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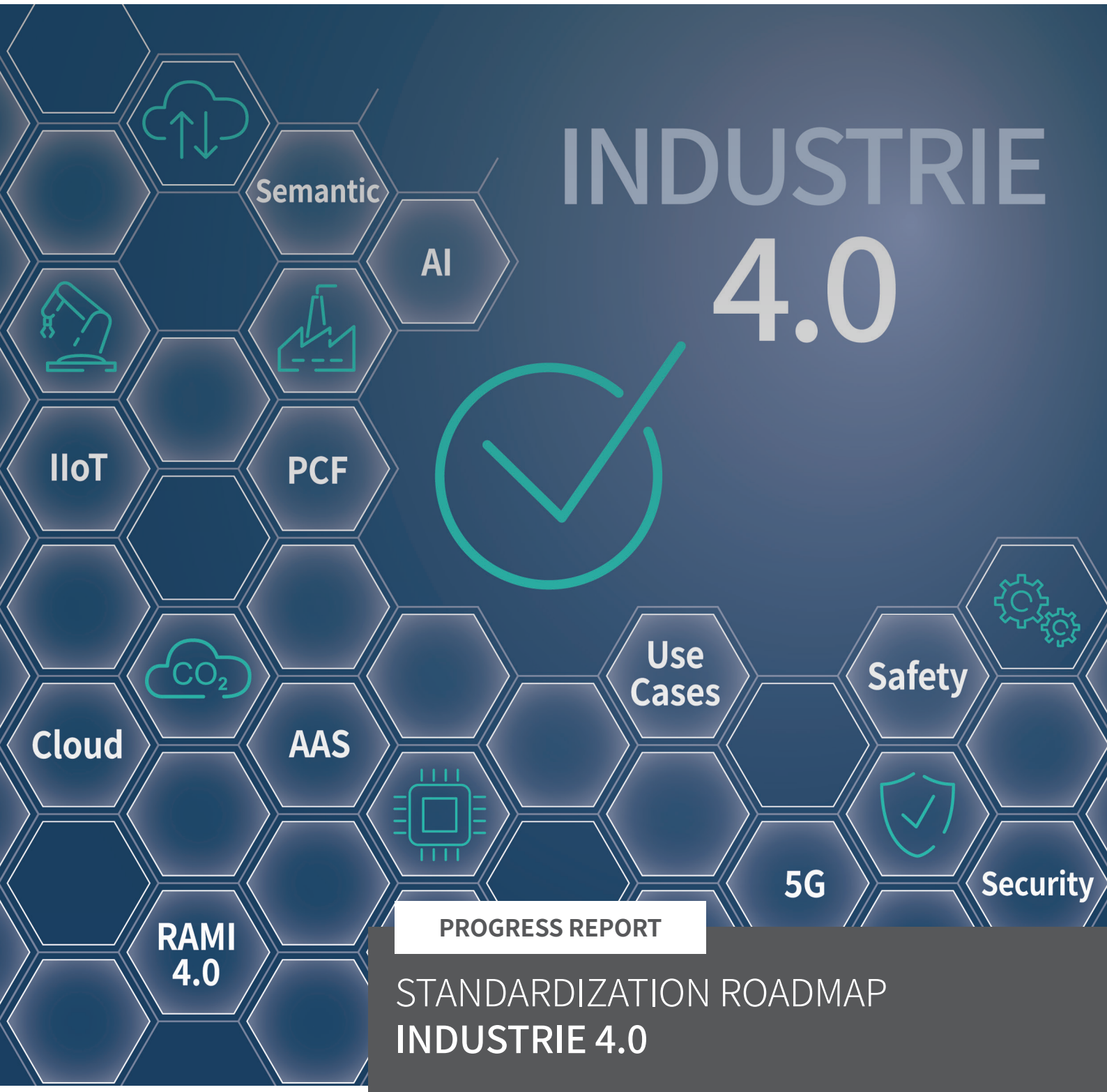

PROGRESS REPORT

STANDARDIZATION ROADMAP
INDUSTRIE 4.0

STANDARDIZATION
COUNCIL
INDUSTRIE 4.0

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GREETING

Olga Meyer
Fraunhofer IPA Chair Working Group
Standardization Roadmap Industrie 4.0

The series of publications on the Industrie 4.0 Standardization Roadmap analyzes both national and international standardization in the field of Industrie 4.0 from a strategic and technical perspective and makes recommendations for action. Under my leadership, the Working Group “Standardization Roadmap Industrie 4.0” of the Standardization Council Industrie 4.0 prepared the fourth version of the German Standardization Roadmap Industrie 4.0 in 2020. This progress report now provides an update on the implementation of the recommendations for action made in the Roadmap .

