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Publishable Executive Summary

The document presents an extension of the Battery-Management-Systems (BMS) ontology and the integration of the Product Carbon Footprint (PCF) metric into the Digital Reference (DR). The BMS ontology is extended by 9 new classes and 9 object properties, while the PCF metric is calculated using a cradle-to-grave approach, taking into account greenhouse gas emissions and savings.

The document also presents 20 use cases (UCs) that demonstrate the application of the BMS ontology and PCF metric in various industries, including automotive, consumer electronics, and semiconductor manufacturing. Each UC is described in detail, including the partners involved, the goal of the UC, and the DrOWLing (a graphical representation of the ontology).

The use cases are categorized into different domains, such as automotive, consumer electronics, and semiconductor manufacturing. Some UCs are related to each other, while others are standalone. The document also discusses the relevance of the PCF and BMS in the context of the Corporate Sustainability Reporting Directive (CSRD) and the Corporate Sustainability Due Diligence Directive (CSDDD). These directives require companies to report on their sustainability and due diligence practices, and the PCF and BMS can play a crucial role in this process. The BMS ontology is extended by 9 new classes and 9 object properties to improve its representation of battery management systems. The PCF metric is calculated using a cradle-to-grave approach, taking into account greenhouse gas emissions and savings.20 use cases are presented, demonstrating the application of the BMS ontology and PCF metric in various industries. The use cases are categorized into different domains, such as automotive, consumer electronics, and semiconductor manufacturing. The PCF and BMS are relevant in the context of the CSRD and CSDDD, which require companies to report on their sustainability and due diligence practices. Further research is needed to refine the BMS ontology and PCF metric.

The use cases presented in the document can serve as a starting point for further research and development in the field of BMS and PCF. Companies should consider using the PCF and BMS in their sustainability reporting and due diligence practices.

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1. Introduction

1.1 Objective and Scope of the Document

AIMS5.0, a collaborative Innovation Action aims at strengthening European digital sovereignty in comprehensively sustainable production, by adopting, extending, and implementing AI-enabled hardware and software components and systems across the whole industrial value chain to further increase the overall efficiency. The project is a large and complex European innovation action, requiring adequate management and quality assurance structures. The key characteristics of the Chips JU project are:

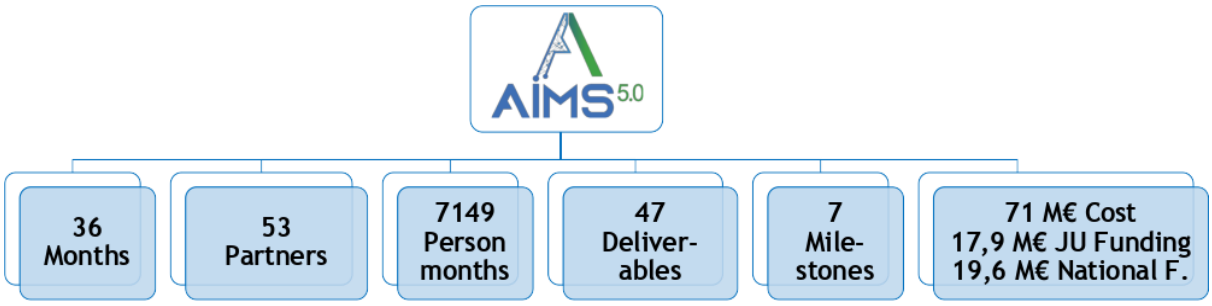

Figure 1: AIMS5.0 key characteristics

The Work Package 4 (WP4) discussed in this deliverable strives to build an Open Access Platform (OAP), which will enable the exchange of data via semantic web technology within the supply chain of the semiconductor industry domain. The so-called Digital Reference (DR) serves as the basis structure of this OAP. The DR is a Semantic Web-based ontology that represents entities being relevant for semiconductor manufacturing and manufacturing employing semiconductors.[14]

Reports on updated Digital Reference 3. This will cover the remaining classes and characteristics missing to come up with a complete ontology allowing to generate computer based efficiently the CO_2 balance (DR): (IFAG) M24

The objective of Deliverable 4.3 is to evaluate and cover the classes needed in the DR and ontologies that can link to the DR for a computer-based CO_2 balance. For this report the focus was placed on the Battery Management System for the needed extensions and improvements for this calculation. We also discuss the importance of applications with the links to the CSRD and CSDD European Sustainability Directives.

In addition, the current work for the Digital Reference Use Case Ontologies for the project will also be reported on.

1.2 Structure of the Deliverable Report

This deliverable is structured as follows, first a brief introduction to the sustainability portion of the Digital Reference Model concerning the battery management system is introduced and extensions are suggested. Thereafter, product carbon footprint calculations and integrations are discussed for the battery management system. Following this, the connection to the CSRD

and CSDD are drawn and explained relating to the value of the ontology assisted product carbon footprint calculations. Finally, an update of the current project use cases are also included.

2. Digital References (DR)

2.1 Extension of Battery-Management-Systems (BMS) Ontology

2.1.1 Introduction to BMS

As presented in "D4.2 Reports on updated Digital Reference 2", Battery Management Systems (BMS) are used in Battery Electric Vehicles (BEV) and other electronics to monitor the batteries' performance [2]. By controlling various components based on the BMS measurements, the management system ensures an optimal use of its parts to maintain reliable, safe and long-lasting batteries [1, 2].

As previously stated, BMS monitor and react to several key parameters, including the Safe Operating Area (SOA), State of Charge (SOC), State of Discharge (SOD), State of Health (SOH), dynamic resistance calculation, capacity measurement, cell leakage assessment and thermal runaway prevention [1,2].

In order to protect the batteries' lifespan, BMS incorporate different components that observe charge current limits (CCL) and discharge current limits (DCL), as well as provide over- and under-voltage protection, active thermal cell monitor and control, and prevention of excessive operations [1].

2.1.2 Extensions and Modifications of BMS Ontology

To improve the BMS ontology used in the DR, the previous BMS ontology concept [2] was first implemented and now is extended by 9 new classes and 9 object properties.

Figure 4 displays the initial classes in yellow, the new classes in blue and modifications of class labels or object properties are highlighted in blue.

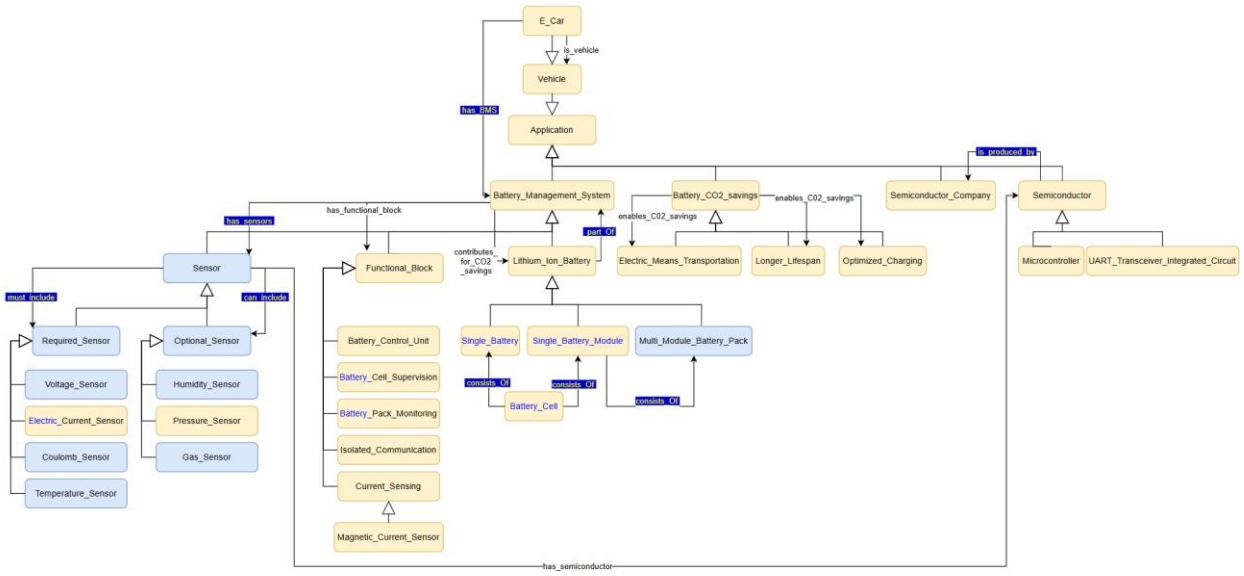

Figure 2: DrOWLing of updated BMS ontology.

3. Product Carbon Footprint Integration

3.1 Introduction to the Product Carbon Footprint

The Product Carbon Footprint (PCF) is a method to calculate the total greenhouse gas (GHG) emissions of a product throughout a products' life cycle, starting with the sourcing of the raw materials used in a product and ending with the end-of-life of a product and optional recycling [6, 7]. This product life cycle is further depicted in Figure 5 and displays the simplified life cycle assessment (LCA) also referred to as cradle-to-grave process of a product.

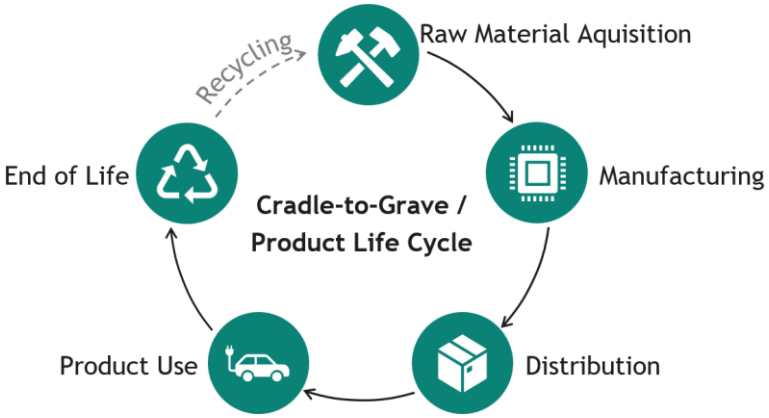

Figure 3: Cradle-to-Gate / Product Life Cycle

The PCF is measured in kilograms of carbon dioxide (kg CO_2) or kilograms of carbon dioxide equivalents (kg CO_2 e) to enable a more accurate and transparent comparison with other product emissions [4].

