

# Navigating the Digital Twin: 3D Exploration for Asset Administration Shell Content

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**Abstract.** The digital twin (DT) as the core for digitalization activities becomes ever more prevalent in both research and industry. One emerging interpretation of the DT concept is the Asset Administration Shell (AAS), which describes – on a semantic and machine-readable level – each asset with a structured data set for its characteristics, lifecycle status, capabilities, etc.

In complex products, such as production systems that consist of many subsystems, there are consequently also many AAS, each with individual submodel structures. Because the AAS hierarchy does not necessarily align with the physical structure of a system, assistance in accessing information and services from the digital twin is required for different processes, e.g., maintenance and service tasks.

In this contribution, the concept for a web-based visualization application is presented, which uses the association of 3D geometry and AAS to create an interactive 3D view. This allows access to AAS hierarchies, submodels, and associated information on different levels and granularity. The goal is to utilize standardized submodels to enable easy navigation through the many-faceted AAS and fast data retrieval. In this way, the AAS and respectively the DT can intuitively be queried, and its contents can be displayed to the user without prior knowledge of the structure. The first working prototype is implemented for a production system, where the focus is on accessing information about its control cabinet with certain terminals.

**Keywords:** Digital Twin (DT), Asset Administration Shell (AAS), Visualization.

## 1 Introduction

The digital twin (DT) is a core concept for representing complex technical systems across the whole lifecycle, particularly capturing information from the use phase. One major challenge in the production sector is the growing complexity of the machines themselves, as well as their increased connectedness and the ability to instantly access operational data. The Asset Administration Shell (AAS) is one interpretation and

formalization of the DT concept, as it describes each asset with structured data for its features, lifecycle status, capabilities, and so on. A smart manufacturing component (SMC) consists of the asset and the associated AAS. This paper aims at enabling shop floor, operating, or maintenance personnel to intuitively access data and services generally available to an SMC through a web-based 3D browsing and visualization tool. In the following section, the current state of the art regarding the AAS concept as well as digital twins implemented using asset administration shells will be explained, which leads into the stakeholder analysis for the proposed application. Thereafter, the concept of the Visual AAS Browser is laid out in detail to lead to the implementation, which is the first working prototype based on a production system, where the focus is on accessing information about its control cabinet with its internal terminals.

## **2 Related Work**

### **2.1 Digital Twin**

Through advanced communication and interaction technologies, real and virtual space are linked to form a Digital Twin (DT), enabling cyber-physical production systems (CPPS)[1], in which intelligent products are interacting and communicating with machines and within complex processes. The DT concept was coined by Grieves [2] back in 2002 and has been adopted by many different industries since then, resulting in the fact that no uniform DT definition exists [3, 4]. In a fully digitized world, every entity can collect or generate data throughout its operation. The data collection creates a digital footprint of a process or product and is an enabler for real-time data evaluation [5]. This digital footprint of operational data can be linked to CAD or simulation models, created during product development in order to create a lifecycle spanning DT of a system. The DT can be used to support various functions, such as visualization, interactions, or simulations. It can also have different hierarchies, i.e., can describe a single component, a product, or entire systems. Depending on the use case and the entity to be described, this results in different levels of complexity [6]. Overall, the common understanding is that the physical product is connected to its virtual representation and a bidirectional link between those two components exists.

### **2.2 Asset Administration Shell (AAS)**

In order to address the different interpretations and implementations of the DT and to form a unified data schema with a focus on production systems, the concept of the asset administration shell (AAS) as a metamodel was introduced by the German Platform Industry 4.0 [7]. In this concept, an SMC consists of the physical object, the asset, and the virtual representation of the asset, the AAS [8]. The AAS is divided into a header and a body. The header contains information for identifying every AAS and the corresponding asset through a unique identifier. The body contains the actual information about the asset. The information is structured in individual submodels which in turn contain an undefined number of properties describing individual data. Each submodel refers to a certain characteristic or function of the asset [9]. Particular submodels for