A total of 115 recommendations for action were assessed and evaluated in terms of their implementation with the involvement of experts from the relevant national standards bodies. The fact that we can classify 62 of these recommendations for action as progress is a positive interim conclusion. With our outlook at the end of the progress report, we are preparing to identify and anchor projects such as the Digital Product Passport, the Digital Nameplate and other application examples in standardization for Industrie 4.0 in the upcoming Roadmap.

The assessments made here also serve as an orientation and compass for the direction of the content of the fifth edition of the Standardization Roadmap, which will be published in 2023.

While the sustainability aspects of humans and work have always been components of the Standardization Roadmap, in the upcoming edition we will focus on the aspects of transparency along the entire life cycle of products and information on the raw materials used, which we already have to take into account from a normative perspective.

I would like to express my sincere thanks to all contributors. Without the tireless efforts of the volunteer experts, the preparation of a progress report as well as a standardization roadmap would not be possible.

I wish all readers an exciting read. We hope that our publications will not only drive forward the standardization of Industrie 4.0 but will continue to be understood as “door openers” for the standardization of digital manufacturing.

Olga Meyer, Group Leader for Interoperability for Digital Production at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA and Chair of the Standardization Roadmap Industrie 4.0 Working Group.

1 At a glance

The Standardization Roadmap Industrie 4.0 (SRI 4.0) was conceived as a "living" document from the very first edition and is accordingly understood as a basis for discussion that is to be continuously updated at regular intervals.

The experts in the Sub-Working Group "Progress Report" spent around a year compiling assessments to provide an up-to-date overview regarding the status of the recommendations stated in version 4 of the roadmap. At the same time, this Progress Report intends to set the direction in terms of content for the fifth edition of the Standardization Roadmap Industrie 4.0, which will be published in 2023. Strict criteria were used as a basis for evaluating the total of 115 recommendations , and the experts agreed on a positive progress rating in 62 cases. This corresponds to a ratio of just over 53 %, which is a positive interim result. The following section presents a summary of the individual sub-topics from Chapter 2 "Need for standardization of core topics" [1] and Chapter 3 "Need for standardization of cross-cutting topics" [2].

PROGRESS RELATING TO THE NEED FOR STANDARDIZATION OF CORE TOPICS (CHAPTER 2 OF THE ROADMAP VERSION 4)

→ With work nearing completion on IEC 63278-1 "Asset Administration Shell for industrial applications – Asset Administration Shell structure" and the submissions for the extension of the standards series with IEC 63278-2: "Information meta model" and IEC 63278-3: Security provisions for Asset Administration Shells", further important standardization projects were consolidated, first nationally and now internationally, in order to make the Asset Administration Shell (AAS) the central "integration plug" for digital ecosystems and to anchor it further in international standardization.

→ IEC 63283-2 "Industrial process measurement, control and automation – Smart Manufacturing – Part 2: Use case", which will be published soon, supplements important normative specifications with regard to formal and precise definitions in order to be able to implement a uniform understanding of Industrie 4.0. The collection of consistent and representative use cases required for this purpose was covered by the standard. This groundwork should continue to be built upon.

→ Progress can also be observed with regard to the harmonization and compatibility of new and existing reference architecture models. Within the framework of this liaison, IEC TR 63319 "A meta-modelling analysis approach to smart manufacturing reference models" and IEC 63339 "Unified reference model for smart manufacturing" were developed to map the first international basic concepts and standards to each other and to identify the essential differences between heterogeneous reference architecture models, as well as to determine the relevant terms and definitions for smart manufacturing. These activities are supported by the "Smart Manufacturing Standards Map Catalogue" (ISO/IEC TR 63306-1) and ISO/IEC TR 63306-2 "Smart manufacturing standards map (SM2) – Part 2: Catalogue". The catalogue is the result of a joint initiative of IEC and ISO via the joint Smart Manufacturing Standards Map Task Force (SM2TF) which aims at creating a standards catalogue modelled on the existing Smart Grid for the bodies involved in Smart Manufacturing, in order to facilitate the search for standardized criteria.