Some sources, such as the International Organization of Standardization (ISO) [5] define PCF by acknowledging not only the GHG emissions but also the GHG savings of a product according to the ISO 14067 norm. In contrast, other sources highlight only the sum of the GHG emissions, excluding the potential GHG savings [6]. To recognize the benefits of products such as BMS in reducing carbon emissions, our PCF calculation takes the GHG savings into account, as depicted in Equation 1.

$$\boldsymbol{PCF} = \sum_{\boldsymbol{GHG\ emissions}} - \sum_{\boldsymbol{GHG\ savings}} [kg\ CO_2e] \quad (1)$$

$\sum_{\boldsymbol{GHG\ emissions}}$ = Sum of emissions during each step in the cradle-to-grave process

$\sum_{\boldsymbol{GHG\ savings}}$ = Sum of emissions saved throughout the products LC

The underlying calculation of the GHG emissions for each step within the cradle-to-grave process is displayed in Equation 2:

$$GHG\ Emissions = Activity * CO_2e\ factor \quad [kg\ CO_2e] \quad (2)$$

Equation 2 highlights the importance of understanding the associated activities that contribute to the GHG emissions within each step of the product's life cycle. Each step involves different sources of emissions connected to the activities, which is why it is essential to understand the complete cradle-to-grave process of a product to ensure an accurate PCF calculation.

For example, considering the distribution of the manufactured products, transport emissions are influenced by the products weight and distance [6]. Further, the type of transportation impacts the CO_2 emissions.

Once the total GHG emissions for each step in the product's LC have been calculated, the sum of GHG emissions can be calculated as presented in Equation 1.

3.2 Extension of PCF in DR

To integrate the PCF metric into the DR, Figure 6 proposes a DrOWLing consisting of 18 classes and 8 object properties that capture relevant components of the PCF calculation.

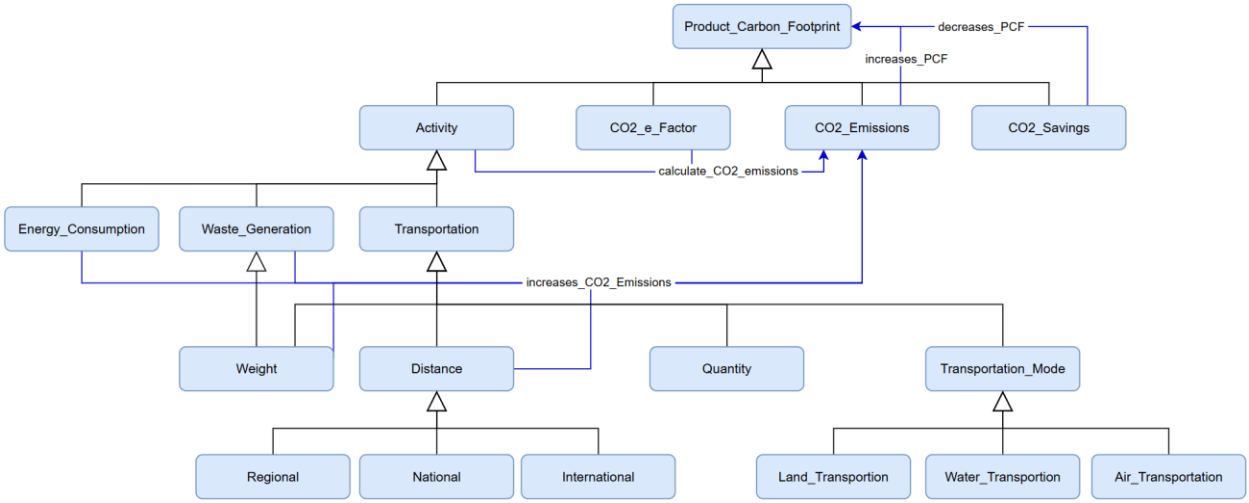

Figure 4: DrOWLing of new PCF ontology.

3.2.1 Connection of PCF to BMS

Given the role of BMS in optimizing battery lifespan and reducing charge cycles, the effective use of BMS are acknowledged as a key factor in minimizing the carbon footprint of BEV. The BMS Ontology in the DR provides initial insights into the needed electrical components of BMS that are necessary in achieving these goals [2], such that the relationship between the BMS and the PCF can be demonstrated with four new blue object properties in the DrOWLing of Figure 6.

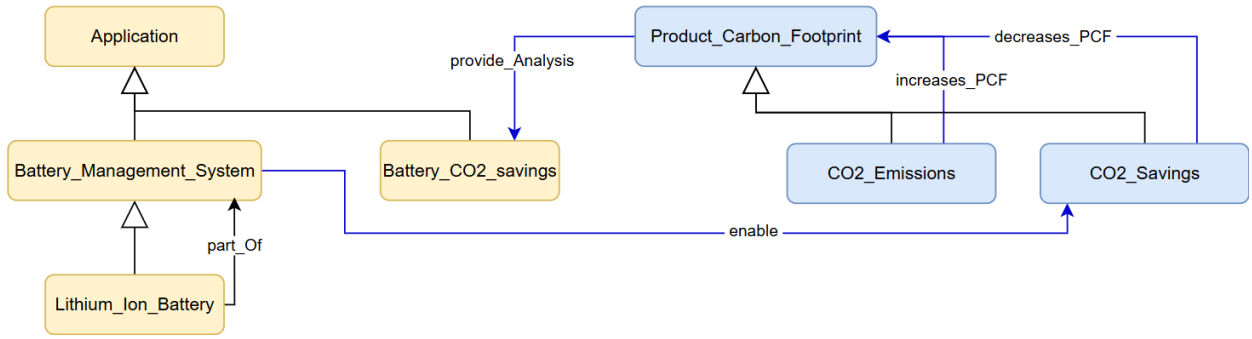

Figure 5: DrOWLing of BMS connection to PCF.

4. Relation to CSRD and CSDD

4.1 Corporate Sustainability Reporting Directive

The Corporate Sustainability Reporting Directive (CSRD) describes the mandatory sustainability reporting for companies above a certain turnover or company size within the EU on environmental, social, and governance (ESG) factors [8, 10, 11]. Building on the previous Non-Financial Reporting Directive (NFRD), the reporting obligation is extended to other corporations and commercial partnerships and must follow the European Sustainability Reporting Standards (ESRS) [8, 10]. Accordingly, the aim of the CSRD is to close gaps in sustainability reporting and introduce them at EU level. These reports aim to provide more transparency for stakeholders to assess the sustainability of companies more easily [8].

4.2 Corporate Sustainability Due Diligence Directive

The Corporate Sustainability Due Diligence Directive (CSDDD) is another EU directive that aims to promote sustainable and responsible business practices throughout the EU [9]. It requires companies to conduct due diligence on their supply chains, including the activities of up- and downstream partners, to identify potential and actual human rights and environmental impacts [12, 13]. This includes considering the EU's climate and environmental goals such as the 1,5°C target of the Paris Agreement [9, 12, 13], Specific companies above a certain turnover or company size are required to propose a business strategy to ensure their contribution to limiting global warming and in alignment with the agreement and European’s climate neutrality target [9]. This strategy can be presented according to the guidelines formalized in the CSRD [9].

4.3 Relevance of PCF and BMS in CSRD and CSDDD

As both the CSRD and CSDDD directives require companies to report on their sustainability, understanding the carbon footprint of a company's products is highly important. With the presented calculation of the PCF, companies are able to assess their products' emissions and savings and use these insights for creating a business strategy on their contribution towards a more sustainable future. The calculation of the PCF grants transparency to the most expensive steps in a product's GHG emission and where a company needs to change their product strategy. BMS in particular present a helpful innovation in reducing the carbon footprint in battery-powered products such as BEV by improving the product’s usage and performance, extending a product's life span.

5. Description of Use Cases

5.1 Introduction to Use Cases:

20 Use Cases (UCs) in total of which we are able to present 16 in detail.

5.2 Use Case 2: AI Enhanced Value Chain

Partners: *PCL, TU/e, Semaku and RUG*

The goal of this UC is to enable a step towards the overall vision of mass customization by creating a value chain leading from the consumer back to the consumer. To achieve this goal, consumer data must be fed back, through several connected data and modelling platforms, to the start of the value chain to be able to offer the consumer a customized and improved product upon renewal.

Everything turns around the Value_Chain class, from which multiple subclasses can be identified, consisting on the different steps of the value chain: Innovation_And_Development, Operations and Customer. From this last one, customer data (Customer_Data) is generated, by the use of a sensor in the shavers, and is fed into Production, Marketing and Design. At the same time, Production_Data from AI_Driven_Production is as well generated and used to feed the same AI_Driven_Production and the MBSE.

This UC is not related to other UCs and is in the domain of Consumer Electronics. The model consists of 7 main classes (17 in total) and could be integrated into the Digital Reference through the lobes (Process, Supply Chain, System and Sensor) and classes (Service, Production Strategy and Digital Factory Twin).

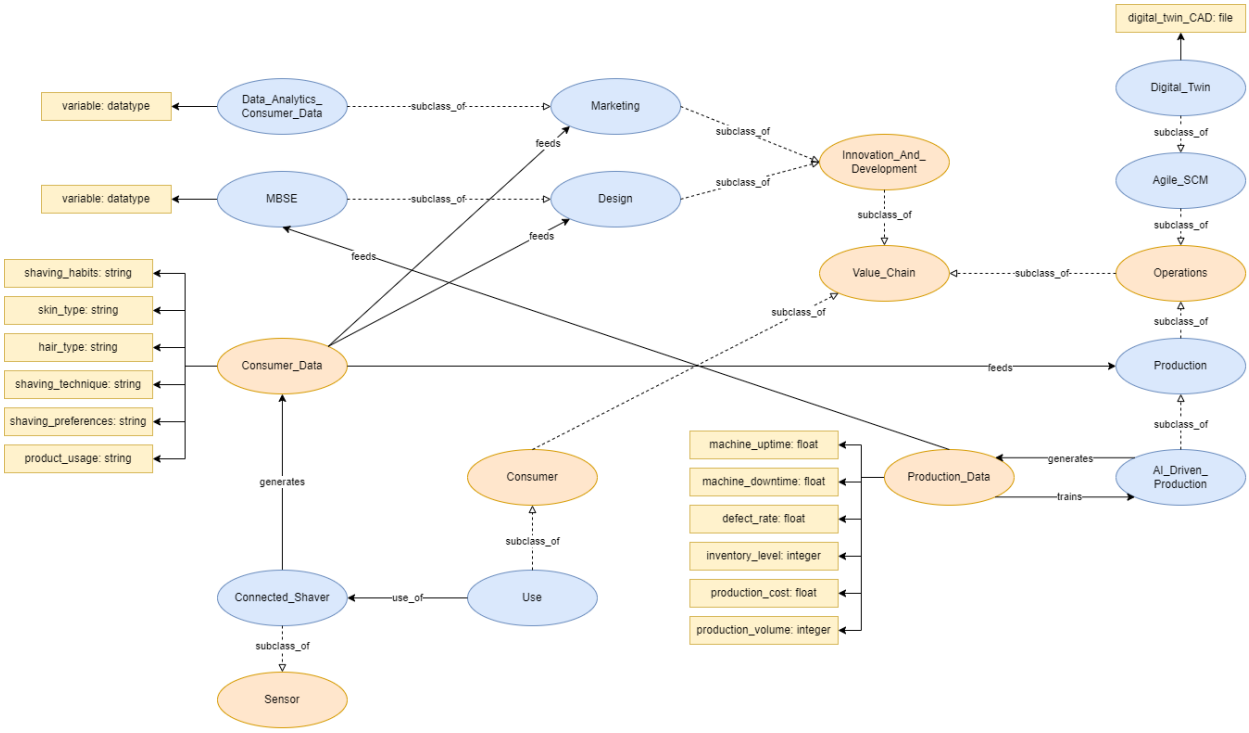

Figure 6: DrOWLing of UC 2: AI Enhanced Value Chain

5.3 Use Case 3: Servitization and service delivery enabled by Zero administration

Partners: *HUSQVARNA, SEB, Stream Analyze and LTU*

The goal of this UC is to connect market actors involved in service delivery through a legally binding smart contract, serving as a hub for data sharing and transparency, initiating financial transactions and activities, and supporting audits.

