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An Introduction to Design a Digital Twin for an Industry 4.0 Training Production Line

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Abstract. Contribution presents a simplified practical procedure for the implementation of Asset administration shells (AAS) of assets from the Festo Didactic Cyber-Physical Factory for Industry 4.0 training and therefore is intended for designers, students and all those interested in the field of Industry 4.0 technologies, standards and procedures. It could be also a small guide for introduction users of AAS as the very standardized digital twin for Industry 4.0 technology and standards.

SPECIFICATION OF THE INDUSTRY 4.0 TESTBED

Autor's aim to demonstrate a general procedure of designing and modeling Asset Administration Shell (AAS) of a typical physical model of Industry 4.0 application. They chose a Cyber-Physical (CP) factory education model as the factory of the future, developed and realized by the FESTO Didactic Ltd. It is shown in the Fig.1, [1].

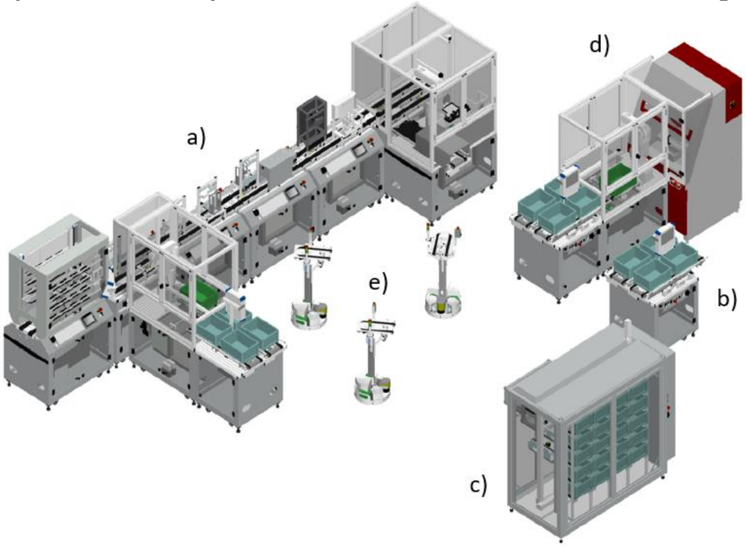

FIGURE 1. *Cyber Physical Factory situated in the laboratory of Industry 4.0 technologies in the Colleague of Polytechnics Jihlava.*

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The CP factory consists of four parts, which are the production line (a), hand workplace (b), supermarket of products (c) and CNC workplace (d). Subproducts are moved by three moving robots Robotinos (e). The education model is situated in the Colleague of Polytechnics Jihlava, Czech republic.

The education production line has several modules, equipped with different application modules which provides operation on a subproducts situated on pallets, moved from one module to other modules by a production belt. Any subproduct, but also any I 4.0 component of the line takes its own AAS with its live cycle information's. The principal of the Industry 4.0 is to virtualize the physical realization of any module in order to enable high distributed automatic control of the module and all the production line, including to optimize economic parameters.

The modeling procedure will be shown on a testbed. The testbed is realized by the module of the store of conveyors. On the begin of experiments, conveyors with subproducts are situated in the store module, that is one module of the production line (Fig. 2).

FIGURE 2. *One module of the CP Factory is our testbed which is described and studied in this contribution (store of pellets with 2D manipulator) the ASRS32 module.*

The store of pallets with 3D manipulator ASRS32 – one module of the CP Factory is chosen for demonstration of modelling in Industry 4.0. The Fig. 3 is a control scheme of the testbed. It consists from two independent belt conveyors, electromechanical construction of the department store, o 2D manipulator of pallets, which is controlled by a PLC. Conveyor belts serves for transport of products, by means of pallets, with RFID chip with the AAS of the product. The function of the store consists of download and take off pallets from maximum 32 places by means of the manipulator. It has two linear drives and appropriate control units. Control units drive engines of belts conveyers. Any of components of the testbed have its own AAS as a standardized digital twin for Industry 4.0 applications. The PLCs serves for control of the manipulator and for moving of conveyors. The ASRS32 can serve for different products who are equipped by AASs as well. The communication among AAS of components and subproducts of the testbed is via OPC UA standard [2].

