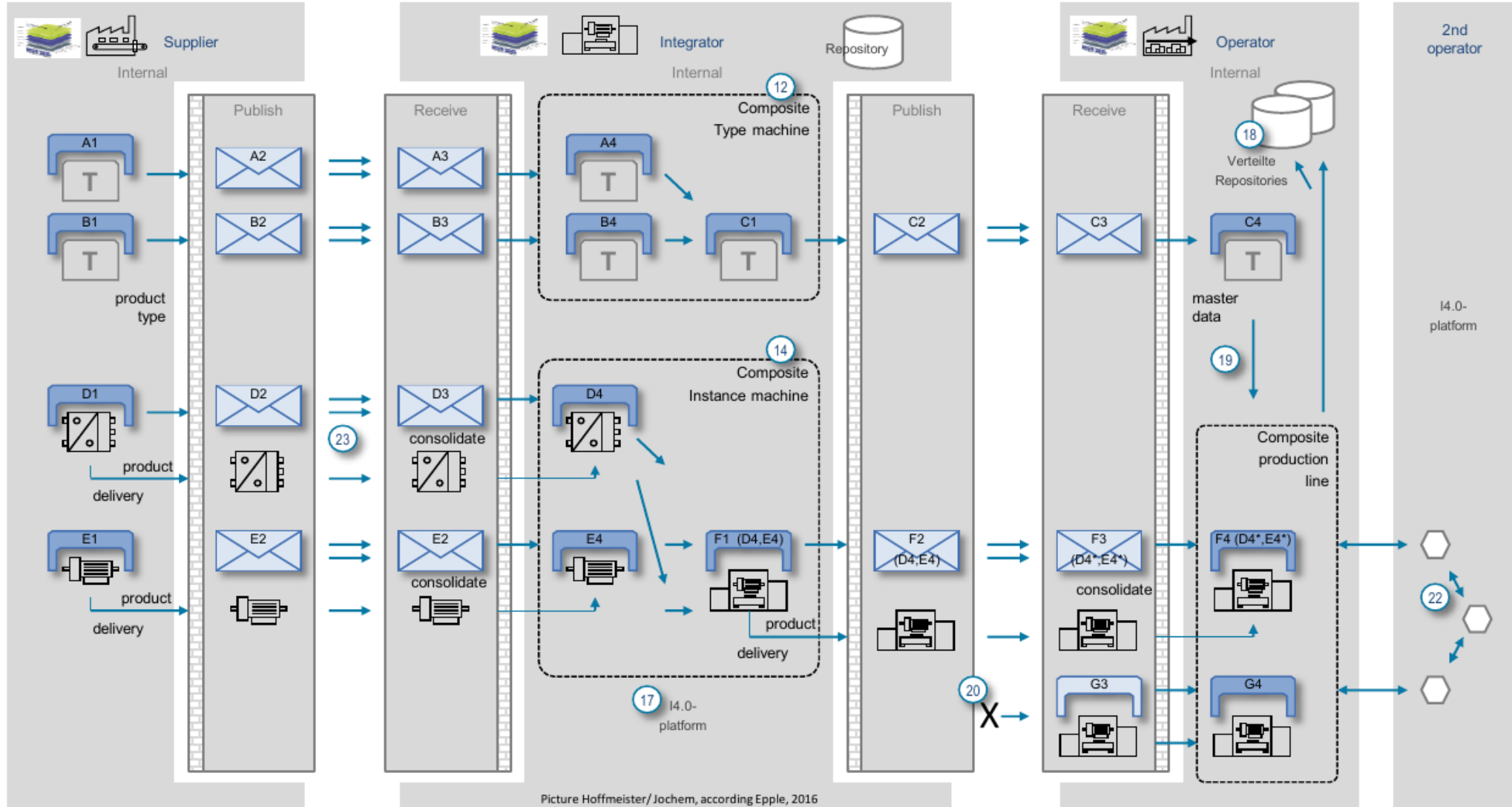
Typical cross-linking of the life cycles of supplied part, machine and factory – as type and instance respectively