The platform, specifically designed for small devices such as edge devices and microcontrollers, supports a machine learning model that performs various analyses, including prediction, segmentation, optimization suggestions, estimation, and recommendations.

This UC is not related to other UCs and is in a cross domain. The model consists of 4 main classes (13 in total) and could be integrated into the Digital Reference through the lobes (Process and Sustainability).

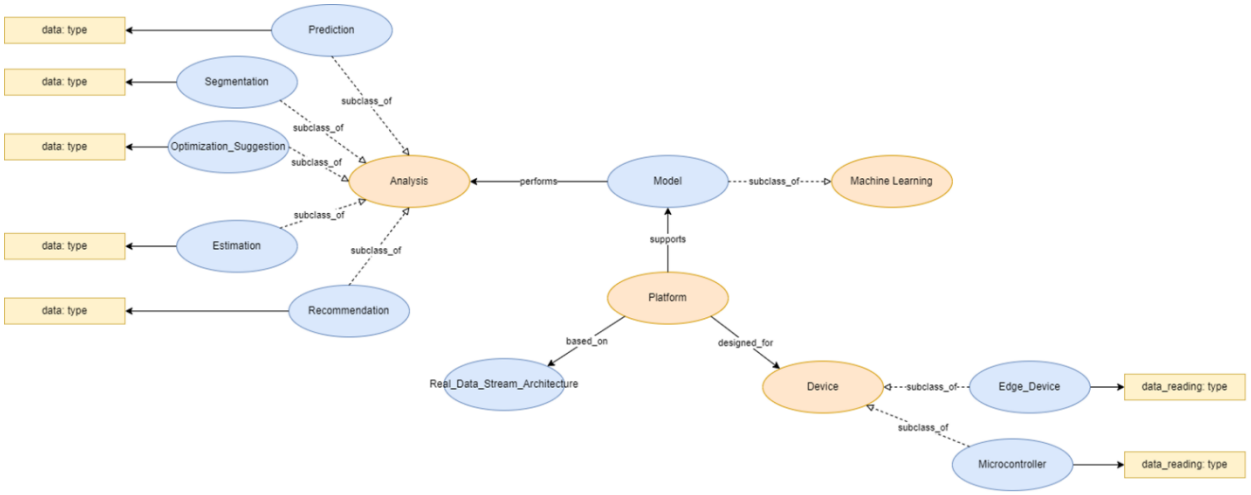

Figure 7: DrOWLing of UC3: Servitization and service delivery enabled by Zero administration

5.4 Use Case 4: AI based improved connection between production and logistics

Partners: *BMW, IPH and UPM*

The goal of this UC is to develop a three-layer AI system that combines handling, transport, and commissioning in intralogistics, enabling a versatile solution for European industries. IoT devices and blockchain technology will enhance data collection and quality, providing a reliable foundation for AI algorithms. Autonomous scan devices, including UAVs, will be used to cover the entire production site and provide gapless production data.

The companies involved in this UC (BMW, IPH, and UPM) have developed an AI model and implemented it on an Autonomous Transport Vehicle. This model is trained on data collected from an autonomous scanning device from the production facilities, including water usage, air quality, raw materials level, humidity, and temperature. A digital twin of the facilities is then created using the data and stored in the blockchain.

This UC is related to UC14 and its domain is Automotive. The model consists of 8 main classes (24 in total) and could be integrated into the Digital Reference through the lobes (Sensor, Cloud and Sustainability) and classes (Transport Robot, Robot, AGV and Digital Factory Twin).

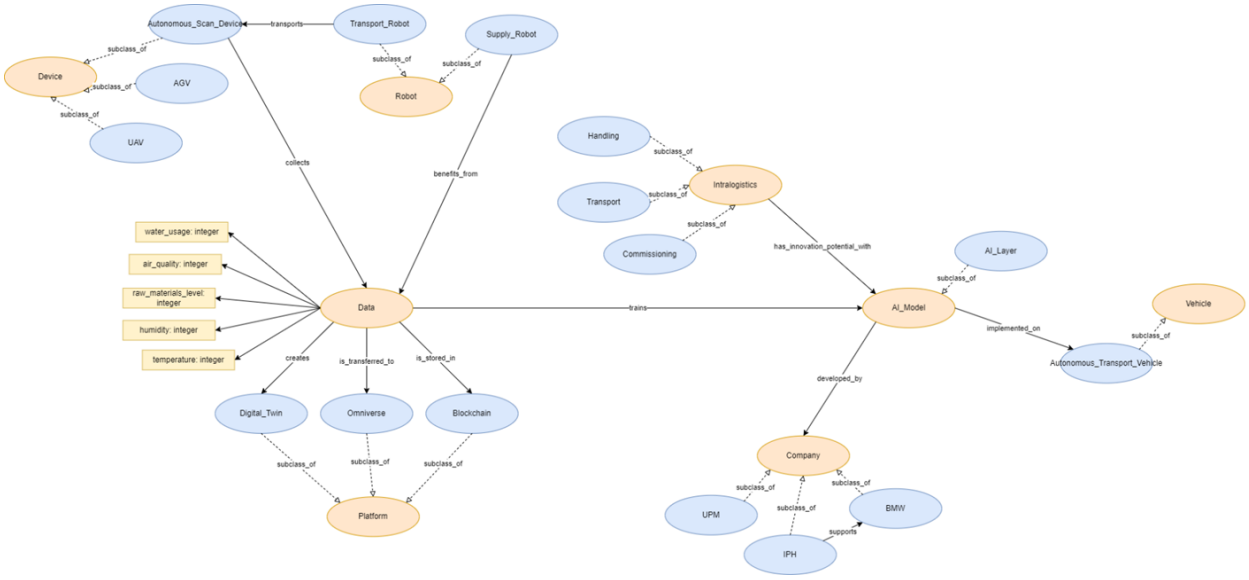

Figure 8: DrOWLing of UC4: AI based improved connection between production and logistics

5.5 Use Case 5: AI techniques at different layers in Machine Tool Domain

Partners: *IDEKO, SORALUCE, GOIMEK, SAVVY, MGEP, IBERMATICA*

This UC is about using AI techniques to answer to Research Questions regarding the predictive maintenance in the machine tool industry, specifically precision machining and solution architecture. CNC program is a Precision Machining technique that is partially controlled by a human operator but who is unaware of the current operation status and must be informed about it. The aforementioned Solution Architecture refers to a platform supporting the share of data from different information layers within the same company, but its specifications need to be investigated.

A DrOWLing has been generated based on the UC descriptions in the AIMS5.0 Proposal and AIMS5.0 D5.2 First Results. The DrOWLing contains 3 central classes representing the Precision Machining, the Research Question and the Solution Architecture. And 26 other classes mainly representing AI techniques and current processes. In addition, the DrOWLing may be extended to represent ideas from other predictive-maintenance-related uses cases:

- UC 06: Reconfigurable AI-based automated conveyer feeding by a robotic system
- UC 07: Digital Automated Luminaire Manufacturing platform
- [semiconductor-manufacturing-related] UC 13: Intelligent Sensors improving Robustness of Automated Wafer Transportation and Storage Systems
- [semiconductor-manufacturing-related] UC 15: Productionized Machine Learning models at scale
- [semiconductor-manufacturing-related] UC 17: Intelligent Contamination Management Prescriptive Control Plans and Process Flows
- [semiconductor-manufacturing-related] UC 20: Harmonization of Automated Digitized Equipment Control



Figure 9: DrOWLing of UC5: AI techniques at different layers in Machine Tool Domain

5.6 Use Case 6: Reconfigurable AI-based automated conveyer feeding by a robotic system

Partners: *EDI, HUA*

This UC is about a Robotic System which, thanks to AI and its modular structure, can automatically adapt to different work scenarios with little downtime. The robot software module comprehends 2 features: Reconfiguration ability and Dynamic Control. The latter is being enabled by Deep Learning, Deep Reinforcement Learning and high-level instructions

related to the specific context of execution. The robot hardware module consists of various robotic parts which can be arranged to match the Nimble Physics Setup, validated in the waste bottle conveyer feeding task at a cosmetics manufacturer.

A DrOWLing has been generated based on the UC descriptions in the AIMS5.0 Proposal and AIMS5.0 D5.2 First Results. The DrOWLing contains 4 central classes representing the AI Robotic System and its hardware and software components. And 40 other classes mainly representing AI techniques and processes in place.

In addition, the DrOWLing may be extended to represent ideas from other predictive-maintenance-related uses cases:

- UC 05: AI techniques at different layers in Machine Tool Domain
- UC 07: Digital Automated Luminaire Manufacturing platform
- [semiconductor-manufacturing-related] UC 13: Intelligent Sensors improving Robustness of Automated Wafer Transportation and Storage Systems
- [semiconductor-manufacturing-related] UC 15: Productionized Machine Learning models at scale
- [semiconductor-manufacturing-related] UC 17: Intelligent Contamination Management Prescriptive Control Plans and Process Flows
- [semiconductor-manufacturing-related] UC 20: Harmonization of Automated Digitized Equipment Control

