APPLICATION OF DIGITAL MATERIAL PASSPORTS WITH INTEGRATED MATERIAL KNOWLEDGE GRAPHS BASED ON DATA SPACES IN THE AEROSPACE INDUSTRY

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Abstract

This publication focuses on the results of the AeroMatPass-X project, which was still under active development at the time of writing and reflects its mid-term status.. A first application for interacting with Aerospace-specific DMP variants is shown and approaches to use data spaces and knowledge graphs is discussed.

Keywords

Aerospace; Digital Material Passport; Data Spaces

1. INTRODUCTION

Despite stringent documentation requirements and complex product development processes, the extensive digitization and end-to-end data exchange in the aviation industry still pose a major challenge due to the heterogeneous nature of supply chains and companies. Data exchange between the various stakeholders is a fundamental component of value creation; at the same time, the proportion of sensitive information – especially at the material level – Is very high. Currently, material data exchange along aerospace supply chains is largely document-based, including the exchange of test reports and inspection documentation[1,2]. These must then be manually integrated into the company's own systems to create, for instance, internal certifications such as a Certificate of Conformity (CoC) in accordance with ISO/IEC 17050-1[3]. While the e-CoC (DIN SPEC 9012)[4,5] represents an initial approach to a data model and connectors it is not yet widely adopted. Data is forwarded directly and stored in the recipient's system. This prevents data that goes beyond the regulatory framework – such as data used to optimize manufacturing processes and reduce associated costs – from being integrated.

In the current paradigm, the management of materials in aerospace applications is hindered by the cumbersome process of manually updating document-based material information often limited to certificates of conformity, which can lead to outdated information being used in critical systems. This outdated data can result in suboptimal material performance, increased maintenance costs, and even safety hazards. Moreover, the lack of real-time data integration makes it challenging to respond quickly to changes in material properties or usage conditions.

The project AeroMatPass-X[6] funded by the Federal Ministry of Research, Technology and Space (BMFTR) under the grant number 13XPM505A is poised to transform the aerospace industry by introducing a cutting-edge approach to material management. The integration of digital material passports with material knowledge graphs that are enabled by data spaces has the potential to streamline the supply chain, reduce integration time, and decrease the error rate associated with current document-based methods.

2. BACKGROUND

The project AeroMatPass-X consists of a consortium with six partners, each addressing a separate part of the challenge. They are all integrated into the overall project. They are supported by 11 associated partners from the aerospace supply chain. The corresponding supply chain can be seen in FIGURE 1.

Baseline for the project is the work of Aerospace-X and Platform MaterialDigital (PMD)[7-9].

The Aerospace-X project of the Manufacturing-X Initiative has developed a data model that addresses the representation of relevant material data as part of a Digital Product Passport (DPP)[10,11]. This component is referred to as a Digital Material Passport (DMP). This data model is modeled as a submodel of the Asset Administrative Shell (AAS) and, as such, can be exchanged via the architectural elements of the Catena-X and Manufacturing-X data ecosystems[12,13].

During its duration, the Digital Modeling project of the MaterialDigital platform[7,14] developed a semantic representation of a preliminary test certificate and transferred the data contained in the certificate into a knowledge graph in a structured manner. Together with semantically mapped characterization processes, the associated material data, and a model calibration procedure, this results in a complete knowledge graph that, thanks to its generic metadata structure, allows for any type of query. Such a knowledge graph represents material data