→ The linking of industrial manufacturing with information technology forms the core of Industrie 4.0. This linking is achieved via the data stream that flows between machines, departments and companies. Essential for this is a uniform, standardized understanding of the semantics of the data generated. For the assessments related to the chapter "Systems and their properties", it is true that all Industrie 4.0 technologies must prove their interoperability. In addition, the high level of interdisciplinarity in these areas also poses new challenges for standardization work and is addressed in V4 of the roadmap with a corresponding number of recommendations for action. Most are currently being implemented, and some will be revisited in an updated form in Version 5 of the roadmap.

1 See Roadmap V4, Chapter 4

2 See Roadmap V4, Chapter 5

PROGRESS RELATING TO THE NEED FOR STANDARDIZATION OF CROSS-CUTTING TOPICS (CHAPTER 3 OF THE ROADMAP VERSION 4)

→ In considering the recommendations for action on industrial security, an increased need for security for industrial supply chains has emerged. This not only involves ensuring the originality and integrity of components, products and data, but also, and in particular, their robustness against attacks on their availability. The EU has responded with the European Cyber Resilience Act (EU CRA), which will accelerate the definition and implementation of appropriate security standards. The creation of necessary use cases in a "data-driven" context of the digital ecosystem increasingly requires the integration of security-by-design approaches to ensure the trustworthiness of an ecosystem for the stakeholders involved.

→ For the aspects of humans and work in the context of Industrie 4.0, the progress assessment reveals an increasingly strong interconnectedness with digitalization, which must be safeguarded via standardization. This is because production staff can also use a laptop with Internet access to monitor and control production from anywhere. Human presence in the production halls will be necessary in certain cases only for maintenance and repairs that are not routine. With the publication of the "German Standardization Roadmap Innovative Work Environment", another document is available alongside the Standardization Roadmap Industrie 4.0 V4, which contains recommendations for action to improve the human-centred design of work in the digital world. The challenge will be to integrate this interlinking with standardization in an even more coordinated and targeted manner, and to identify the right addressees.

→ For Functional Safety in Industrie 4.0 in particular, the review reinforced the assessment that the relevance of the topic in the committees and working groups has increased even more than was the case in previous years. Thus, Functional Safety is implemented into liaison activities between IEC/TC 65 and ISO/IEC JTC 1/SC 42 Artificial Intelligence in the first working groups and projects related to safety. However, the projects are currently dealing with pre-normative publications, such as technical reports. In conclusion, it can be said that Functional Safety in Industrie 4.0 has been further developed, particularly at the conceptual level, and has now become a permanent fixture on the standardization agenda, although the actual transfer to standards with corresponding normative specifications and requirements has yet to take place.

→ In the area of Artificial Intelligence (AI), which was firstly included within the context of the latest roadmap version, progress was also made in implementing the recommendations for action, such as in the context of collecting and specifying AI use cases. For the industrial environment, this is an essential cornerstone for deriving necessary standardization requirements in industrial applications. Regarding the development and updating of a standardization roadmap and the derivation of action strategies, work has been initiated at national, European and international level on AI standardization roadmaps and action strategies. Worth mentioning are two major publications: the first edition of the DIN/DKE German Standardization Roadmap Artificial Intelligence, which was published at the end of 2020, and the CEN-CENELEC Road Map Report on AI, which was published in September 2020. In addition to these publications, there is the DIN/DKE German Standardization Roadmap Artificial Intelligence 2nd edition, work on which began at the start of 2022. Similarly, the committee landscape has expanded, with the establishment of CEN-CLC JTC 21 Artificial Intelligence in June 2021. In addition, an AI-specific advisory group was established at international level within ISO/IEC JTC 1/SC 42 in the fall of the same year. Both committees are developing a standardization map and an overview of ongoing and published projects.