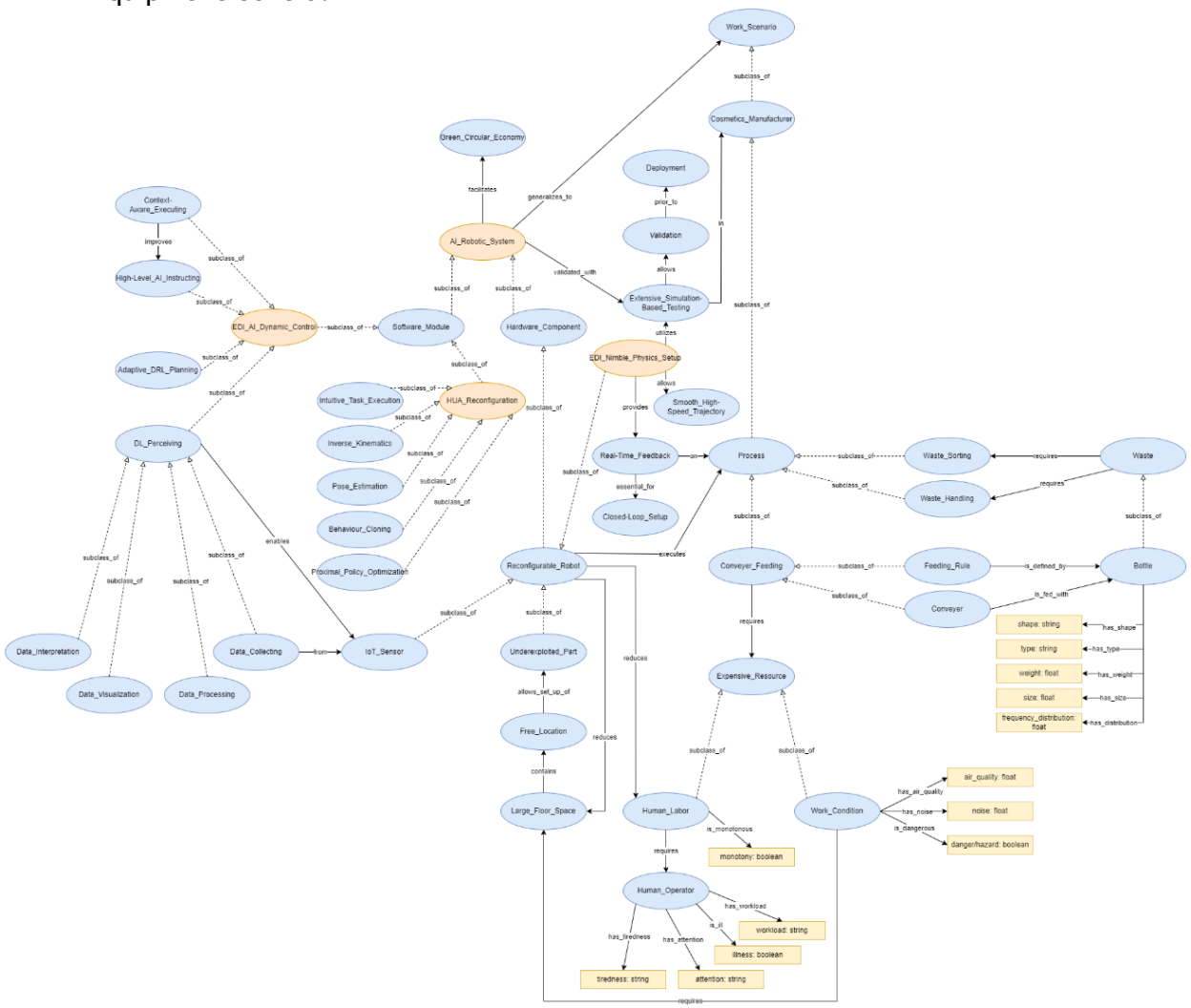

Figure 10: DrOWLing of UC6: Reconfigurable AI-based automated conveyer feeding by a robotic system

5.7 Use Case 7: Digital Automated Luminaire Manufacturing platform

Partners: *SIGNIFY, TU/e, RUG*

This UC describe 3 Digital Transformation innovations for the 3D Printing Industry. Adaptive Planning is achieved by training an AI model in an environment that simulates real printing hubs, with real manufacturing data.

For Additive Manufacturing, two machines have been tested but only one proved to be truly a successful application: A Proprietary 3D Printing Machine. The Assembly process is supported thanks to Action Recognition by a fine-tuned pre-trained AI model.

A DrOWLing has been generated based on the UC descriptions in the AIMS5.0 Proposal and AIMS5.0 D5.2 First Results. The DrOWLing contains 6 central classes representing the printing process and the main sub-processes. And 63 other classes mainly representing AI techniques and models' specifications.

In addition, the DrOWLing may be extended to represent ideas from other predictive-maintenance-related uses cases:

- UC 05: AI techniques at different layers in Machine Tool Domain
- UC 06: Reconfigurable AI-based automated conveyer feeding by a robotic system
- [semiconductor-manufacturing-related] UC 13: Intelligent Sensors improving Robustness of Automated Wafer Transportation and Storage Systems
- [semiconductor-manufacturing-related] UC 15: Productionized Machine Learning models at scale
- [semiconductor-manufacturing-related] UC 17: Intelligent Contamination Management Prescriptive Control Plans and Process Flows
- [semiconductor-manufacturing-related] UC 20: Harmonization of Automated Digitized Equipment Control

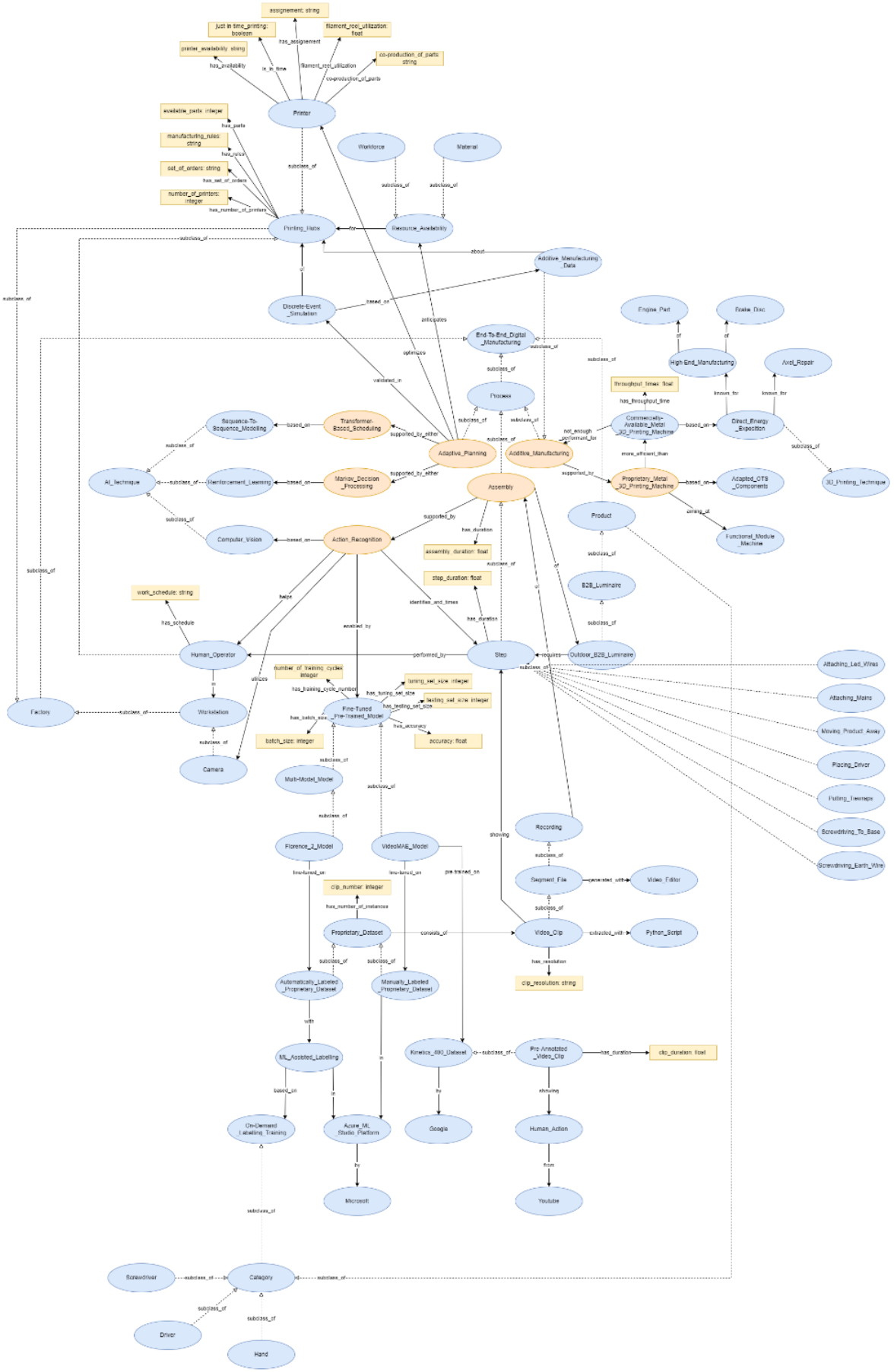

Figure 11: DrOWLing of UC Digital Automated Luminaire Manufacturing platform

5.8 Use Case 8: AI supporting and strengthening human and manufacturing cycles

Partners: *TUBITAK and SU*

The goal of this UC is to develop an AI system that supports and strengthens manufacturing cycles in two main ways: an AMR Task & Traffic Management System that enables safe and efficient intra-logistics within factories, and an AI-supported Human Assistance Exoskeleton that assists human factory workers with disabilities, enhancing their ability to work safely and efficiently.

Regarding the AMR Task & Traffic Management System on which TUBITAK is working, its process has been included in the DrOWLing, as well as which type of data can be expected from each of the steps. When it comes to SU, it's been working on a control framework (detecting hand gestures) for Autonomous Guided Vehicles (AGV).

Also, TUBITAK has been developing an exoskeleton equipped with EMG sensors and an EEG headset to gather different types of data. So far, it's just a passive device, but it's supposed to have motion in the future.

This UC is not related to other UCs and its domain is Automotive. The model consists of 12 main classes (36 in total) and could be integrated into the Digital Reference through the lobes (Sensor, Process and Sustainability) and classes (Robot and AGV). UC 9: Energy-Aware Scheduling of Batch Processing Machines in Wafer Fabs.

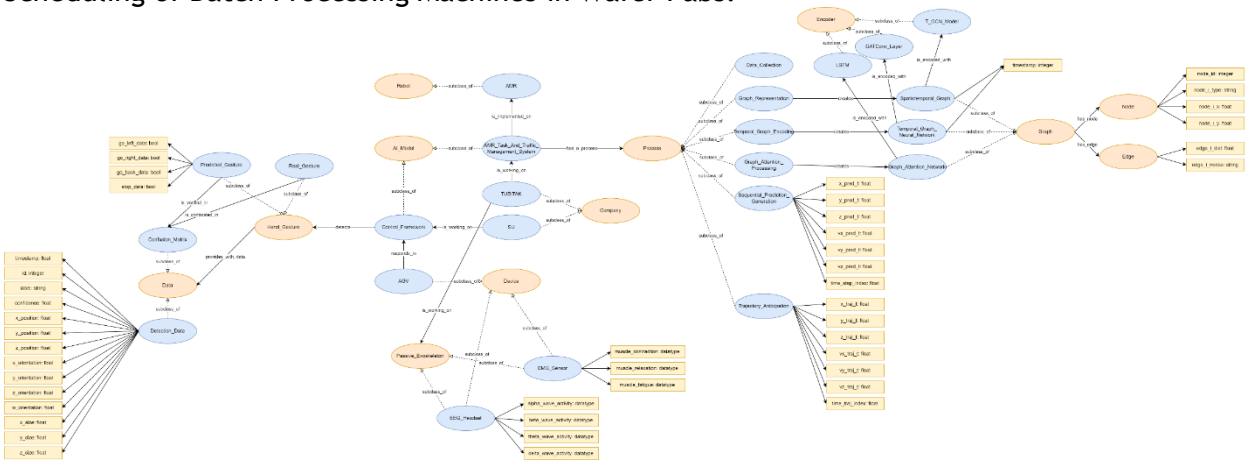

Figure 12: DrOWLing of UC8: AI supporting and strengthening human and manufacturing cycles

5.9 Use Case 9: Energy-Aware Scheduling of Batch Processing Machines in Wafer Fabs

Partners: *FUH, IFD, IFAT, SYSTEMA, and VIF*

The key problem addressed by the main UC is the substantial energy consumption of batch processing machines during energy-scarce periods. The solution approach involves the creation of energy-aware production schedules, based on consumption patterns of processing tools and load adjustment requests from grid operators, while respecting production constraints. A DrOWLing has been generated based on the UC descriptions in the AIMS proposal and D6.2 status report about Tier 2 UCs for Y2. The DrOWLing contains three central classes representing the key entities of Production Scheduler, Processing Tool, and Grid Operator, and 17 other classes

representing their key inputs and outputs, inclusive of existing classes from the Digital Reference.