the AAS are already standardized and published and more standardized submodels are in development [10]. The Platform Industry 4.0 presented a first prototype of an implementation for a pick and place station, in which the AAS consists of sub-AAS and therefore contains a bill of material submodel (BOM) [11]. Three different types of AAS can be distinguished. The first type is the passive AAS where the content is represented in a file for data exchange between partners in the value chain. Re-active AAS is the second type and specifies server-based access to AAS information via an API for applications or services. The third type is the proactive AAS. A proactive AAS can interact with other AAS and exchange information using the I4.0 language [12]. The interface for exchanging or accessing information via API is also specified by Platform Industry 4.0. The interface is specified technology agnostic but also gives implementation guidelines for given technologies like REST, OPC UA, or MQTT [13]. For creating a new AAS, an open-source tool named AASX-Package Explorer was developed and provided [14]. To host the AAS on a server and access it via an API, several solutions already exist [15, 16]. The AASX Server also provides a graphical user interface for exploring all AAS hosted on the server [15].

### 2.3 Implementations based on AAS

Platenius-Mohr et al. illustrated how they achieved file- and API-based information exchange for interoperable digital twins. In the paper, they proposed a mapping system to transform existing digital twins to the AAS format [17]. Schelter presents two examples to show what a prototypical AAS for industrial plants might look like and how data from these machines could be updated in the AAS. For example, AAS for electron beam machines and vacuum pumps are developed and it is shown that it is extremely difficult to link data from actual machines or plants to an AAS in a meaningful way [18]. How submodels for pumps can be constructed and converted into XML schemas for usage in an OPC-UA mapping is demonstrated by Müller and Both [19]. Cavaleieri and Salafia presented an approach of representing an IEC 61131-3 program and its relationships by using the AAS metamodel. With this approach engineers and technicians from different domains can understand the relations between the plant and its control programs better [20].

## 3 Concept

CPPS consist of many subsystems with varying levels of connectivity, access to operational data, or documentation. In this paper's example, a smart manufacturing system is composed of certain individual components, which are manufactured by different companies. These different components were integrated and supplied by one general contractor. When viewing the smart manufacturing system as a singular asset with its accompanying DT, which holds all relevant (meta) data about the asset as well as references to its components, the operator needs a way to understand and use this particular hierarchy. This is getting more complex if the components of themselves are considered assets that provide individual DT. It is assumed that each of these (partial) assets

has an AAS as the representation of the DT, in which information about the asset and its functionalities is stored. The operator now needs to be enabled to retrieve the contents of a selected AAS as the follow-up step of understanding the asset hierarchy. Therefore, the following concept aims to develop a concept for human interaction with asset administration shells focused on exploration and depending on the user's access rights. The authors propose a Visual AAS Browser that allows browsing through an asset's AAS, as well as their accessible contents, by using an interactive version of the 3D geometry of the primary smart manufacturing system as the user interface. The concept starts with a stakeholder and use case analysis, before detailing the IT implementation concept of the Visual AAS Browser.

### 3.1 Basic scenario and stakeholder analysis

In the given scenario, a system supplier acquires the components required for the smart manufacturing system from component suppliers. In addition to the physical components, the system supplier also receives 3D representations of the components from the component suppliers as well as the AAS belonging to the components in the AASX exchange format.

After receiving the purchased components, the system supplier can build the smart manufacturing system and simultaneously create the DT in the form of a structured AAS hierarchy. Access to the final system's AAS is to be provided via standardized (web)services, which also includes access to all other AAS belonging to the system in the lower tiers of the hierarchy. In the assumed scenario, the server is hosted by the system supplier, who is the provider of the Visual AAS Browser as a service to the customer and takes care of access rights, data, and system availability. However, different stakeholders can be considered as consumers of the service. The first stakeholder is the system supplier. The Visual AAS Browser can support the production of the smart manufacturing system's components as well as the integration of the third-party components and quality control, as all of those components offer AAS, which in the assumed process, have already been integrated and are available before physical assembly. During operation, the operator of the smart manufacturing system becomes the consumer of the Visual AAS Browser services. After handover to the customer, only the customer shall have access to the current usage and operating data of the product, while the static descriptive data of the AAS remains unchanged from the as-delivered state until changes are made to the physical system.

When configuring the Visual AAS Browser service, the provider (system supplier in this case) specifies the customer-individual server on which the AAS is provided, which is then published from the internal representations. The functionality of browsing the AAS should be as simple as exploring the 3D representation of the smart manufacturing system in a general 3D viewer.