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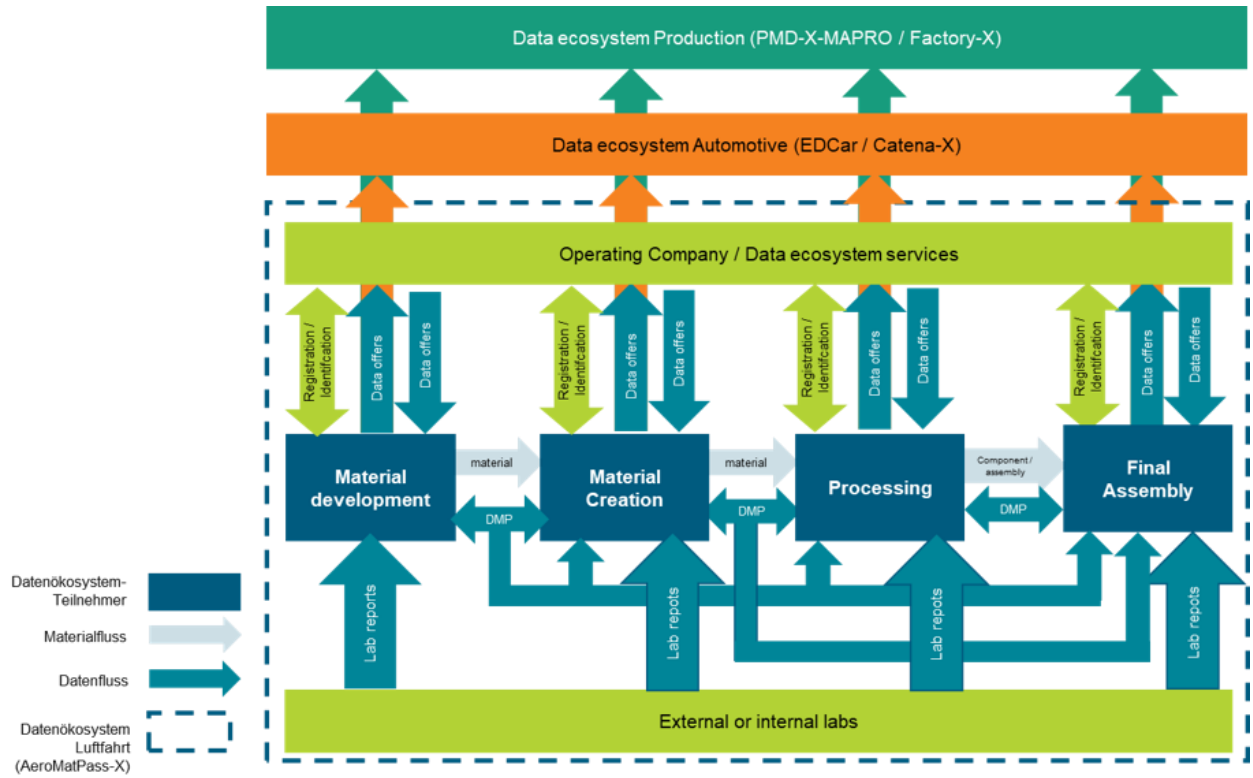


FIGURE 1: overview of supply chain addressed in the AeroMatPass-X project

that is generated along a supply chain consisting of individual data silos.

The project itself is part of series of projects and runs next to EDCar[15] and MAPRO[16]. Alignment with the other projects was conducted in common Sprint reviews and workshops.

3. METHOD

The project is conducted as a one-year project from January 2026 to December 2026. At point of publication the project was close to its mid-term milestone.

It is conducted as an agile project with roughly 1-month sprints. Each sprint review associated partners and consortium partners can integrate their requirements to reach a usable result for the supply chain at the end of the project.

The approach is separated into three phases: (1) Assessment and specification, (2) technical realization and (3) recommendation paper. The results presented in the following focus on results gathered in phase (1) and (2).

4. RESULTS

The results are structured based on the content of the solution and not the phases. There is currently a reference application for DMPs, first knowledge graphs and Ecosystem solutions. None of them are currently publicly available but is under review for open publication until end of project.

4.1. DMP application

A preliminary application has been created based on the Industry Core Hub[17]. For testing purposes, it was transformed to be usable locally (instead of server-based approaches) as well as a static website accessible to the consortium and associated partners as well as mobile application. This approach was presented at the ILA 2026. It builds on the data models developed within Aerospace-X and gives an easy interface to view (See FIGURE 2) and to provide Digital Material Passports.