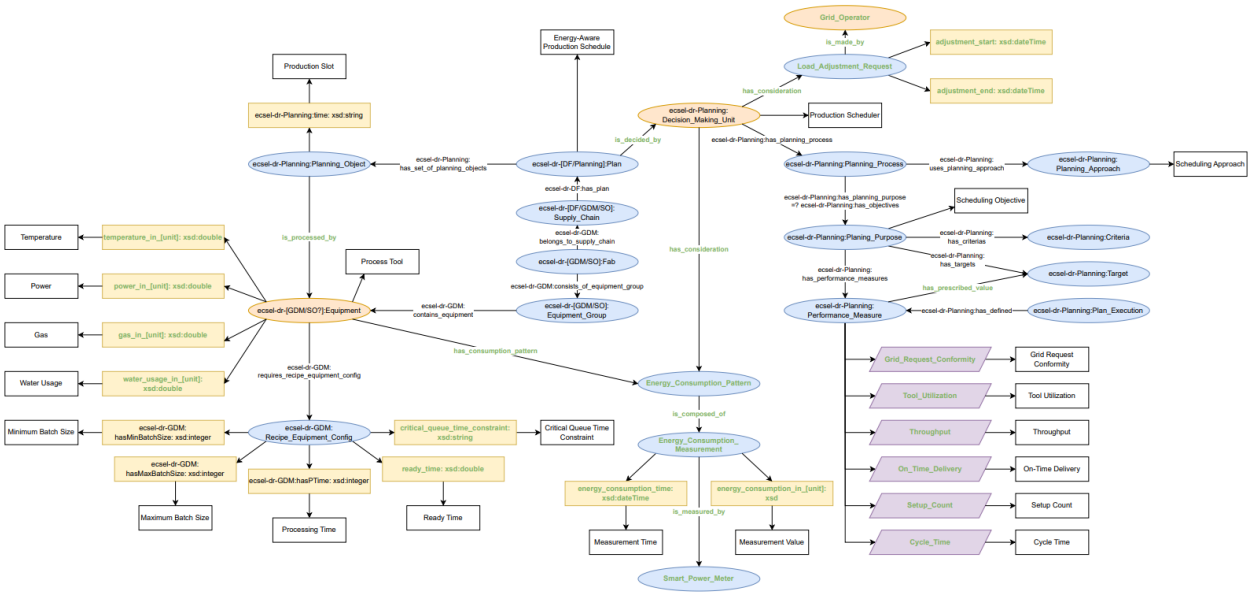

Figure 13: DrOWLing of UC9: Energy-Aware Scheduling of Batch Processing Machines in Wafer Fabs

5.10 Use Case 11: AI-supported Industrial IoT for Indoor Food Production

Partners: *TIAG, RSA, AIT, PYT and GUT*

The goal of this UC is to create a flexible and decentralized Indoor Food Production framework, prioritizing security, safety, and scalability. The framework will address the complexity of interconnected IoT devices, AI-driven automation, and digital infrastructure in industrial indoor vertical farming systems. A key challenge is ensuring end-to-end security and compliance with regulatory frameworks like the Cyber Resilience Act, given the integration of multiple digital components with varying cybersecurity postures. The proposed approach seeks to optimize plant growth and production efficiency while maintaining a secure and scalable operation.

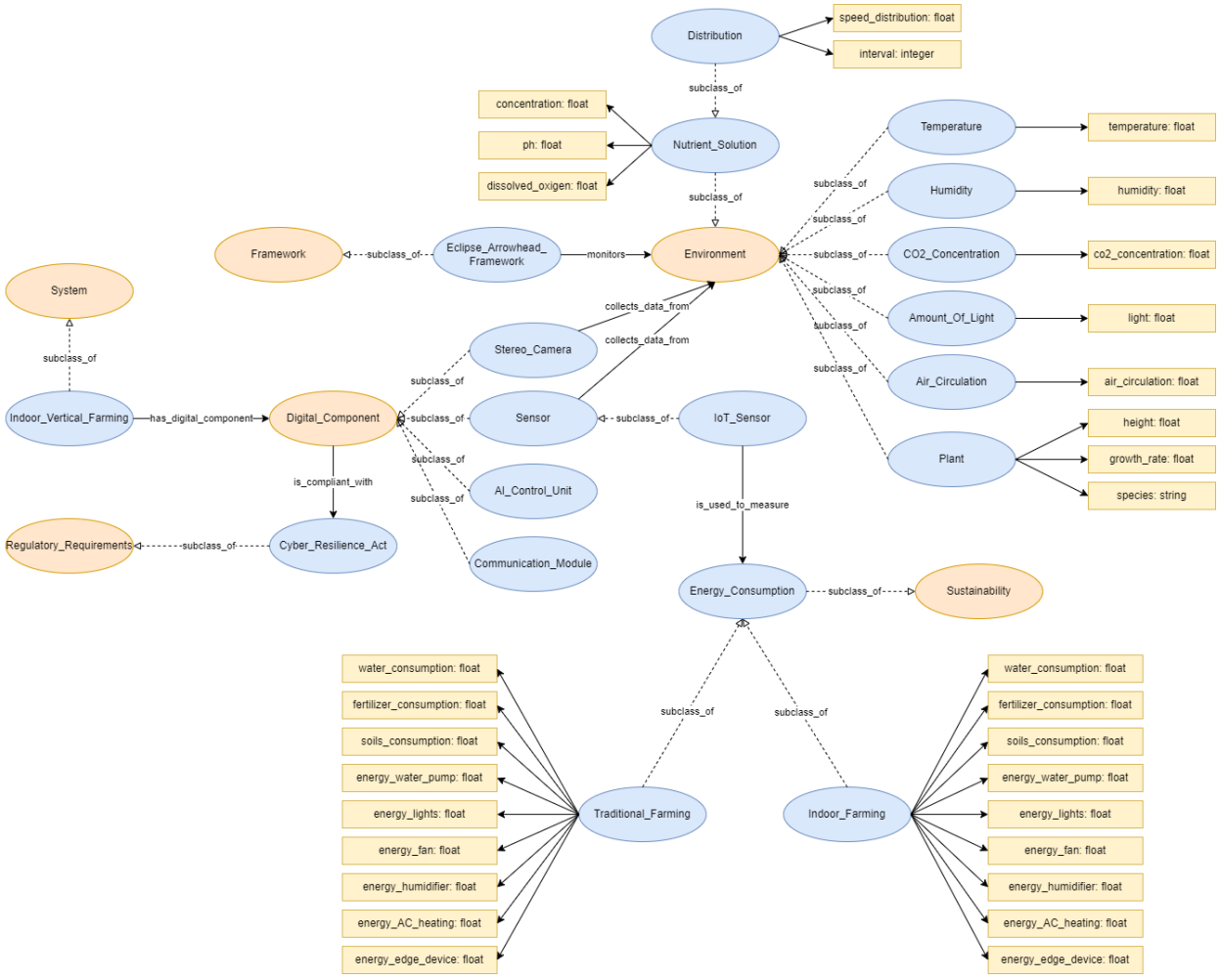

Figure 14: DrOWLing of UC11: AI-supported Industrial IoT for Indoor Food Production

This UC is not related to other UCs and its domain is Food Production. The model consists of 6 main classes (25 in total) and could be integrated into the Digital Reference through the lobes (Sensor, Process and Sustainability) and classes (Arrowhead and Environmental Data).

5.11 Use Case 13: Intelligent Sensors improving Robustness of Automated Wafer Transportation and Storage Systems

Partners: *HOST, IFD, IFAT, FMX, TUD, HSZG, IFAG*

This UC revolves around 2 IoT-based sensing strategies to collect high quality data from the clean room, to train anomaly detection models and prevent malfunctions of the Over-Head Transportation System (a component of the AMHS in wafer fabs).

The first strategy is about implementing a Hardware System Control Platform with various type of sensors installed. The second strategy consists of implementing a Small-Scale Autonomous-Driving Platform able to perform extensive researches and collect data from other hardware. A DrOWLing has been generated based on the UC descriptions in the AIMS5.0 Proposal and AIMS5.0 D6.2 Status Report.

The DrOWLing contains 4 central classes representing the key Over-Head Transportation entities: OHT System, OHT Data, Hardware System Control Platform and Small-Scale

Autonomous-Driving Development Platform. And 50 other classes mainly representing sensor components and data.