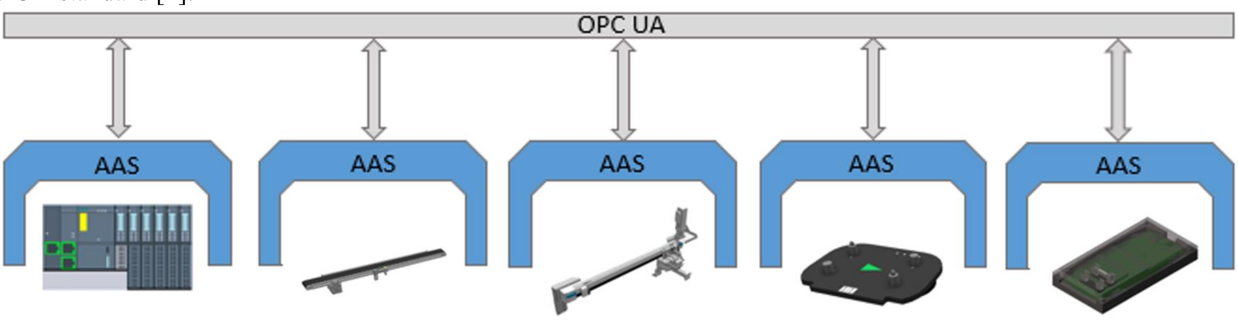

FIGURE 3. *Control scheme of the testbed.*

Autor's show to convert chosen assets of the testbed to the I 4.0 components. They will be equipped by their AASs. In the virtual world, the AASs fully represent assets. For the complexity reasons of the testbed the relevant information about assets are named submodels of AASs. These information's are making available to potential users of products.

The list of AAS of the testbed is as follow:

AAS of the all testbed

AAS of any component of the testbed

Some component can have its own AAS because of complexity of the application. The AAS of the testbed contains information of AASs other components of the testbed.