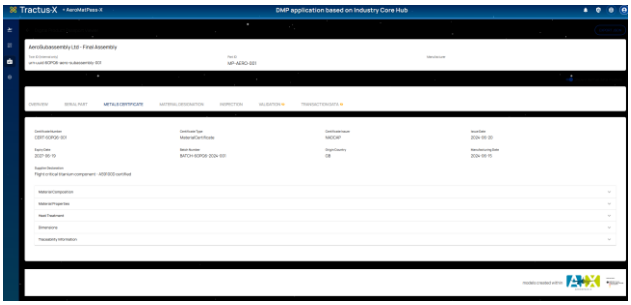


FIGURE 2:Overview of the DMP application

It also offers a view to showing the full supply chain of the corresponding material information (see FIGURE 3). This supply chain view is generated only on entities that allow the current user to see their information within the ecosystem.

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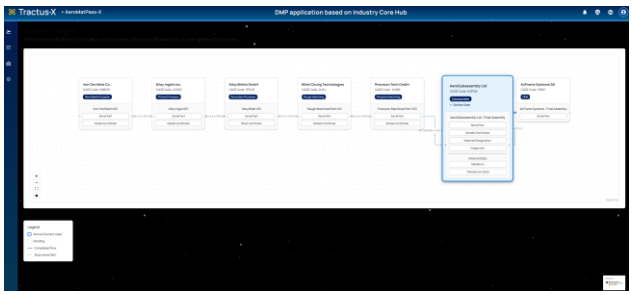


FIGURE 3: Supply Chain view

Providing and consuming are currently possible by importing and exporting as well as by directly typing in the relevant data in a guided form. Direct integration with IT stacks is under development as well as the data space integration.

4.2. Knowledge Graphs and AI

The knowledge graphs have been based on the Aerospace-X data models and aligned with PMD core ontology (PMDco)[14]. Current evaluations focus on the realization of specific requests. The cross-industry use case from EDCar and MAPRO is considered but should be extended by means of Skills within the data ecosystem.

It is also addressed as a solution for the company data integration, as it can support the semantic mapping of internal data sources and the DMP.

For AI first proof of concepts has been demonstrated on the DMP data and are currently further refined. The AI functions are considering both local questions but also questions requiring ecosystem wide knowledge which requires data spaces.

4.3. Data Spaces

For the integration with data spaces the current focus is on the integration if Knowledge Agents and Skills. Most ecosystem are focusing on offering assets in a static way rather than the offering of knowledge. Catena-X with the Knowledge Agents KIT[17] focused on that as well – as it is currently not that widely adopted, it is still under consideration for this project how to best implement it to gain the most benefit out of the ecosystem. Besides that, some use cases have been identified which require IP protection and thus the approach of sharing through a data space is seen as viable, such as the sharing of additional material information to better assess the quality of a component[18,19].

5. DISCUSSION

For the DMP application, the main feedback was multi-language support, as most users for whom the shown data is relevant are working in shop floors where their own language should be usable in application. The usability was seen as good with some minor errors that are planned to be addressed in the project. Main use case is the provisioning and decision making with the application as front-end for that.

The integration with company data is currently an ongoing topic. The companies are preparing their data accordingly and integrate their findings within the recommendation paper (phase 3), that will be distributed at the end of the project.

Data space integration requires the stakeholders to have added value as is a trade-off of deploying data space components to their usage. In the evaluated use case, direct file-based exchange appears sufficient for basic CoC exchange, whereas data-space components become relevant when controlled access, traceability, or usage policies are required. These are currently integrated more deeply and tested. For simple approaches such as CoCs there should always be easy exchange methods such as importing and exporting jsons or similar formats. A specific focus has to be set on the current data ecosystems under establishment such as Aerospace-X.

6. CONCLUSION AND OUTLOOK

In summary, the AeroMatPass-X project is a significant leap forward in material management, offering a more reliable, efficient, and error-resistant alternative to traditional paper-based approaches. By embracing digital transformation, this project is set to revolutionize the aerospace industry, ensuring that materials are managed with the precision and foresight necessary for the next generation of aerospace component design.

Knowledge Graphs promises to offer knowledge instead of static fixed assets in the network which is required for difficult material related questions. Nevertheless, the approaches need further refinement and testing that is currently addressed in the project.

The results are in open-sourcing and release discussion until end of project and can be afterwards seen on the project websites.

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