In addition, the DrOWLing may be extended to represent ideas from other predictive-maintenance-related uses cases:

- UC 05: AI techniques at different layers in Machine Tool Domain
- UC 06: Reconfigurable AI-based automated conveyer feeding by a robotic system
- UC 07: Digital Automated Luminaire Manufacturing platform
- [semiconductor-manufacturing-related] UC 15: Productionized Machine Learning models at scale
- [semiconductor-manufacturing-related] UC 17: Intelligent Contamination Management Prescriptive Control Plans and Process Flows
- [semiconductor-manufacturing-related] UC 20: Harmonization of Automated Digitized Equipment Control

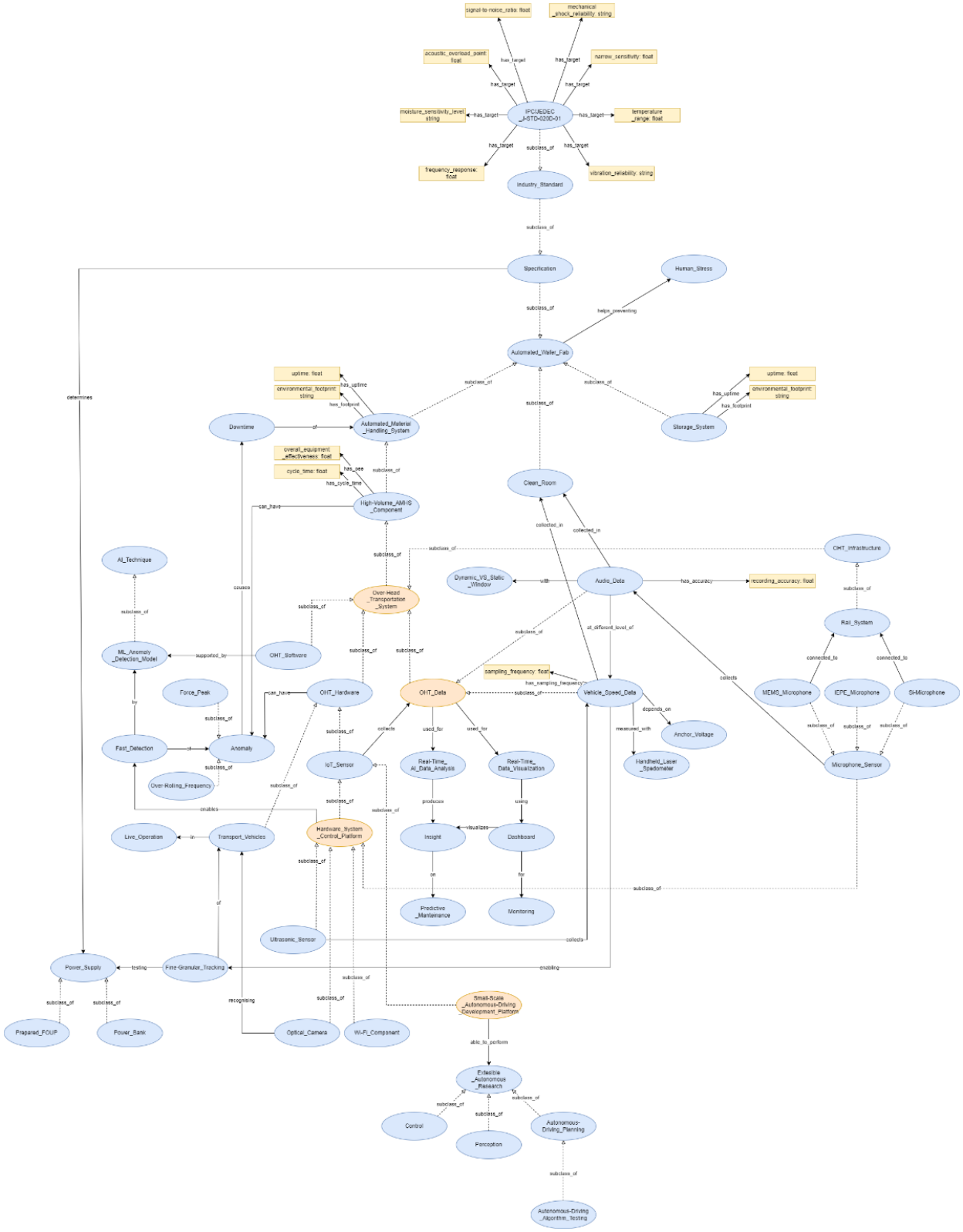

Figure 15: DrOWLing of UC13: Intelligent Sensors improving Robustness of Automated Wafer Transportation and Storage Systems

5.12 Use Case 14: Speeding-up the Benefit of Automation by Virtual Commissioning through Digital Twins

Partners: *FMX, IFD, HOST, TUD and IFAT*

The goal of this UC is to leverage digital twins to address challenges in automation products. The objective is to reduce lead times, accelerate software development, and enable software adjustments after delivery. Digital twins facilitate virtual commissioning, code testing, and feature development without physical hardware, allowing for enhancements and new features even after delivery.

A digital twin based on the CAD model of the robotic cell FMX TWC is integrated with the Staubli Robotics Suite. This model includes peripherals (both input and output conveyors), payloads (wafers and carriers used in the semiconductor industry), and transducers (sensors and actuators). The digital twin is connected to an emulated PLC, where information is written (by sensors) and commanded (to actuators) through PLC variables.

This UC is related to UC04 and is a cross domain. The model consists of 11 main classes (23 in total) and could be integrated into the Digital Reference through the lobes (Sensor, System and Sustainability) and classes (Robot and Digital Factory Twin).

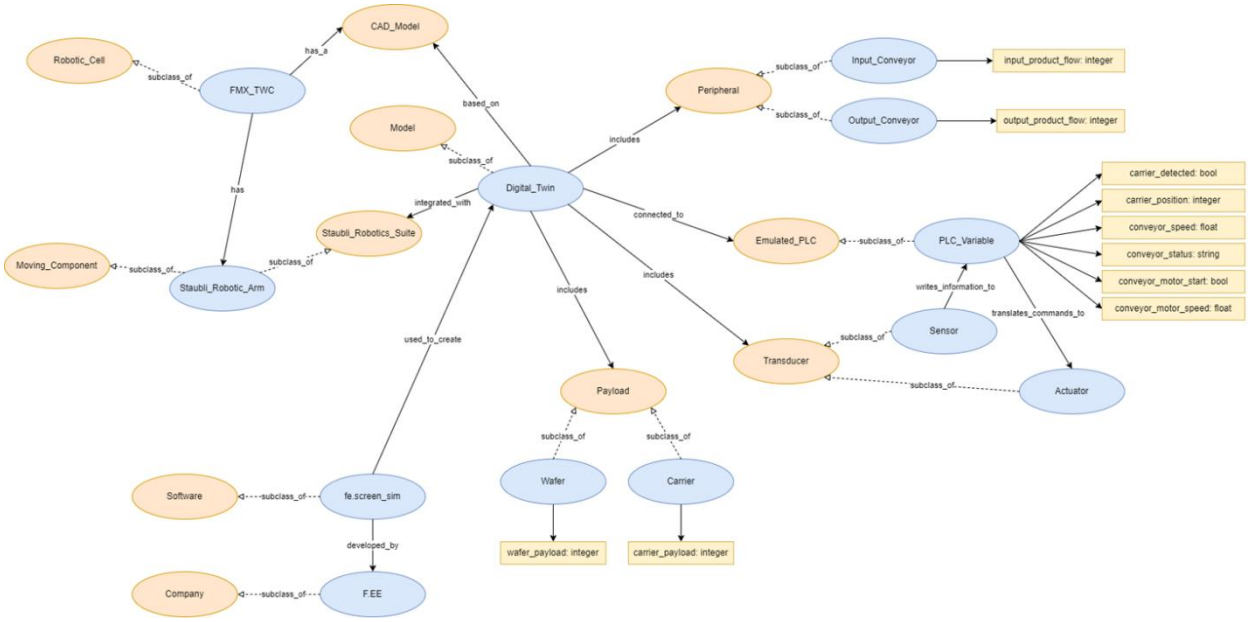

Figure 16: DrOWLing of UC14: Speeding-up the Benefit of Automation by Virtual Commissioning through Digital Twins

5.13 Use Case 15: Productionized Machine Learning models at scale

Partners: *IFD, UniPD, IFAG, IFAT, UNIPD, STATWOLF, LFO, KAI*

This UC presents five different machine learning applications to optimize and scale up the predictive maintenance in the semiconductor manufacturing industry. The UC also describes the shared, as well as the individual requirements.

The applications are: (1) Anomaly Detection & Virtual Inspection, (2) Defect & Defect Pattern Classification, (3) Automatic Status Classification After Maintenance, (4) Overall Equipment Effectiveness Prediction, (5) Defect Density Image Classification.

A DrOWLing has been generated based on the UC descriptions in the AIMS5.0 Proposal and AIMS5.0 D6.2 Status Report. The DrOWLing contains 6 central classes representing each one single ml-model, and 106 other classes representing key inputs and outputs.

In addition, the DrOWLing may be extended to represent ideas from other predictive-maintenance-related uses cases:

- UC 05: AI techniques at different layers in Machine Tool Domain
- UC 06: Reconfigurable AI-based automated conveyer feeding by a robotic system
- UC 07: Digital Automated Luminaire Manufacturing platform
- [semiconductor-manufacturing-related] UC 13: Intelligent Sensors improving Robustness of Automated Wafer Transportation and Storage Systems
- [semiconductor-manufacturing-related] UC 17: Intelligent Contamination Management Prescriptive Control Plans and Process Flows
- [semiconductor-manufacturing-related] UC 20: Harmonization of Automated Digitized Equipment Control