2 Introduction

Over nearly a decade and with a total of four editions, the Standardization Roadmap Industrie 4.0 has become a central element of German standardization work and is an integral Part of the Industrie 4.0 standardization strategy. It is therefore time to take a closer look at the status of the implementation of the recommendations for action made in the roadmap and to show what concrete implementations and progress have been made in the past 24 months since the publication of the latest version.

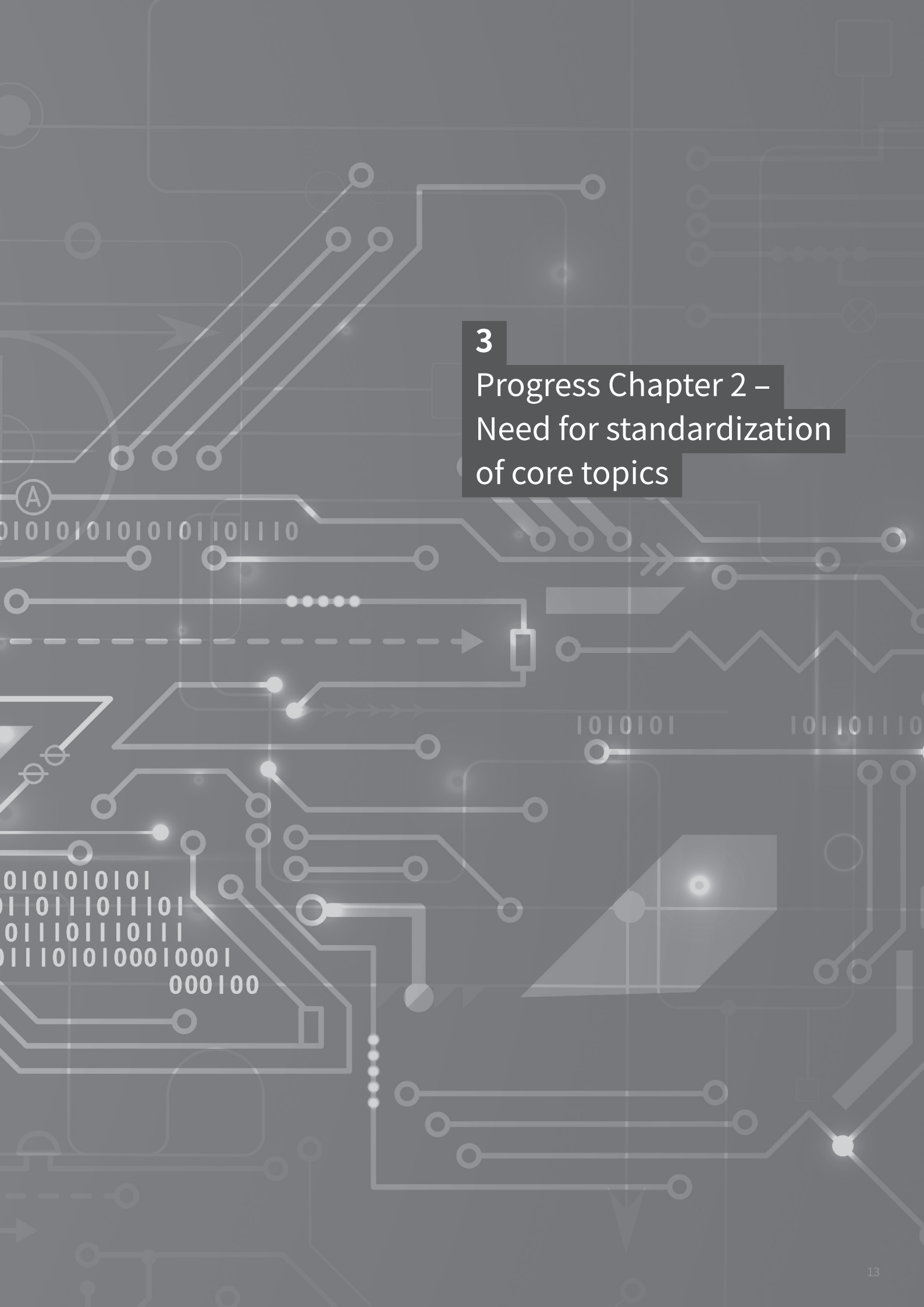
Basically, the review confirmed that applications such as digital twins are critical tools for industrial automation to identify stress points more quickly and to describe scenarios from product development and operation to effective asset utilization and risk. However, there are emerging challenges to consider in terms of data security, the need for robust real-time connectivity, specific technical capabilities, and the deployment and maintenance of sensor networks that enable the digital twin to collect environmental or operational data, for example.