When selecting a component, the user selects not individual physical components that would be represented by a typical BOM, but the actual assets as represented by the accompanying AAS. The Visual AAS Browser retrieves the data through the standardized web service interface from the supplier's AAS-server instance that is provided specifically for the customer. Fig. 1 summarizes the basic scenario.

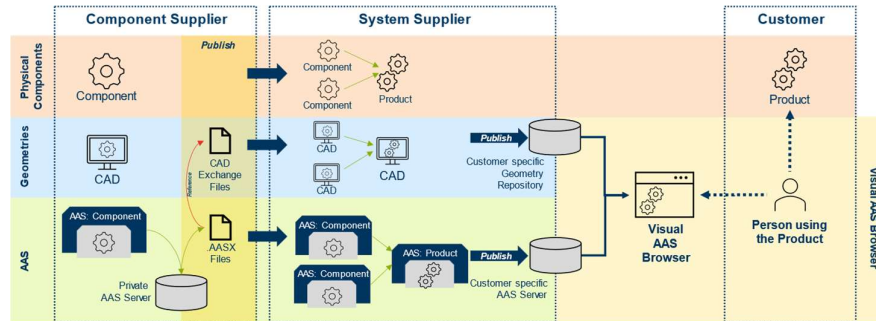


Fig. 1. Basic Scenario

### 3.2 AAS creation

To deliver a SMC, one needs to provide the physical product alongside the corresponding AAS, which also includes the associated CAD files. Since a component can consist of several subsystems, the component AAS itself can be composed of several subjacent AAS. The references are stored in a specific submodel of the corresponding AAS.

In the context of the presented approach, each AAS contains (at least) the submodels *Nameplate* and *TechnicalData*. Further submodels are added for additional use cases, such as for quality control. If the component AAS refers to further AASs, a *BOM* submodel referencing these subjacent AASs must also be added to the component AAS by the component supplier. The component supplier sends the AAS to the system supplier as a file in the AASX format.

### 3.3 Preparation of a CAD model for the Visual AAS Browser

To enable the correct interaction between the Visual AAS Browser and the AAS belonging to the selected element, an association must be accessible between the selectable geometry and the associated SMC, to then retrieve the correct AAS in the hierarchy of the system. For this purpose, a unique ID is required that realizes the reference to the associated AAS. In this concept, the ID of the AAS is stored in the 3D model of the component in the form of a user-defined property named *AAS\_ID*. It should be noted that multiple instances of the same type of component can be installed in a system. Accordingly, the ID of the associated AAS instance must be stored in the user-defined property in the CAD model that is instance-specific.

### 3.4 Integration process by the system supplier

The system supplier's role is to create the SMC, which in the assumed use case includes the components from other suppliers. The integration happens on both the virtual layer, with the CAD and BOM information, and the physical layer, with the assembly of the real production system. Additionally, the BOM is added to the smart manufacturing system's AAS as reference. The system supplier can also add the AAS received from

the component suppliers to the hierarchy of the smart manufacturing system's SMCs. The system supplier now associates the CAD models of the BOM components with the SMCs. The AAS and the referenced 3D models are then put in repositories accessible to the Visual AAS Browser with the customer's credentials.

### 3.5 Visual AAS Browser

The Visual AAS Browser is the main component of the concept, which provides a user interface between the smart manufacturing system and the operator. The main functions of the viewer are displaying the 3D model and the SMC hierarchy of the complete system, enabling the selection of SMC in the 3D model and hierarchy, and retrieving and displaying the AAS data of the selected component.

For displaying the complete production system with its components, the Visual AAS Browser accesses the AAS and the associated 3D models provided by the system supplier's repositories, authenticated with the customer's credentials. After selecting the currently available systems to browse, which in this case is the smart manufacturing system only, the global 3D view is loaded and ready for the user to interact with.

Figure 2 shows a rough sketch of the planned front end of the Visual AAS Browser. The object of study in this sketch is the smart manufacturing system consisting of various machines and parts provided by the component supplier, as well as a control cabinet. The user of the Visual AAS Browser has the option to select an asset in either the 3D model, in the BOM structure, or the SMC structure. Both latter two are displayed in tree views. Either way, the associated components are highlighted in all three representations, and the contents of the associated AAS are displayed in a separate window next to the 3D model, which can display either tabular data or specific other formats, if supported.