Source: ZVEI SG Modelle und Standards

1. Digital Twin – AAS – Use Cases during Lifecycle

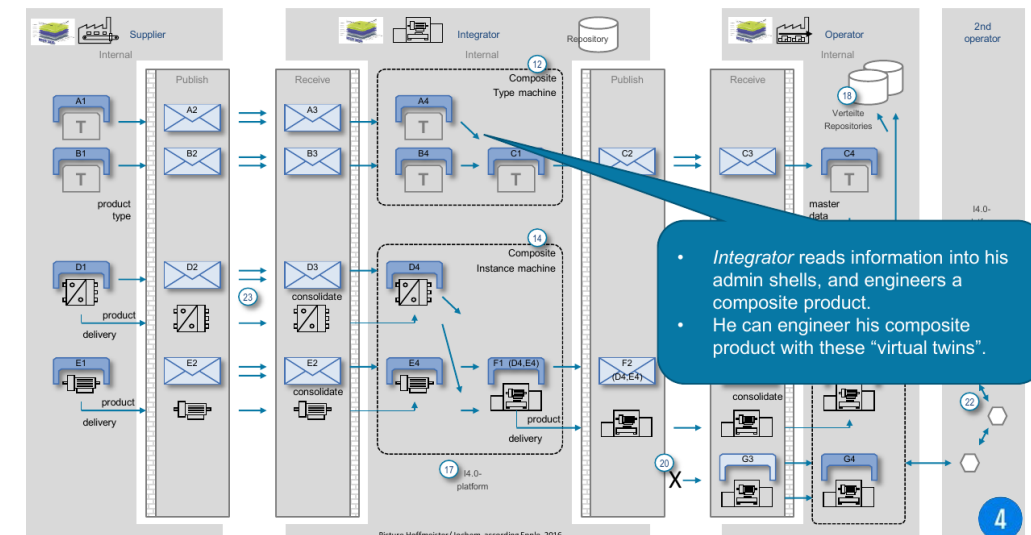
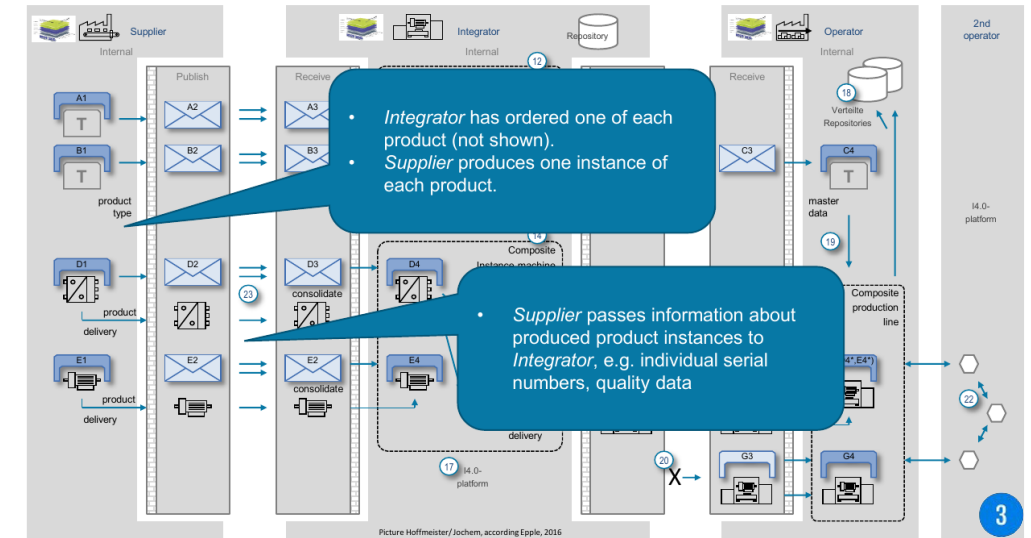
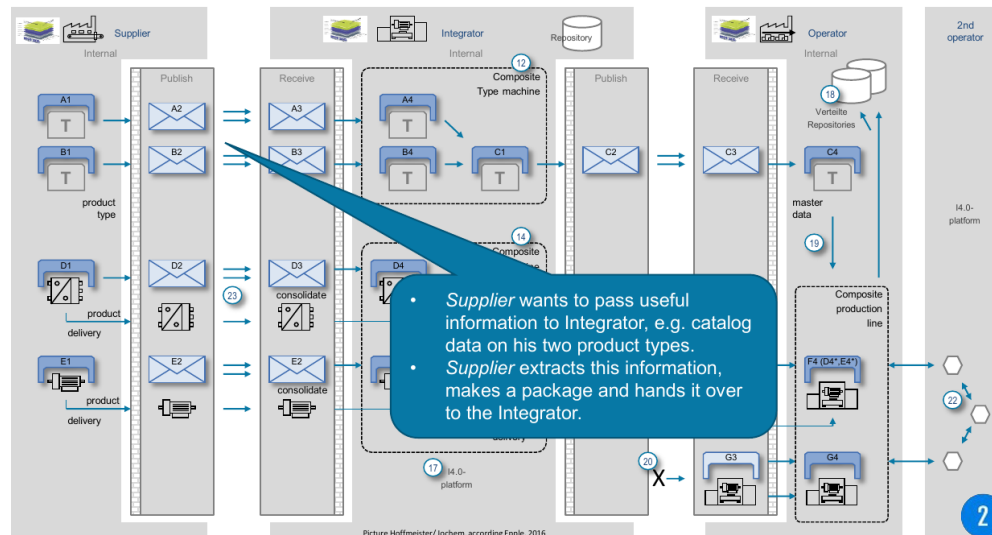
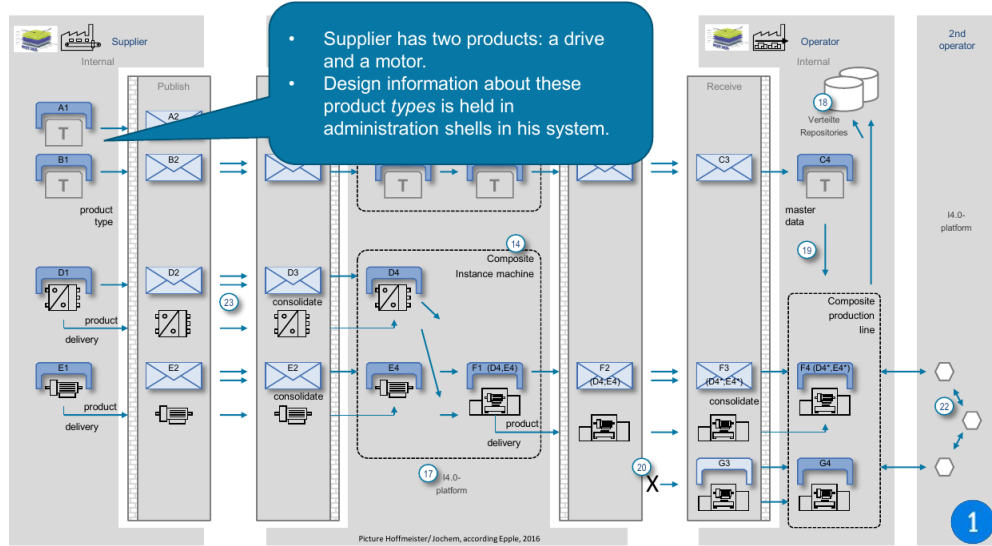
数字孪生 – AAS – 生命周期中的用例