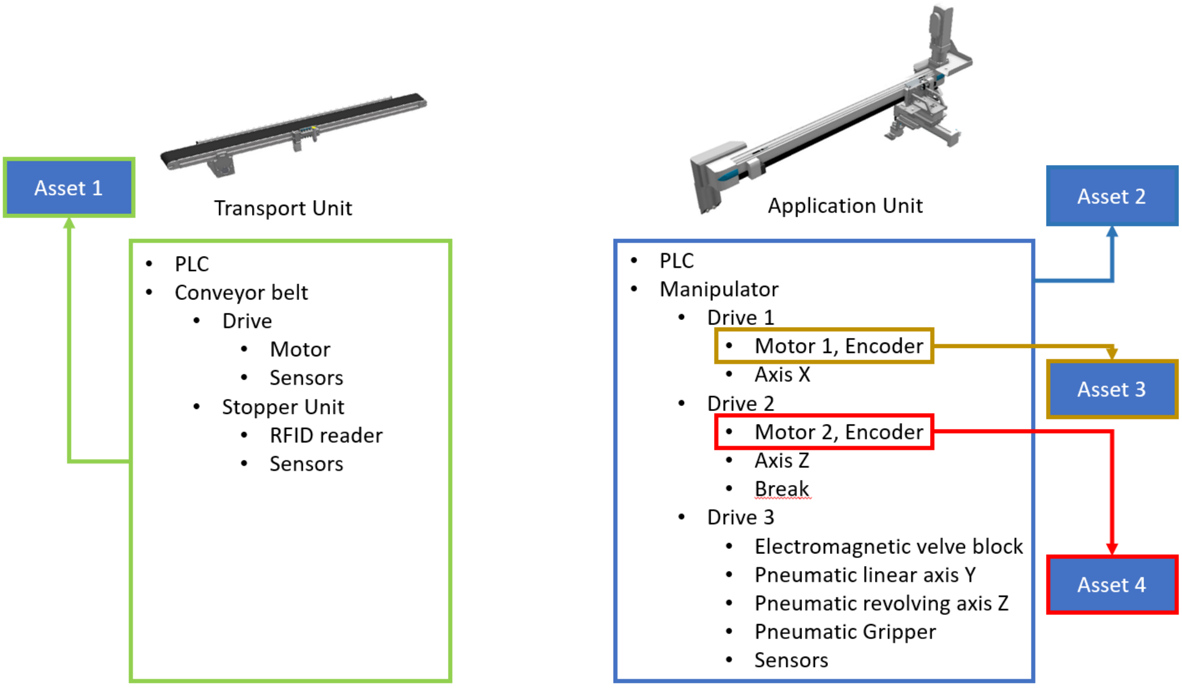

FIGURE 4. *Specification of components (assets) of the testbed (ASRS32) to be provided by their AAS.*

For demonstration purposes of different modelling technique of AAS authors show modelling of two subcomponents of the testbed and they are a transportation unit and an application unit as two independent units. The transportation unit consists of a control unit which contain a DC motor, limit sensors of a stopper unit. Stopper unit contains RFID reader and presence sensors. That all is from modelling point of view one asset. Likewise, in case of the application unit, it can be also seen as one asset. It consists from a control unit pro a linear motor in the axis X, a linear motor of the axis Y and a linear motor of the axis Z. Next contain the application unit an actuator of the pneumatic gripper and some proximity sensors. The application unit contains submodels of linear motors, including encoders with breaker und without braker. In the whole there will be following assets for modeling purposes considered in the testbed:

- Asset 1: Completed transportation unit
- Asset 2: Completed application unit
- Asset 3: motor with encoder
- Asset 4: motor with encored and a break
- Asset 5: the all ASRS32 module

MODELING PROCEDURES

For these purposes it is necessary to provide a standardized procedure. Authors present an introduction in this procedure of modelling and discuses necessary steps in providing design, commissioning and partner-related interaction among Industry 4.0 (I4.0) components of the chosen module of the production line of the CP Factory, hence the testbed.

From the set of possible roles of interaction nodes authors have chosen three roles, which are appropriate to the testbed. While AASs are to have all information about their assets throughout their entire lifecycle, it is necessary to look on an asset from different points of view. Different AAS of interaction nodes could have different views of an asset and this fact should be considered in different representations of the asset in its AAS. Therefore, authors have chosen three roles of AASs of interaction nodes [3]-[5].

First is a tool for planning, second one is a commissioning tool for the all testbed. The 3rd role of interaction nodes is the role of SR and SP. Service requesters and service providers were introduced as the third interaction partner role. Some components of the testbed can be considered as autonomous service providers in some I4.0 application scenarios, such as transport unit and workstation as providers of transport or drilling services. To characterize these AAS interaction node roles, the eventual requirements for the AAS content from the perspective of these roles can be specified.

The definition of AAS interaction partner roles, the selection of submodels, and their contents are not universal, but corresponds with the testbed structure and content only, see Fig. 5.