In this context, concrete industrial solutions such as the Asset A S (AAS) not only enable predictive maintenance, more transparency and insights into product behaviour (until the end of its useful life), but also enable the creation of what-if scenarios and data-driven decision making. These new digital solutions not only make production more efficient and profitable, but they also enable the entire supply chain to be connected smoothly and with minimal effort to form a collaborative value network. Here, too, standardization is needed to ensure a high level of data sovereignty, data security and data integrity for the participants in such a collaborative data space. Against this background, the upcoming issue of the Standardization Roadmap Industrie 4.0 will also address the topic of “Data spaces and collaborative aspects in Industrie 4.0”.

The following two chapters on the need for standardization of core topics (Chapter 2) and the need for standardization of cross-cutting topics (Chapter 3) draw on the recommendations for action in Version 4 and assess their progress. This

updated picture will inform Version 5 of the roadmap and help draw a clear map of the standards environment and identify gaps.

With the outlook given in Chapter 4, this progress report not only focuses on the upcoming challenges for the individual sub-topics that will be addressed in the upcoming standardization roadmap. To the same extent, achieving sustainable and ecological development has also become a high priority for standardization, and the trend towards this will certainly intensify. Version 5 of the roadmap will therefore have to answer the question of how the path to resource-efficient and CO_2-neutral production can be designed. Today, the time seems favourable to further consolidate and expand Germany's and Europe's good position in international competition by emphasizing the sustainability aspects of Industrie 4.0. Evolving approaches, such as the Digital Product Passport (DPP) as an implementation of an AAS, and other activities will be represented in the upcoming Version 5.



3 Progress Chapter 2 – Need for standardization of core topics

3.1 Use cases and application scenarios

Recommendation for action Roadmap V4 **2.1-1**	The task force **“Smart manufacturing use cases”** of **IEC/TC 65/WG 23** (IEC 63283-2 “Industrial-process measurement, control and automation – Smart manufacturing – Part 2: Use cases”) should be actively supported by Germany in order to obtain a consistent and representative collection of use cases for Industrie 4.0. This will help the task force to establish itself as the central hub for a systematic consolidation of the many different use cases in the Industrie 4.0 environment.
Progress assessment	In the area of international cooperation, a personal union ensures that German use case activities are coordinated with the **„Smart manufacturing use cases task force”** of **IEC/TC 65/WG 23** via important international (bilateral) cooperation.
Recommendation for action Roadmap V4 **2.1-2**	The various concepts that formulate use cases based on more detailed descriptions such as the IIRA template should be continued. Examples are the joint activities with China and Japan, selected activities of Labs Network Industrie 4.0 (LNI 4.0)[3], as well as activities at European Union level, such as those planned in particular in the context of artificial intelligence within the AI-PPP[4].
Progress assessment	The work on the usage view “Edge Management”[5] as Part of the LNI 4.0 test bed and, at the business view level, the results of digital business models, which is being carried out with Japanese cooperation, are worthy of particular mention. In addition, use case discussions have begun in bilateral country collaborations (including those with China, Japan, South Korea) in the context of the AAS l, as well as data spaces. It is to be expected that this dialogue will be intensified in the run-up to standardization (see 2.1-A1).
Recommendation for action Roadmap V4 **2.1-A1**	Efforts should continue to be made to avoid overloading the term **“use case”** unnecessarily. It is not the aim to prescribe a uniform understanding, but it is recommended that activities position themselves in relation to the understanding formulated in this standardization roadmap so that this can be further enhanced.
Progress assessment	Feedback to various presentations and publications indicates that a consistent separation into a business perspective, an application perspective, and implementation perspectives derived from these is accepted and supported.