Picture Hoffmeister/ Jochem, according Eppele, 2016

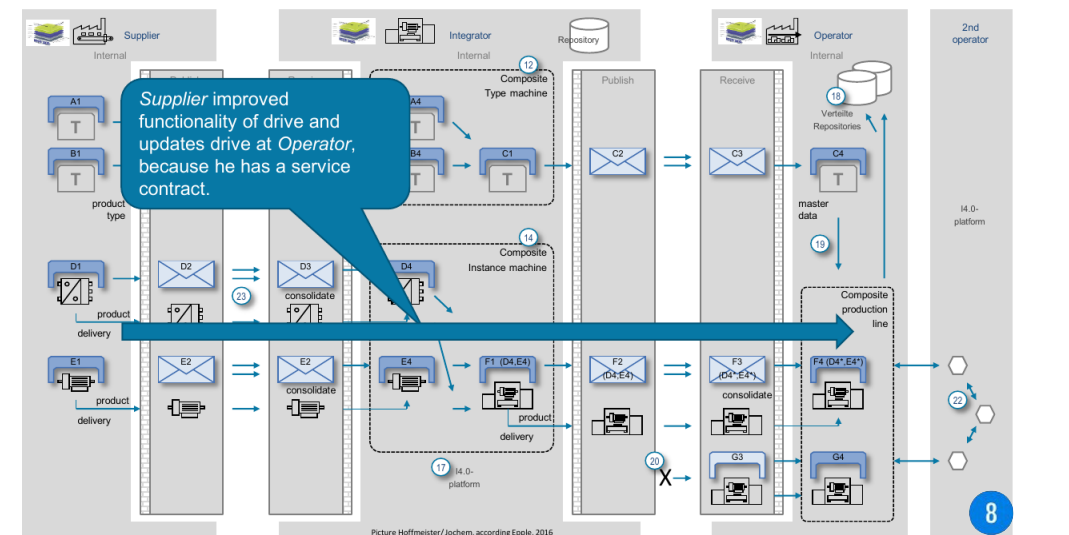
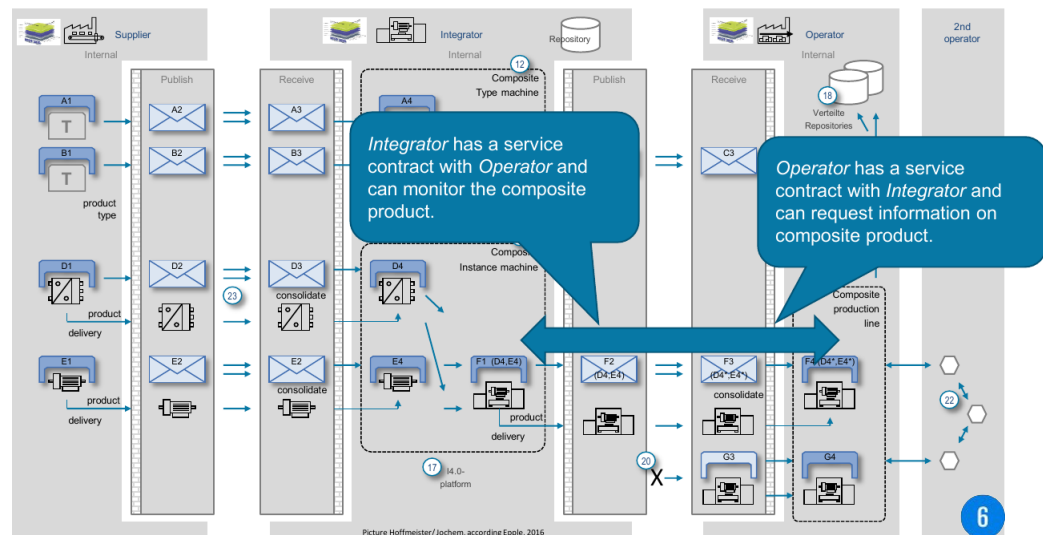
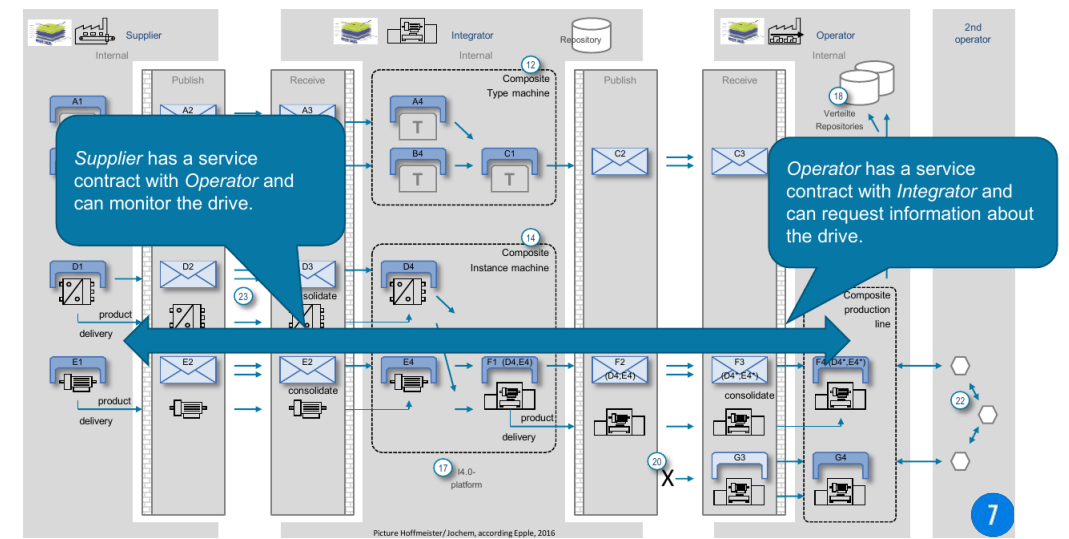
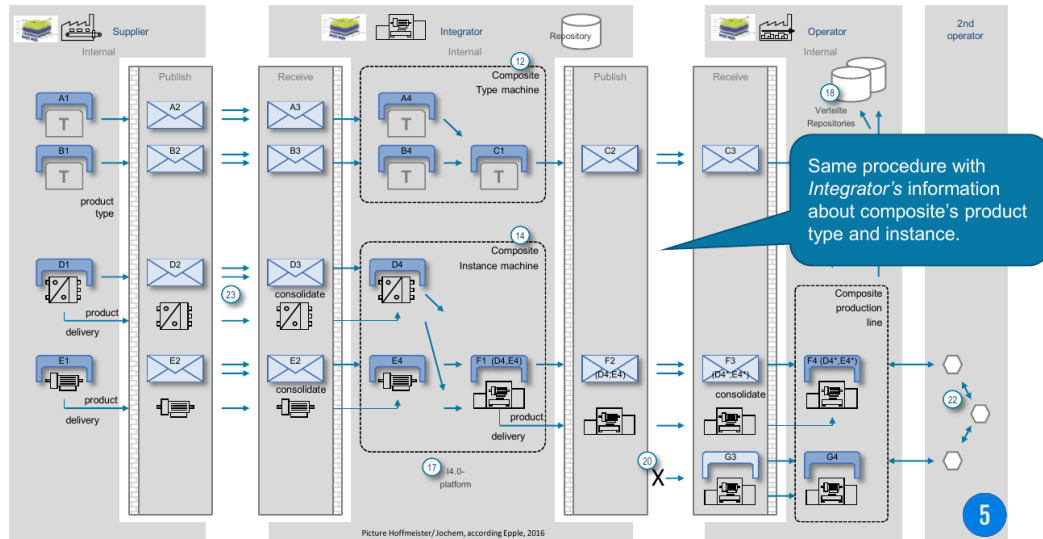
1. Digital Twin – AAS – Use Cases during Lifecycle – Type → Instance