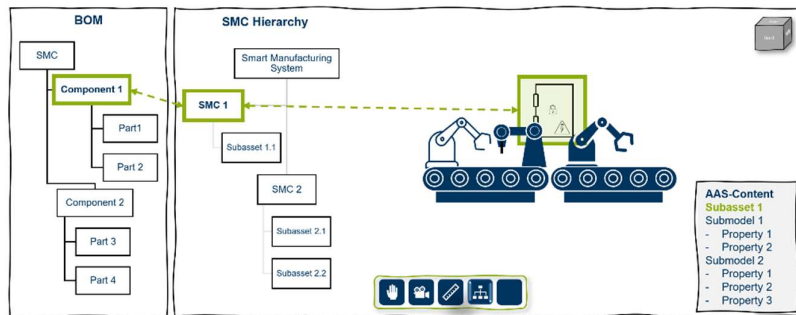
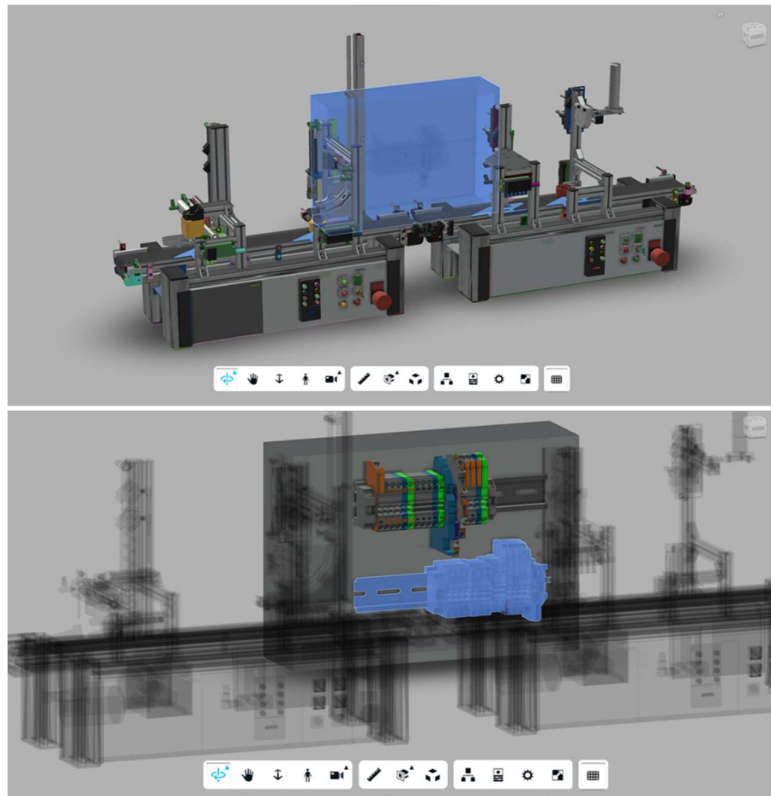


Fig. 2. Visual AAS Browser concept user interface

## 4 Prototypical Implementation

The aforementioned object of study is a smart production system with various components, as depicted in figure 3 (top). For the implementation, the drill-down using the Visual AAS Browser is shown by first selecting the control cabinet as a sub-component

to the production system (fig. 3, top) and then a profile rail with terminals (fig. 3, bottom) as part of the control cabinet. In this implementation example, the CAD model and AAS repositories are set up in a way that the system supplier would provide to the customer as per the proposed concept. The Visual AAS Browser loads the selected global 3D geometry from the online repository with the accompanying AAS and displays it to the user, to start the browsing process. When an SMC is selected by the user, the data is retrieved from the associated AAS and visualized accordingly.



**Fig. 3.** Smart Production System with selected control cabinet (top) and control cabinet with selected terminal rail component (bottom)

#### 4.1 Implementation of the AAS and the AAS-Server

The AAS required for the system and its SMC were created manually with the open-source tool AASX Package Explorer in preparation for the implementation. A new aasx-file is created for each AAS, containing the submodels *Nameplate* and *Technical-Data*, which are both templated and published by the Industrial Digital Twin Association (IDTA). The AAS for the system itself also contains a BOM submodel. These files

are published on the open-source AASX Server and accessible to the Visual AAS Browser through the REST web service Interface.