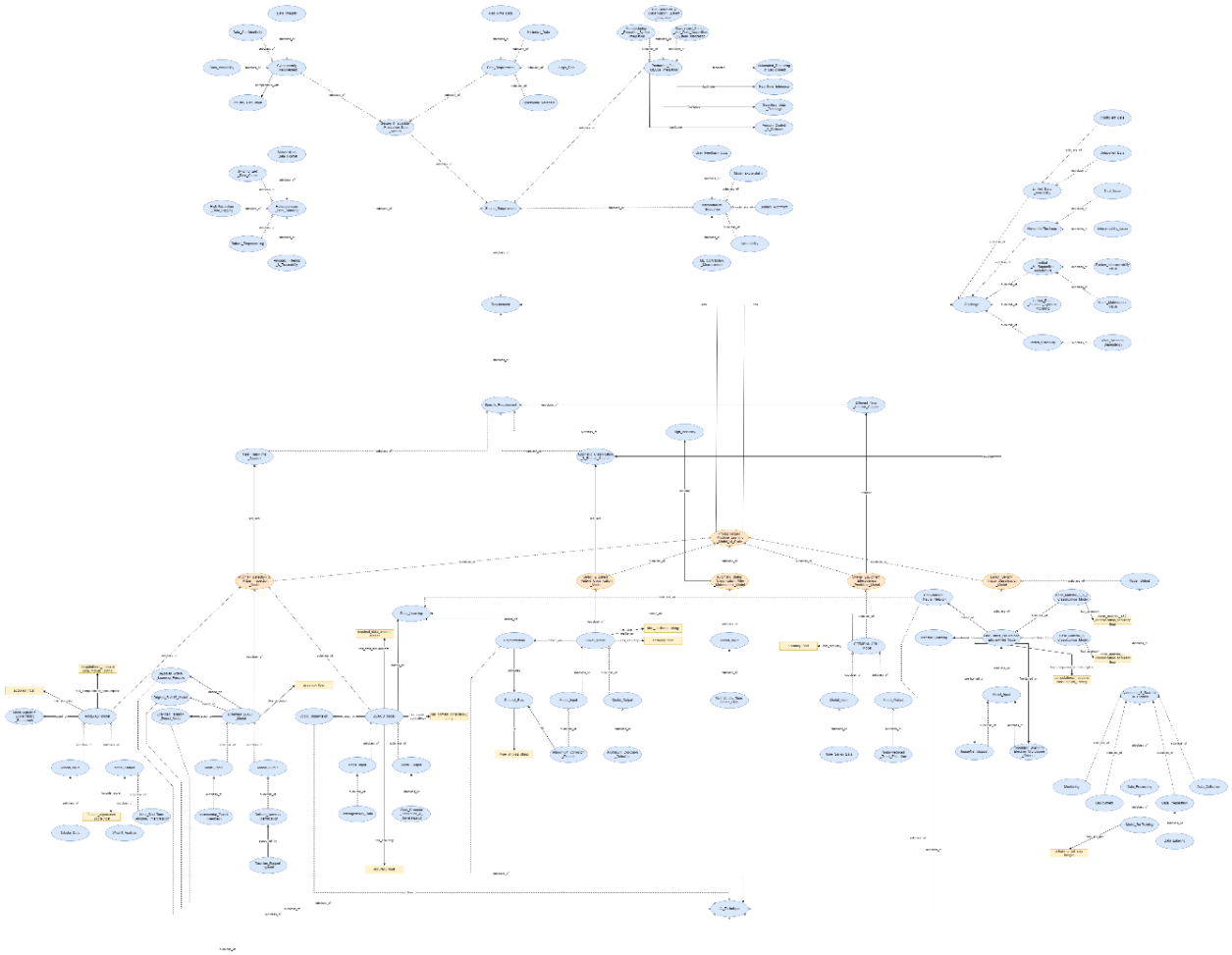

Figure 17: DrOWLing of UC15: Productionized Machine Learning models at scale

5.14 Use Case 16: AI enhanced production and performance of RF transceivers for civilian SATCOM and radar applications

Partners: *TRT and FORTH*

The goal of this UC is to utilize AI-enabled solutions to optimize the development of RF components and systems for avionic and SATCOM applications. THALES and FORTH are implementing machine learning techniques to improve manufacturing throughput and sustainability, with the aim of developing components that can support specific UC applications, such as airport Radars, and other similar applications across different RF bands. Regarding the Process class, it can be considered the central one. It brings together the Software, the Sustainability and the Data_Generation through the AI_Tool.

This UC is not related to other UCs and its domain is Aviation. The model consists of 6 main classes (17 in total) and could be integrated into the Digital Reference through the lobes (Process and Sustainability) and class (Software).

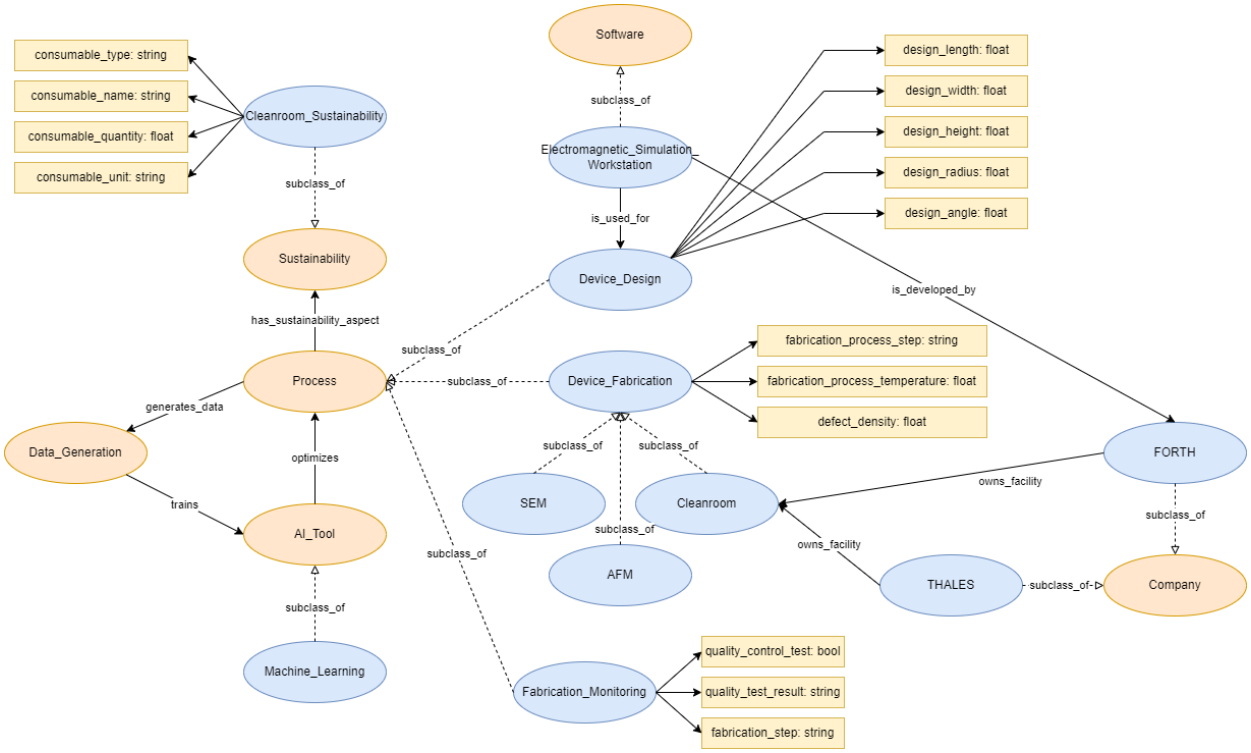

Figure 18: DrOWLing of UC16: AI enhanced production and performance of RF transceivers for civilian SATCOM and radar applications

5.15 Use Case 17: Intelligent Contamination Management Prescriptive Control Plans and Process Flows

Partners: *FhG-IISB, PFEIFFER, IFD, IFAT, IFAG, SYSTEMA*

This UC is about the implementation of a pool of sensors to automatically collect and process contamination data within the clean room in near real-time, then supporting the maintenance. The data integration and processing are made possible by means of a data platform (data lake specifically) based on the KNIME workflow and AI techniques.

A DrOWLing has been generated based on the UC descriptions in the AIMS5.0 Proposal and AIMS5.0 D6.2 Status Report. The DrOWLing contains 4 central classes representing the Cleanroom Environment, the Automated Maintenance, a Data Platform and the Sensor. And 45 other classes mainly representing sensor components and data.

In addition, the DrOWLing may be extended to represent ideas from other predictive-maintenance-related uses cases:

- UC 05: AI techniques at different layers in Machine Tool Domain
- UC 06: Reconfigurable AI-based automated conveyer feeding by a robotic system
- UC 07: Digital Automated Luminaire Manufacturing platform
- [semiconductor-manufacturing-related] UC 13: Intelligent Sensors improving Robustness of Automated Wafer Transportation and Storage Systems
- [semiconductor-manufacturing-related] UC 15: Productionized Machine Learning models at scale
- [semiconductor-manufacturing-related] UC 20: Harmonization of Automated Digitized Equipment Control

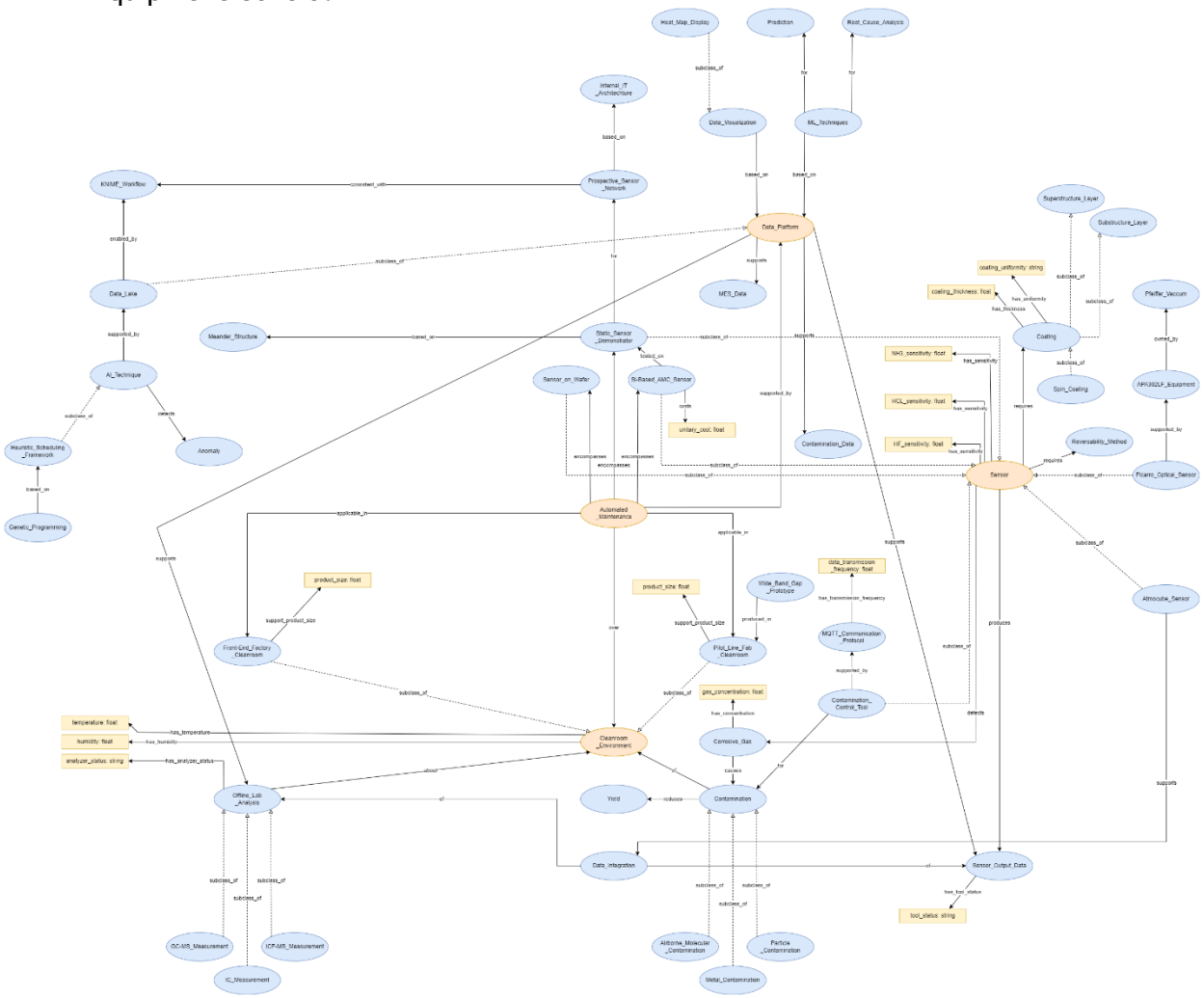

Figure 19: DrOWLing of UC17: Intelligent Contamination Management Prescriptive Control Plans and Process Flows

5.16 Use Case 18: Using Semantic Data Model as Base for AI-Optimized Economic & Ecologic/Societal Supply Chain Improvements

Partners: *IFAG, FUH, and NXP*

The key problem addressed by the UC is the need for greater transparency around the end-to-end sustainability of a given semiconductor product and supply chain, so as to enable ecologically-focused optimizations and improvements. The solution approach involves the use of an end-to-end supply chain simulation model which leverages operating curve (OC) and ecological operating curve (eOC) concepts to enable companies to estimate the effect of different utilization levels on sustainability for a given product, supplier, and customer.