数字孪生 – AAS – 生命周期中的用例 – 类型 → 实例



1. Digital Twin – AAS – Use Cases during Lifecycle – Services

数字孪生 – AAS – 生命周期中的用例 – 服务



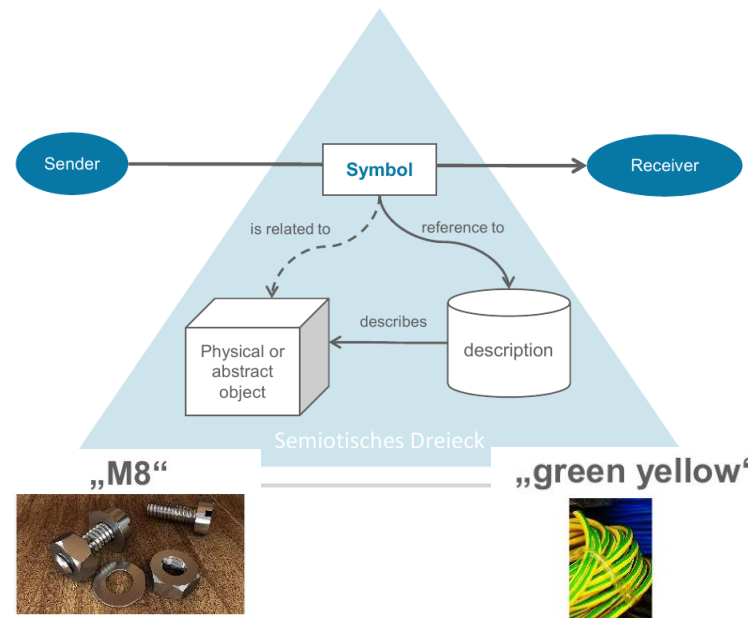
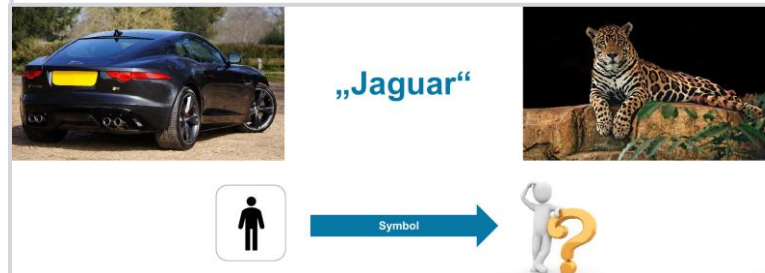
1. Digital Twin – AAS – Semantics "What are we talking about?" 数字孪生 – AAS – 语义学 "我们在说什么？"

Clear, unambiguous, technical, machine-readable communication needs identifiers!

Identifier:

- Refers to an object.
- Its meaning is known to both sender and receiver.
- Anyone can look up the meaning of the identifier (in different languages) in a dictionary.
- It is machine-readable and made for communication between machines.

Semantics:
"The Jaguar is in the garage!"



清晰、明确、技术性强、机器可读的通信需要标识符!

标识符:

- 指一个对象。
- 发送方和接收方都知道其含义。
- 任何人都可以在字典中查到标识符的含义（不同语言）。
- 它是机器可读的，可用于机器之间的通信。

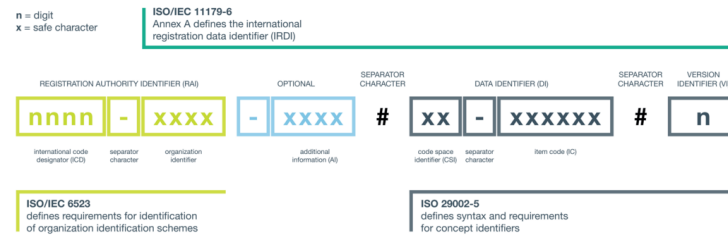
1. Digital Twin – AAS – Semantics – Identifiers – Format

数字孪生 – AAS – 语义学 – 标识符 – 格式



- **IRDI** – Internat. Reg. Data Identifier.
ISO29002-5, ISO IEC 6523, ISO IEC 11179-6.
- **Internationalized Resource Identifier (IRI, <https://www.rfc-editor.org/rfc/rfc3987>) or Uniform Resource Identifier (URI and URL, <https://www.rfc-editor.org/rfc/rfc3986>)**.
- **Custom:** Internal custom identifiers such as **UUIDs/GUIDs**
→ Universally Unique Identifier (**UUID**) is a 128-bit label used for information in computer systems.
(Microsoft: GUID)
<https://www.rfc-editor.org/info/rfc4122>
https://en.wikipedia.org/wiki/Universally_unique_identifier

International Registration Data Identifier



- **IRDI** - Internat. Reg. 数据标识符。
ISO29002-5、ISO IEC 6523、ISO IEC 11179-6。
- 国际化资源标识符
(IRI, <https://www.rfc-editor.org/rfc/rfc3987>) 或统一资源标识符 (**URI** 和 **URL**, <https://www.rfc-editor.org/rfc/rfc3986>) 。
- **自定义:** 内部自定义标识符, 如 **UUIDs/GUIDs**
→ 通用唯一标识符 (**UUID**) 是一种 128 位标签, 用于计算机系统中的信息。(微软: **GUID**)
<https://www.rfc-editor.org/info/rfc4122>
https://en.wikipedia.org/wiki/Universally_unique_identifier

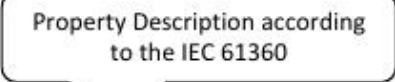
1. Digital Twin – AAS – Semantics – Identifiers – Content 数字孪生 – AAS – 语义学 – 标识符 – 内容

- **ISO/TS 29002-5:2009** - Industrial automation systems and integration
-- Exchange of characteristic data.
- **IEC 61360:**
The IEC provides a technical dictionary for the use in the electro-technical and electronic domain which is published as IEC 61360-4. This dictionary is called IEC Common Data Dictionary (IEC CDD) and can be accessed as a web page.
(<https://cdd.iec.ch>, ICD = 0112).
- **ECLASS** (based on IEC 61360):
<https://eclass.eu/en> (ICD = 0173)
<https://eclass.eu/en/eclass-standard/search-content>
→ Semantic mapping between different dictionaries and ontologies.