## 4.2 Adaptations to the CAD model

Only one extra step is required for the preparation of the Visual AAS Viewer usage when creating the CAD model in the engineering process, as described in the concept section. The ID of the corresponding AAS must be added to the part that has its own AAS. For this implementation, Autodesk Inventor is used as the CAD software. In Autodesk Inventor, custom properties can be added to parts or assemblies via the so-called iProperties by defining the name, type, and value of the property. In this case, the name is “*AAS\_ID*”, the type is “*string*” and the value is the ID of the corresponding AAS created in the step before.

## 4.3 Implementation of the Visual AAS Browser

The first two parts of the implementation can be considered preparation for the implementation of the Visual AAS Browser. The authors chose Autodesk Platform Services as the visualization framework for the implementation [21]. The prepared CAD model is made available on Autodesk Fusion Team to be accessible online for the Visual AAS Browser. It is already possible to display 3D models and their basic component structure with the original Autodesk viewer. However, since the main intention of the Visual AAS Browser is to display and browse the contents of the AAS of SMC selected in the viewer, a JavaScript-based extension is created to enhance the base functionality and to enable the concept’s functionalities.

When clicking on a component, the ID stored in the CAD model of the selected element is evaluated by the extension. The viewer retrieves the AAS from the AAS server based on the mapping of the element in the associated AAS. The response from the server returns a list of all submodels’ *shortIDs* contained in the AAS. Consequently, a new request is sent to the server for each submodel *shortID*, once the user wants to access a particular submodel. The server’s answer contains the content of the requested submodel.

Figure 4 shows a screenshot of the Visual AAS Browser. In this case, the part “2-Leiter-Schutzklemme” (2-wire protective terminal) inside the control cabinet is selected as a part in the lowest tier of the SMC hierarchy. The Visual AAS Browser is configured to display the data of all submodels in a tabular view, which the user can collapse based on the structure of the individual submodels. The data in this table can also be sorted by attribute name or value by the consumer.



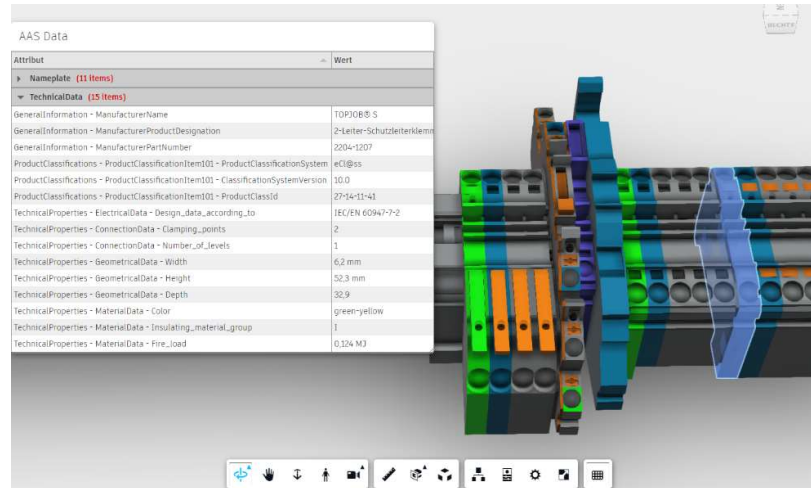


Fig. 4. Focus on the lowest tier (part level) of an SMC in the Visual AAS Browser

## 5 Conclusion and Outlook

The presented approach of visualizing and browsing through a complex system's AAS was implemented based on established industrial software products, with most of the planned functions of the Visual AAS Browser's concept. Firstly, it is possible to load the corresponding AAS and display its contents when selecting an SMC. This function was prototypically implemented and is functioning as intended. Contents of any AAS can be queried dynamically, independently of how many properties are stored in a submodel or how many submodels an AAS contains. One possible improvement of the developed viewer extension is the optimized display of the contents of the AAS submodel, especially for standardized submodels, while falling back to the tabular view for any non-standardized submodels with textual content and the option for both image and PDF viewing capabilities.

Future work will encompass the implementation of a second extension for the Autodesk platform services for showing the SMC hierarchy and enabling the selection of an asset from the structured hierarchy while highlighting all linked components in the 3D model and part and SMC hierarchy, as laid out in the concept.

Once the full concept is implemented, the scope of the use cases will be broadened to enable writing access to the AAS. This allows scenarios like quality inspection processes to be performed based on submodel availability and the therein-contained data fields and instructions.

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