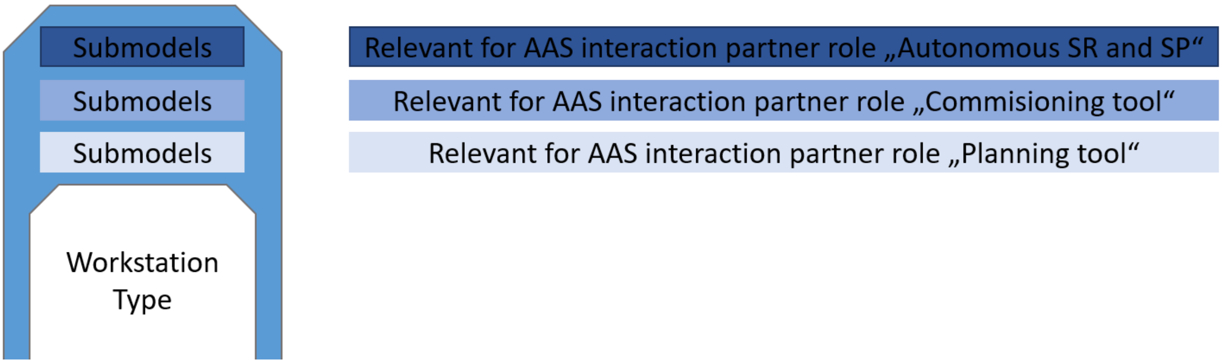

FIGURE 5. *Specification of roles of AAS by interaction nodes, inspired by [1].*

Planning as an AAS interaction node role

The planning of any complex plant (application, testbed etc.) plays a key role within the life cycle of the complex. The designer of a plant (application, testbed etc.) work out a specification in which the basic requirements for the properties of the planned application will be defined.

Designers of components make a description of technical data of their components. This description goes out from Industry 4.0 principles in the form of AAS with its corresponding submodels.

The comparison of the requested and achieved properties of components, in the sense of I4.0, is to be as automated as possible with the help of some design tool. This requires a consistent and interoperable description of the properties in the AAS of the asset type in the form of corresponding submodels of the components.

Service provider and service requester as a role of interaction nodes

Semantically unambiguously by computer readable description of properties and abilities of assets is very important for designers and clients. It is provided by submodels of AAS and create an importantly step towards enhancement of interoperability and integrity of technologies for automation. In this moment serve as such tool particularly a Manufacturing Execution System (MES) and an Enterprise Resource Planning (ERP).

But the initial idea of the I4.0, which is fully accepted and supported by authors in this moment as well as in the future requires important autonomy of production systems and their components, e.g. a dynamic optimization of production utilization, order controlled production, dynamic coordination of sources for cost optimized production in piece production. In order to reach this goal, the AASs should be able to offer information of component abilities and services of products to cooperating partners.

In such scenario components of production become autonomy service providers or service requesters (Fig. 6). As it has been said – a component of production becomes an Industry 4.0 component by its AAS and as an I 4.0 component is able to participate in horizontal integration based on protocols specified in VDI/VDE 2193 – recommendation for a tender process.