The screenshot shows the ECLASS website interface. At the top, there's a navigation bar with links: 新闻, 标准 ECLASS, 应用中ECLASS, 关于我们, 技术支持, 淘宝店. Below this, there's a search section with dropdowns for Version (13.0), Language (CN), and Search in (Classification), along with a 'Search for' input field. The main content area displays 'ECLASS BASIC 13.0 (cn)' with a list of categories: 13 研发 (服务), 14 物流 (服务), 15 维修 (服务), 16 食品, 饮料, 烟草制品, 17 机器, 机组 (特殊应用领域), 18 矿山、冶金、轧制及铸造设备, 19 信息、传播和媒体技术, 20 包装材料, 21 厂房设备, 车间设备, 工具, 22 建筑技术, 23 机器元件, 紧固件, 五金件, 24 办公材料, 办公设备, 办公技术, 文具纸张用品, 25 一般服务. Below this, a detailed classification tree is shown for '32 Laboratory material, Laboratory technology'. The tree is divided into levels: 1st level (32-02 Furnishing, installation (lab)), 2nd level (32-03 Laboratory incidentals, utilities), 3rd level (32-03-11 Plug (lab), 32-03-12 Foil (lab), 32-03-13 Manual device (lab)), and 4th level (32-03-13-01 Double spatula (lab), 32-03-13-02 Flour scoop (lab), 32-03-13-03 Micro spatula (lab, discontinued), 32-03-13-04 Spatula spoon (lab)). The 'Spatula spoon (lab)' is further detailed with properties: Length of spoon, Material, and Material (10CrMo910, 13CrMo44). The tree is labeled 'Classification' and 'Product Descript'.

- **ISO/TS 29002-5:2009** - 工业自动化系统和集成 - 特性数据的交换。
- **IEC 61360:**
IEC 为电子电气领域提供了一本技术词典，按照 IEC 61360-4 标准出版。该字典称为 IEC 通用数据字典 (IEC CDD)，可通过网页访问。
(<https://cdd.iec.ch>, ICD = 0112)。
- **ECLASS** (基于 IEC 61360) :
<https://eclass.eu/en> (ICD = 0173)
<https://eclass.eu/en/eclass-standard/search-content>
→ 不同词典和本体之间的语义映射。

数字孪生-AAS-语义学-带属性的应用程序类



Property	02-AAD222 Rotation speed
shortname	-
Format	STRING
Definition:	Quotient of number of rotations divided by the associated time span
Values:	

01	IRDI of an explicit Value	at 50 Hz, 720 1/min at 60 Hz	} Explicit Values
01		at 50 Hz, 800 1/min at 60 Hz	
0173-1#C7-B4B745#00		at 50 Hz, 1200 1/min at 60 Hz	
0173-1#C7-B4B757#00		at 50 Hz, 1500 1/min at 60 Hz	
0173-1#C7-B4B789#00		at 50 Hz, 3600 1/min at 60 Hz	

IRDI of an
explicit Value

Explicit Values

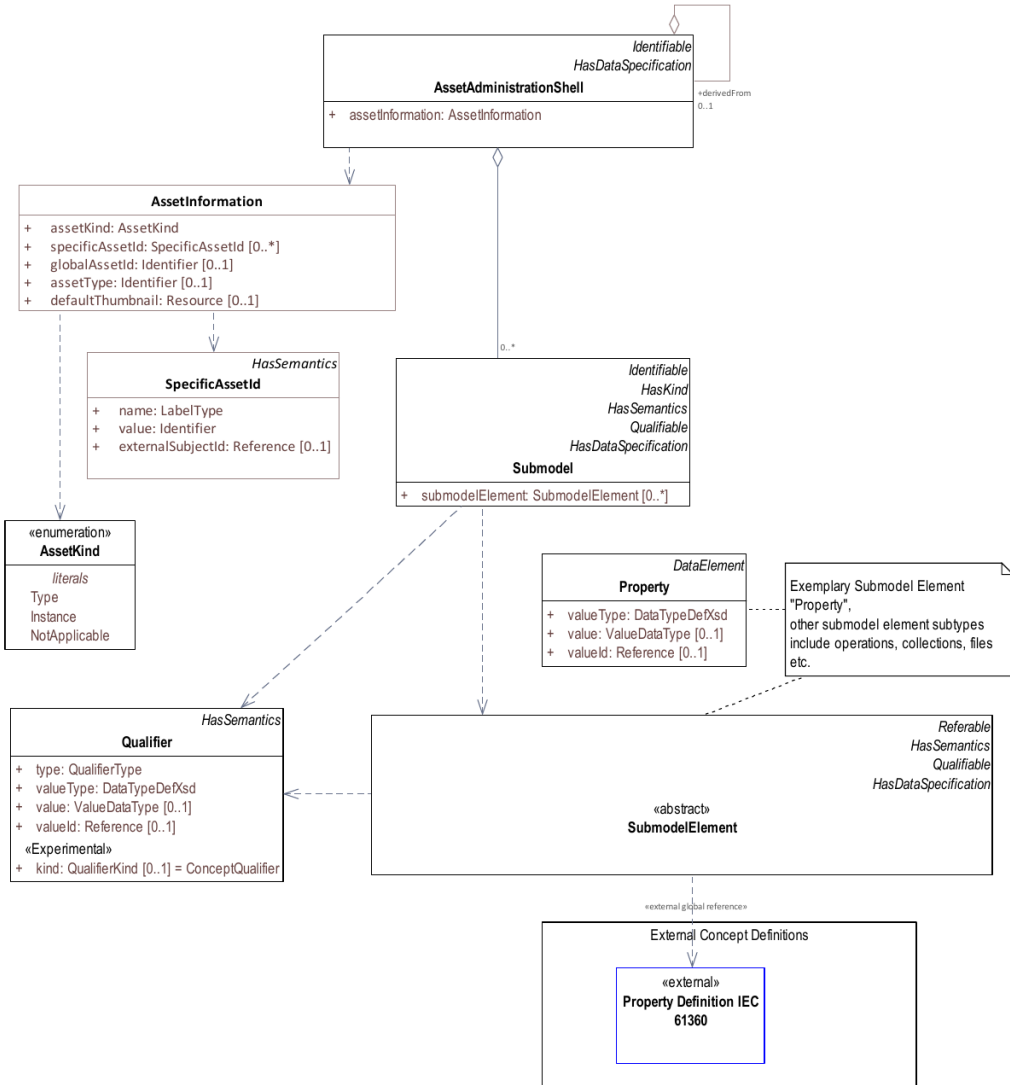
IRDI	0173-1#07-BAB757#001
Preferred name:	1500 l/min at 50 Hz, 1800 l/min at 60 Hz
short name	
Definition:	
Properties:	