A DrOWLing has been generated based on the UC description in the AIMS proposal, and ongoing work at IFAG on the simulation model. The DrOWLing contains three central classes representing the key entities of Customer, Available to Promise (ATP), and Supplier, and 29 other classes representing key inputs and outputs of the simulation model, inclusive of existing classes from the Digital Reference.

In addition, the DrOWLing may be extended to represent ideas from three other potentially-related uses cases:

- UC 01: Development of Green AI Lifecycle Management Approaches
- UC 10: MES Concept Based on AI Improving Production Cycle (AI-Prod MES)
- UC 12: Human-Centered AI for the Optimization of Robust and Competitive Semiconductor Manufacturing Networks

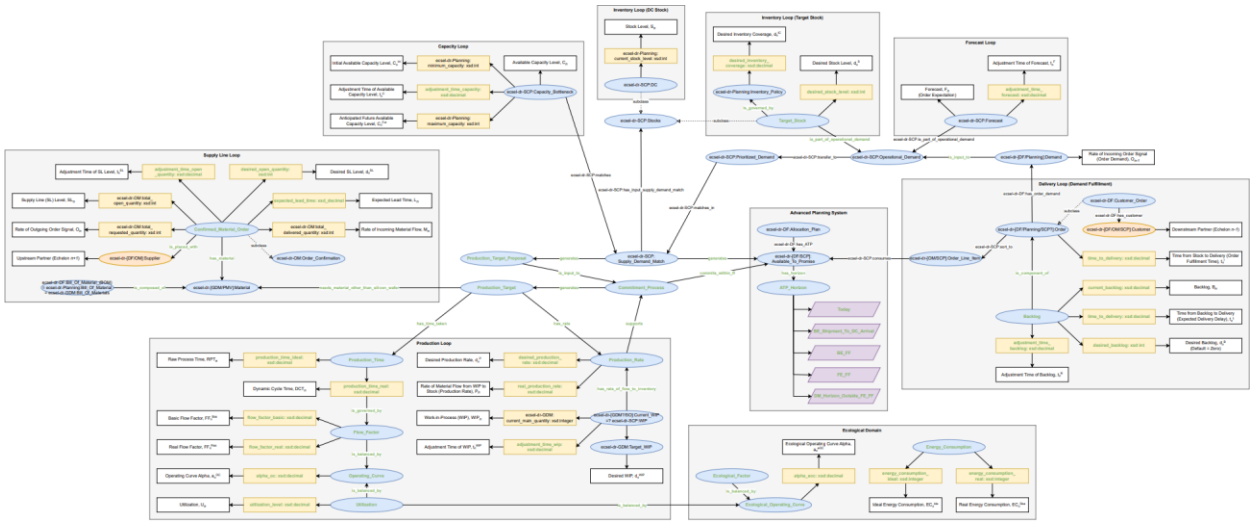

Figure 20: DrOWLing of UC18: Using Semantic Data Model as Base for AI-Optimized Economic & Ecologic/Societal Supply Chain Improvements

5.17 Use Case 20: Harmonization of Automated Digitized Equipment Control

Partners: *IFAT, IFD, IFAG, TUD*

This UC regards a OneVirtualFab platform that integrates data from various sources and is equipped with an ANKO UI for ease of access. The platform aims at harmonizing the large amount of data coming from production plants dedicated to 300mm, with the finality of assisting in the optimization of the Test-Production Wafer Trade-Off.

A DrOWLing has been generated based on the UC descriptions in the AIMS5.0 Proposal and AIMS5.0 D6.2 Status Report. The DrOWLing contains 3 central classes representing the OneVirtualFab Platform, its ANKO Harmonization UI and the Data Sources needs. And 30 other classes mainly representing sensor components and data.

In addition, the DrOWLing may be extended to represent ideas from other predictive-maintenance-related uses cases:

- UC 05: AI techniques at different layers in Machine Tool Domain
- UC 06: Reconfigurable AI-based automated conveyer feeding by a robotic system
- UC 07: Digital Automated Luminaire Manufacturing platform
- [semiconductor-manufacturing-related] UC 13: Intelligent Sensors improving Robustness of Automated Wafer Transportation and Storage Systems
- [semiconductor-manufacturing-related] UC 15: Productionized Machine Learning models at scale
- [semiconductor-manufacturing-related] UC 17: Intelligent Contamination Management Prescriptive Control Plans and Process Flows

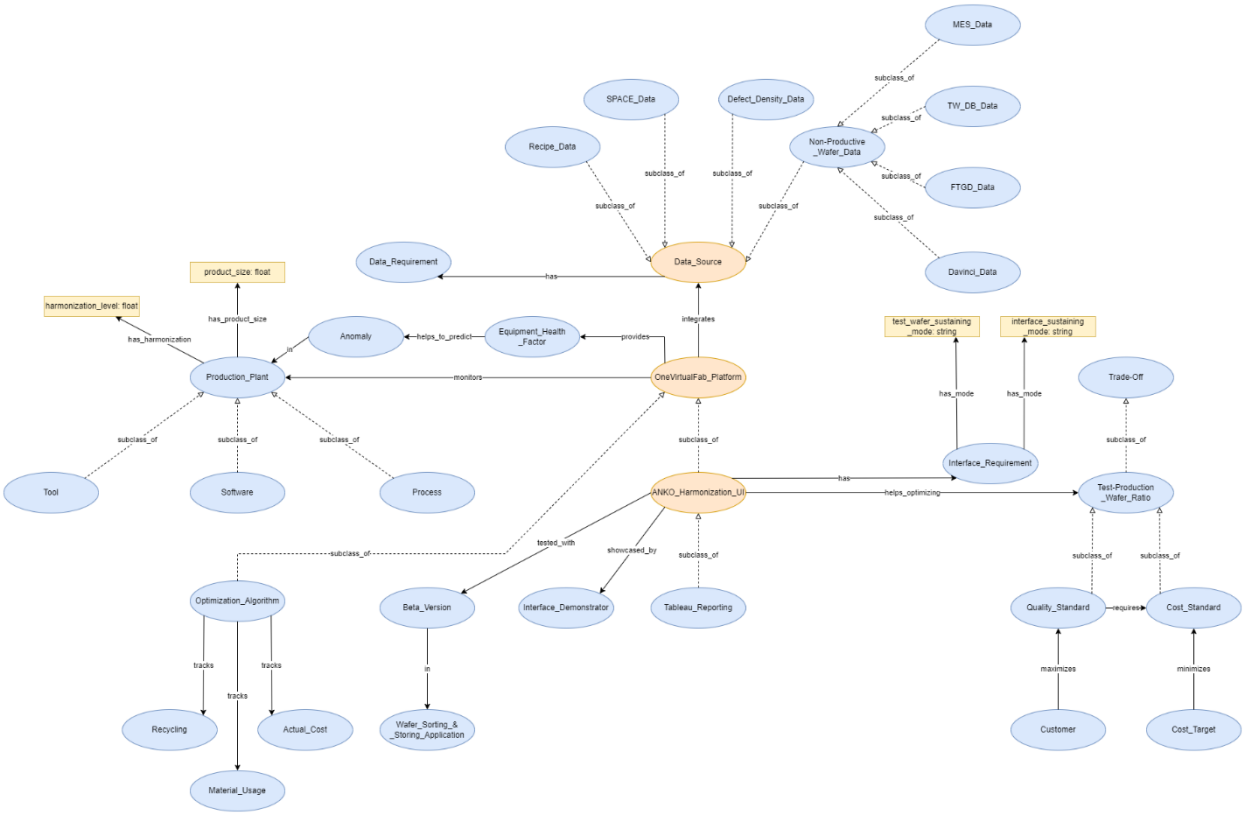

Figure 21: DrOWLing of UC20: Harmonization of Automated Digitized Equipment Control

6. Conclusions

The extension of the Battery-Management-Systems (BMS) ontology and the integration of the Product Carbon Footprint (PCF) metric into the Digital Reference (DR) have been successfully achieved. The BMS ontology has been extended by 9 new classes and 9 object properties, while the PCF metric has been calculated using a cradle-to-grave approach, taking into account greenhouse gas emissions and savings. The connection between the BMS and PCF has been demonstrated through the use of four new blue object properties in the DrOWLing of Figure 6. The relevance of the PCF and BMS in the context of the Corporate Sustainability Reporting Directive (CSRD) and the Corporate Sustainability Due Diligence Directive (CSDDD) has also been highlighted. The 20 use cases presented in the document demonstrate the application of the BMS ontology and PCF metric in various industries, including automotive, consumer electronics, and semiconductor manufacturing.

Each use case has been described in detail, including the partners involved, the goal of the use case, and the DrOWLing. The use cases have been categorized into different domains, such as automotive, consumer electronics, and semiconductor manufacturing. Some use cases are related to each other, while others are standalone. The document concludes that the extension of the BMS ontology and the integration of the PCF metric into the DR have the potential to improve the sustainability and efficiency of various industries. The use cases presented in the document can serve as a starting point for further research and development in the field of BMS and PCF.

Key Takeaways

- The BMS ontology has been extended by 9 new classes and 9 object properties.
- The PCF metric has been calculated using a cradle-to-grave approach, taking into account greenhouse gas emissions and savings.
- The connection between the BMS and PCF has been demonstrated through the use of four new blue object properties in the DrOWLing of Figure 6.
- The relevance of the PCF and BMS in the context of the CSRD and CSDDD has been highlighted.
- The 20 use cases presented in the document demonstrate the application of the BMS ontology and PCF metric in various industries.

Future Work

- Further research is needed to refine the BMS ontology and PCF metric.
- The use cases presented in the document can serve as a starting point for further research and development in the field of BMS and PCF.
- The integration of the PCF metric into the DR can be further explored to improve the sustainability and efficiency of various industries.

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8. Appendix - Abbreviations

Table 1: Abbreviations

Abbreviation	Meaning
AGV	Autonomous Guided Vehicles
AI	Artificial Intelligence
AIMS5.0	Artificial Intelligence in Manufacturing leading to Sustainability and Industry5.0
AMR	Autonomous Mobile Robot
BMS	Battery Management System
BEV	Battery Electric Vehicle
CCL	Charge Current Limits
CNC	Computer Numerical Control
CSDDD	Corporate Sustainability Due Diligence Directive
CSRD	Corporate Sustainability Reporting Directive
DCL	Discharge Current Limits
DR	Digital References
eOC	Ecological Operating Curve
GHG	Greenhouse Gases
IFX	Infineon Technologies
IoT	Internet of Things
ISO	International Organization for Standardization
LC	Life Cycle
OC	Operating Curve
OHT	Over-Head Transportation
PCF	Product Carbon Footprint
PLC	Programmable Logic Control
SOA	Safe Operating Area
SOC	State of Charge
SOD	State of Discharge
SOH	State of Health
UC	Use Case