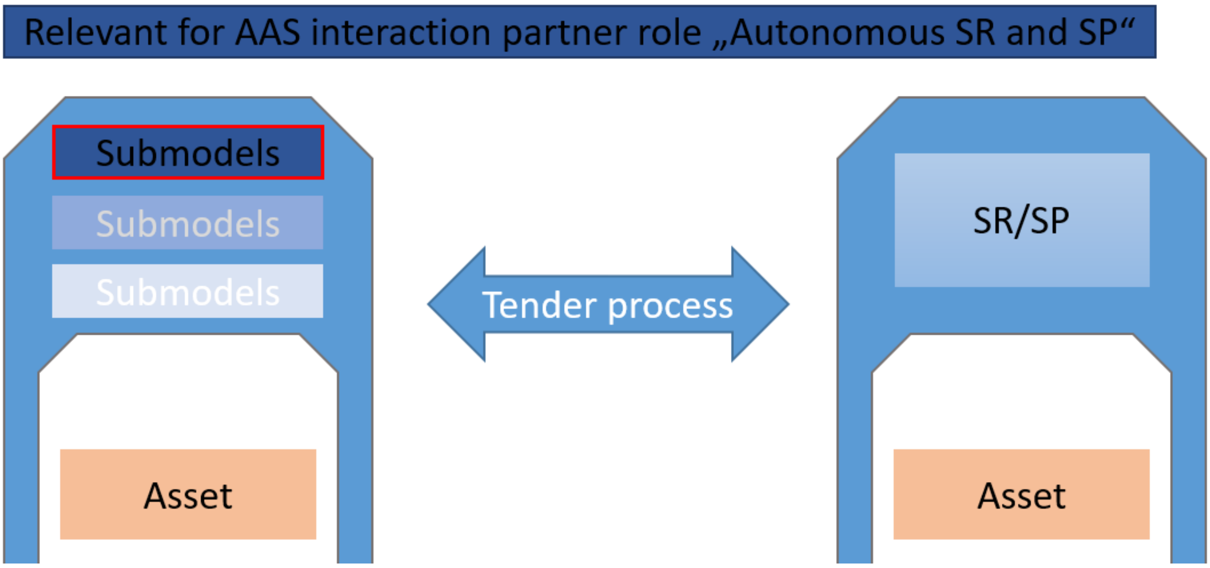

FIGURE 6. *Specification of sumodels for the autonomous SR/SP, inspired by [1].*

The tender process is specified by information such as:

- What purpose does the asset serves?
- What are the capabilities of the asset and what services can the asset/I 4.0 component offer?
- Technical data for detailed verification of the requirements etc.

SPECIFICATION OF A RECOMMENDED PROCEDURE MODELING

This chapter describe a procedure how to provide the testbed Fig.1 as a digital representation in the Industry 4.0 framework and how to integrate it with its AAS. Following requirements and assumptions worked out the structure of the AAS of our testbed, who is one of physical module of the CP Factory.

Components of Industry 4.0 system consist from an asset and its AAS. Assets can be specified by its own AAS or in a part models AAS, where the asset is a component. It is described by a *SelfManagedEntity* a *CoManagedEntity*. It is shown here in the BoM.

Some AAS of an autonomous asset have BoM (submodel with semantic Id BoM).

- The framework with its mechanical parts is described as a submodel of the P&P station AAS and does not have its own AAS.
- The components used in this document are the components of the P&P station, or the components of the assets in general.
- The assets are provided with one or more AAS, which are considered as a stand-alone component. The idea be-hind this is that the standalone component also contains a consistent descrip-tion in itself, e.g. provided by the supplier. These assets are called *"Self-Man-agedEntity"*.
- The entire P&P station is considered as an asset and receives its own AAS. The AAS of the P&P station contains references to the AAS of the other modelled assets as a so called composite component in a special submodel.
- Assets are understood to be the auto-mation components actually built into the P&P station. Accordingly, the AAS of these assets are understood as the AAS of asset instances.
- Additionally, it is assumed that asset types exist. For the sake of complete-ness, selected AAS of the corresponding asset types are modelled in this document in addition to AAS of the asset instances. AAS is a

digital representation of an asset. In different life cycle phases, this digital representation is used by different interaction partners.

- To enable the different interaction partners to identify the submodels that are relevant to them, the concept of "view" for structuring AAS content is introduced as an example. Views can also be used to group information that is relevant to the asset type and the asset instance. Then both the aspects can be contained within an AAS.
- Each AAS has a submodel for Nameplate, Documentation and Technical Data.

CONCLUSION

The aim of the contribution is to show interested readers to have a look in the procedures of modelling in the virtual Industry 4.0 technologies, that are represented by standardized digital twin for Industry 4.0, hence by the Asset Administration Shell. It is presented, that a totally distributed automatic control of machines, production lines as well as technological processes in the Industry 4.0 technology is possible by standardized I 4.0 components only. The I 4.0 component consists from an asset (component) and its standardized AAS. There were introduced basic scheme of a physical testbed, stemming from one physical module of FESTO Didactic CP factory education production line, the module ASRS32 – the store of pallets with 3D manipulator. Control scheme with four Assets in two units were also provided by their AASs. Because of too large necessary background for understanding the complex problem, the contribution has to be considered as a first step in implementation Industry 4.0 technologies into practical applications.

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