Semantic
Description of an
explicit Value

Semantic
Description of an
explicit Value

1. Digital Twin – AAS – Metamodel Overview

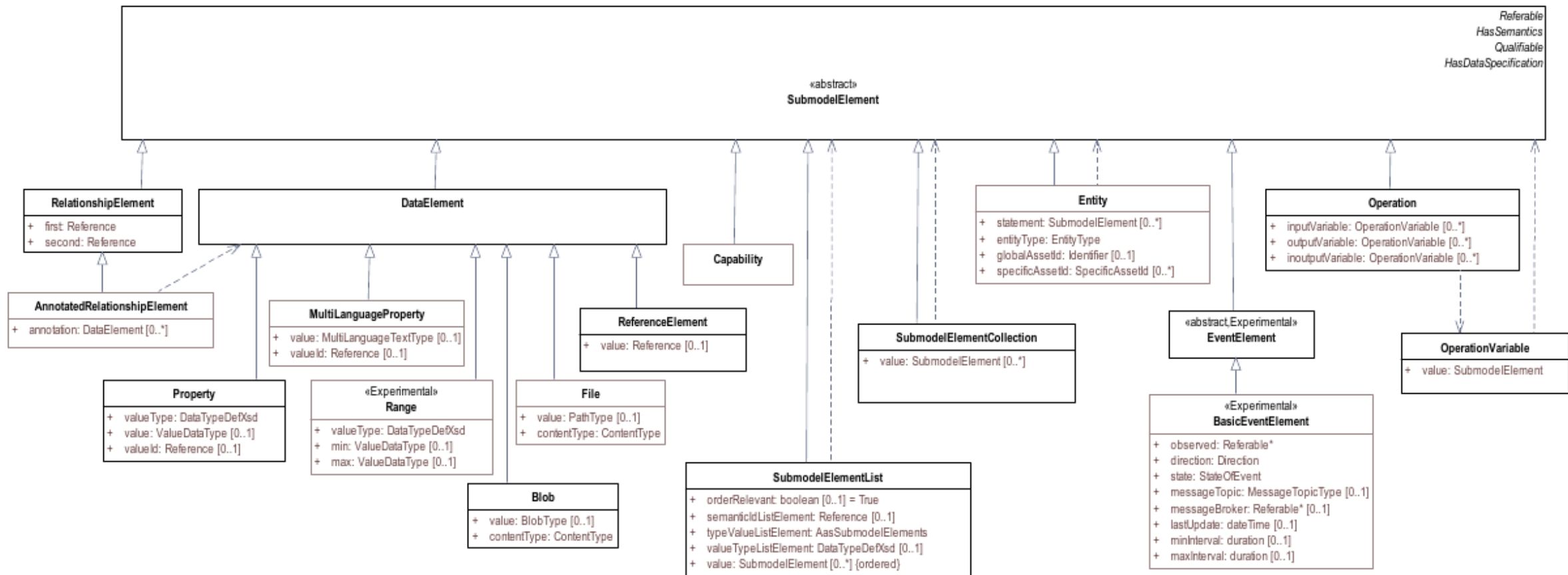
数字孪生 – AAS – 元模型概述



- Overview of the main classes of the Asset Administration Shell (AAS) metamodel, used to describe a single Asset Administration Shell.
资产管理壳（AAS）元模型主要类概览，可用于描述单个资产管理外壳。
- An Asset Administration Shell represents exactly one asset (*AssetAdministrationShell/assetInformation*).
一个资产管理壳正好代表一种资产（*AssetAdministrationShell/assetInformation*）。

1. Digital Twin – AAS – Submodel Element Overview

数字孪生 – AAS – 子模型-元素概述



- Submodel elements include data properties as well as operations, events and other elements needed to describe a model for an asset.

子模型元素包括数据属性以及描述资产模型所需的操作、事件和其他元素。

1. Digital Twin – AAS – Example

数字孪生 – AAS – 示例

AASX Package Explorer V3.0 - local file: F:\USERS\klaus_NB_Beruf\Industrie-4.0\IDTA-AAS-Docs\AASX-Samples\04_Bosch.aasx buffered to: C:\Users\Admin\AppData\Local\Temp\tmp107.aasx

File Workspace Option Help

INDUSTRIE 4.0 IDTA

Submodel

Submodel element

Submodel element

http://dc-qr.com?m=R036037000&s=1005625831090001&vc=CKK-090-NN-1



AAS "Bosch_CompactModuleBallRailSystem" [http://boschrexroth.com/shells/R036037000/1]

Asset AssetInformation http://dc-qr.com?m=R036037000&s=1005625831090001&vc=CKK-

SM "Nameplate" [http://boschrexroth.com/shells/R036037000/1005625831090001/submodel]

HSU Nameplate Submodel of the HSU ready

Prop "ManufacturerName" = Bosch Rexroth AG

Prop "ManufacturerProductDesignation" = Compact Module with ball screw drive (C)

SMC "PhysicalAddress" (5 elements)

Prop "CountryCode" = DE

Prop "Street" = Zum Eisengießer 1

Prop "Zip" = 97816

Prop "CityTown" = Lohr am Main

Prop "StateCountry" = Bayern

Prop "ManufacturerProductFamily" = Compact module

Prop "SerialNumber" = 1005625831090001

Prop "BatchNumber"

Prop "ProductCountryOfOrigin" = DE

Prop "YearOfConstruction" = 2019

SMC "Marking_CE" (2 elements)

SM "Document" [http://boschrexroth.com/shells/R036037000/1005625831090001/submodel]

SM "Service" [http://boschrexroth.com/shells/R036037000/1005625831090001/submodel]

SM "Identification" [http://boschrexroth.com/shells/R036037000/1005625831090001/submodel]

SM "TechnicalSpecification" [http://boschrexroth.com/shells/R036037000/1005625831090001/submodel]

Element Content

Submodel Element (Property)

Referable:

idShort: CityTown

category: PARAMETER

HasExtension:

Semantic ID:

semanticId: (ConceptDescription) 0173-1#02-AAO132#001

Supplemental Semantic IDs:

Qualifiable:

HasDataSpecification (Reference):

ConceptDescription

Referable:

idShort: CityTown

HasExtension:

Identifiable:

id: 0173-1#02-AAO132#001

id (Base64): MDE3My0xIzAyLUFBTzEzMmMwMDE=

HasDataSpecification (records of embedded data specification):

Property

valueType: xs:string

value: Lohr am Main

Reload Drag from here! Show Content

0 bytes No errors Clear Log..

Content /aasx/Nameplate/markingsce.png displayed.

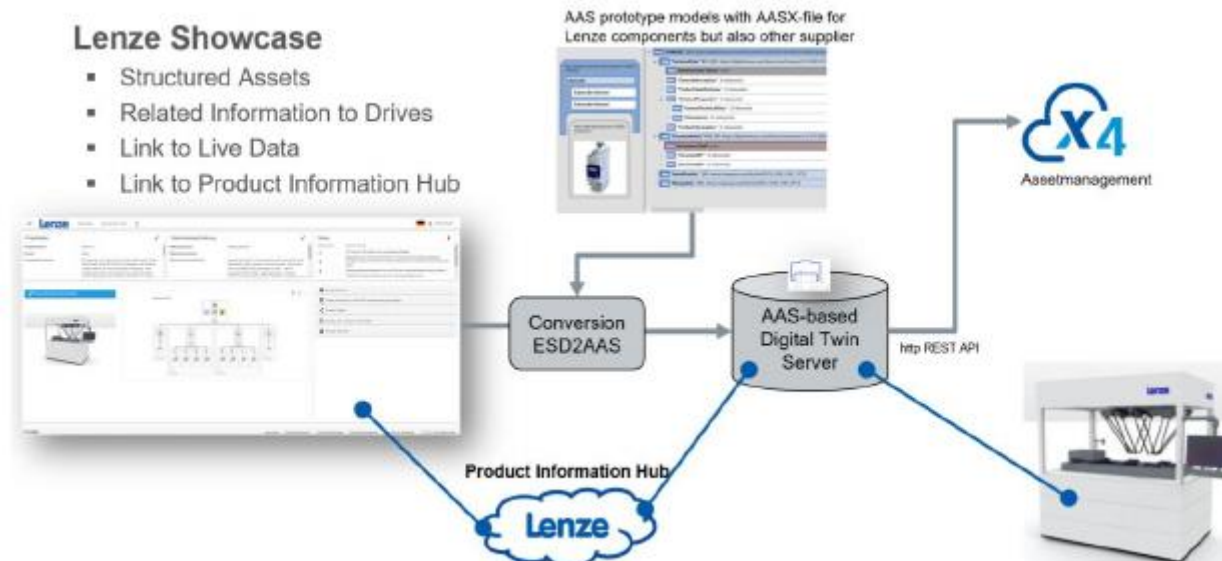
1. Digital Twin – AAS – Utilization 数字孪生 – AAS – 利用率

What does a product manufacturer need to do to provide its customers with product data in AAS format?

- Create the AAS-Class for a product.
(e.g.: using sub-model templates provided as OpenS.)
- For each product specimen create an instance.
- Publish product class to all customers.
- Publish instance information to customer, who bought that instance.

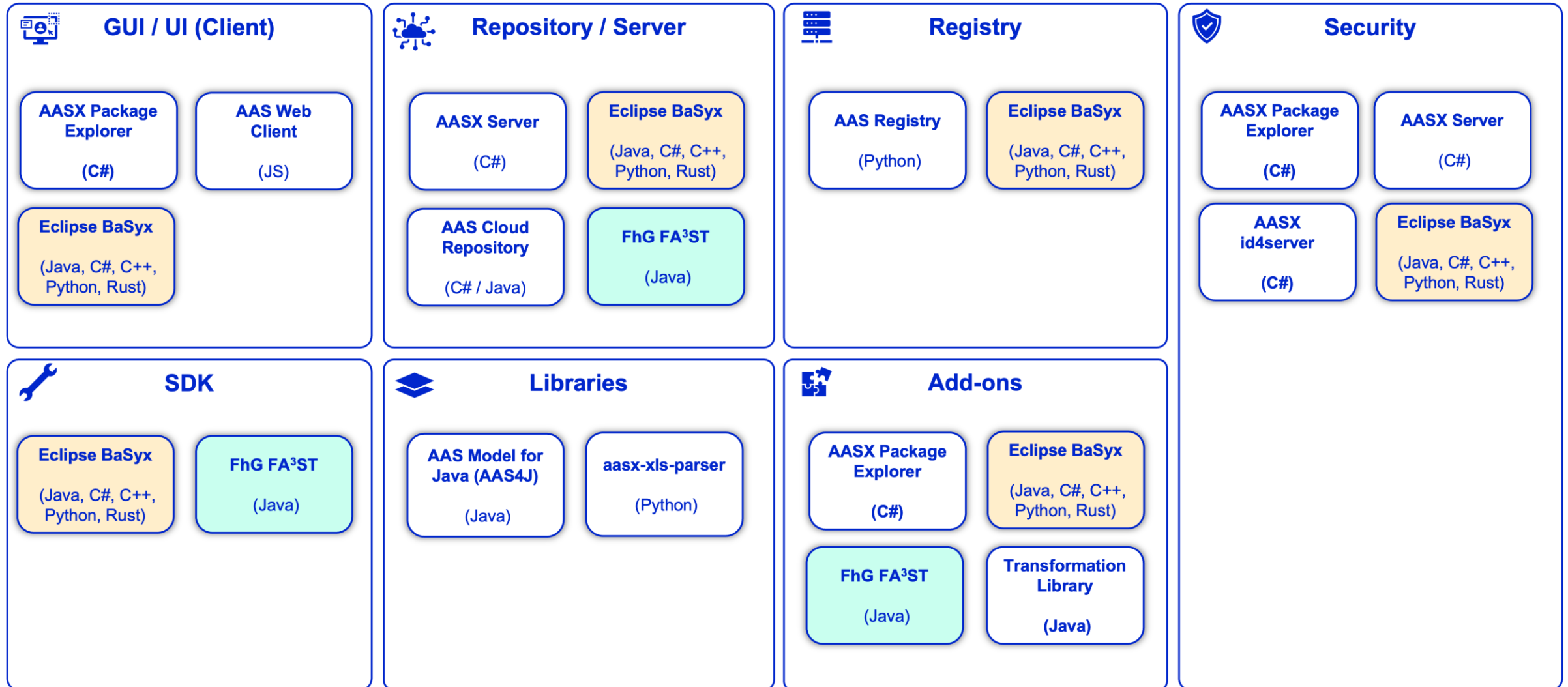
产品制造商需要采取哪些措施，才能向客户提供AAS格式的产品数据？

- 为产品创建AAS类。
(例如：使用作为开源提供的子模型模板。)
- 为每个产品样本创建一个实例。
- 将产品类发布给所有客户。
- 将实例信息发布给购买该实例的客户。



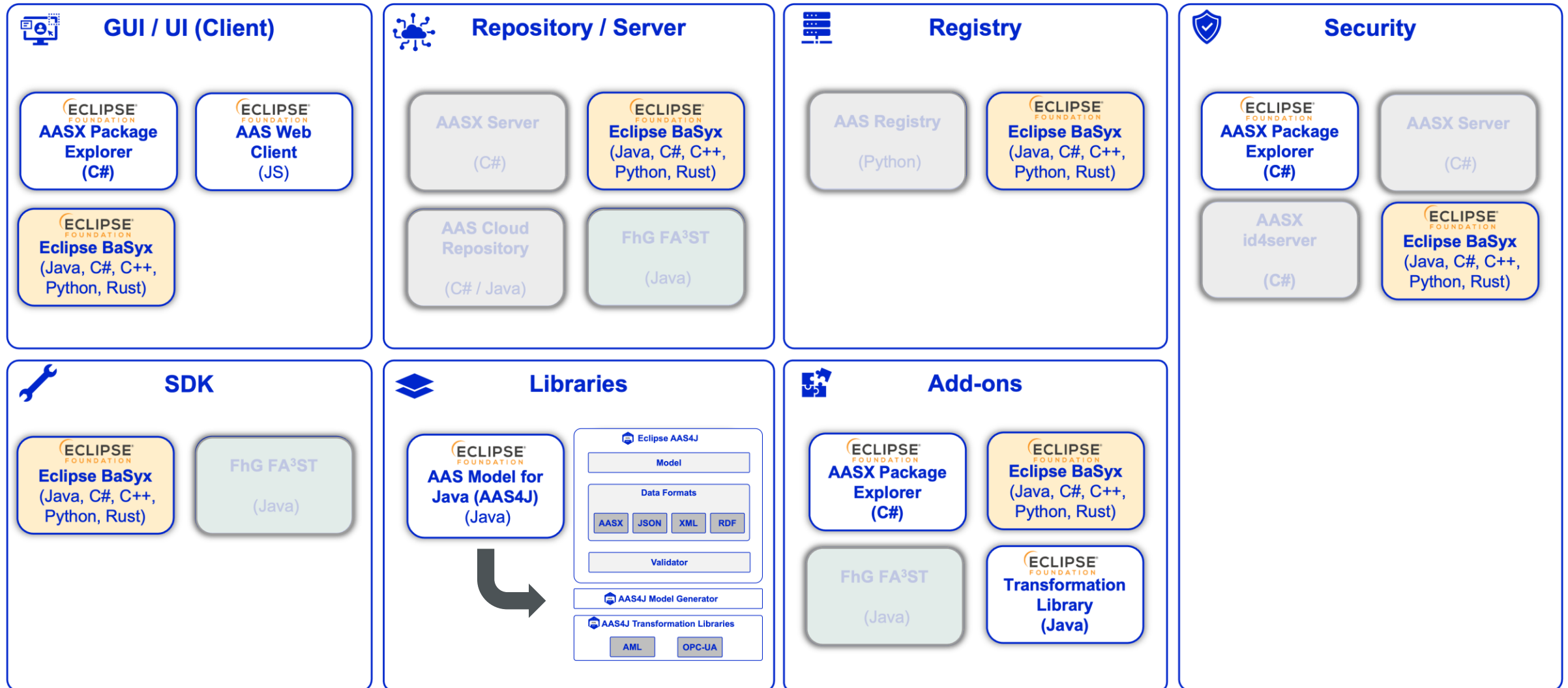
1. Digital Twin – AAS – Open Source Landscape

数字孪生 – AAS – 开放源代码环境



1. Digital Twin – AAS – Open Source Landscape @eclipse.org/projects/dt

数字孪生 – AAS – 开放源代码环境



1. Digital Twin – Documents for Reference

数字孪生 – 文件 供参考

For Download:

- On IDTA WebSite:
<https://industrialdigitaltwin.org/en/content-hub/downloads>

AAS-Tutorials:

- 2023-07-27_IDTA_Tutorial_V3.0_Specification_AAS_Part1_Metamodel.pdf
- 2023-07-27_IDTA_Tutorial_V3.0-Specification-AAS-Part-2_API.pdf
- 2023-09-28_IDTA_Tutorial_AAS-Specification_Part3a_DataSpec_IEC61360.pdf

AAS-Specifications: (<https://industrialdigitaltwin.org/en/content-hub/aasspecifications>)

- IDTA-01001-3-0_SpecificationAssetAdministrationShell_Part1_Metamodel.pdf
- IDTA-01002-3-0_SpecificationAssetAdministrationShell_Part2_API.pdf
- IDTA-01003-a-3-0_SpecificationAssetAdministrationShell_Part3a_DataSpecification_IEC61360.pdf

AAS-Submodels: <https://industrialdigitaltwin.org/en/content-hub/submodels>

AAS-Solutions: <https://industrialdigitaltwin.org/en/solutions-hub>

AASX-Samples.

AAS – Package Explorer:

- On GitHub:
<https://github.com/eclipse-aaspe/aaspe>
→ As well: References to Other Open Source Implementations of AAS.