3 See Labs Network Industrie 4.0 – Praxiserprobungen und Standards (lni40.de)

4 See euRobotics and BDVA publish a joint vision for a European AI PPP

5 See LNI 4.0 Testbed Edge Management:

Recommendation for action Roadmap V4 **2.1-A2**	It is recommended to further promote the formulation of business scenarios, as it is especially promoted in cooperations with China, since business scenarios are not – at least at the moment – within the scope of **IEC/TC 65/WG 23**.
Progress assessment 	In addition to the publications "**Digital platforms in the manufacturing industry**"[6] by the Platform Industrie 4.0 and Robot Revolution Initiative and "**Examples of platform-based value networks in digital ecosystems**"[7] by the Expert Group Platform Economy of the VDMA, the initiated discussions on the value proposition of the AAS and on business scenarios in the context of Gaia-X and Catena-X are worth mentioning.

3.2 Reference architecture models

Recommendation for action Roadmap V4 **2.2-1 Differentiation and standardization of the terms "reference architecture" and "reference architecture model"**	It is recommended to investigate and describe the use of RAMI 4.0 model in comparison with other common methods for a continuously structured requirements management.
Progress assessment 	To harmonize the existing reference models and to monitor the development of the underlying architectures, a joint working group was established involving the committees **ISO/TC 184 "Automation systems and integration"** and **IEC/TC 65 "Industrial process measurement, control and automation"**. The resulting group is called **ISO/IEC/JWG 21 (Joint Working Group) "Smart Manufacturing Reference model(s)"** and brings together numerous experts from various countries. The Joint Working Group is currently dedicated to the development of IEC 63339 **"Unified reference model for smart manufacturing,"** which is intended to guide organizations in developing their own architectural models for the deployment of standards-based solutions for smart manufacturing. The concept is based on a complex representation for generating simple views from different models, which are specified by "views" in a vertical axis. The RAMI 4.0 model is referred to as a practical example.

6 See Industrie 4.0 – Digital Platforms in Manufacturing 2021

7 https://vdma.org/viewer/-/v2article/render/51299437

Recommendation for action Roadmap V4 **2.2-2 Differentiation and standardization of the terms "reference architecture" and "reference architecture model"**	A deeper understanding among Standards Developing Organizations (SDOs) and consortia, as well as corresponding standardization activities (such as inclusion in a glossary) regarding the differentiation of the terms "reference architectures" and "reference architecture models" seems necessary. The generated model patterns of a reference architecture can be differentiated according to the class of the architectures to be modelled. This means that there is an operational and functional differentiation between reference architectures and reference architecture models. A uniform understanding of this must be created in standardization and laid down in standards.
Progress assessment	The corresponding term differentiation is addressed with the activitieson IEC 63339 "**Unified reference model for smart manufacturing**" and IEC TR 63319 "**A meta-modelling analysis approach to smart manufacturing reference models**". Both projects make a recommendation for differentiating relevant terms such as "**model**", "**meta-model**", "**reference architecture**", "**reference model**", "**smart manufacturing reference model**".
Recommendation for action Roadmap V4 **2.2-3 Harmonization and compatibility of new and existing reference architecture models**	There is currently a need for harmonization due to the heterogeneous solutions for reference architecture models in the Industrie 4.0 environment. It is recommended that the reference architecture models (both existing and new) are critically reviewed for functional and operational aspects, i.e. whether they are already covered by existing models. However, if the functional and operational aspects do not correspond, no further harmonization activities should be undertaken. The activities of **ISO/IEC JTC 1/AG 8** and **ISO/IEC JWG 21** are thus to be coordinated.
Progress assessment	The harmonization and compatibility of existing and new reference models is one of the tasks of **ISO/IEC JWG 21**. Specifically identified in this effort were the development of a meta-modelling approach that can incorporate all key properties of each proposed reference model, including RAMI 4.0, IIC Industrial Internet Reference Architecture, Smart Manufacturing Standards Map (SM2), among others. The properties will be represented in a uniform manner and as a model, as well as in an abstract language (see IEC 63339). This activity is being supported by the "Smart manufacturing standards map catalogue (ISO/IEC TR 63306-1) "**Smart manufacturing standards map (SM2) – Part 1: Framework**" and ISO/IEC 63306-2 "**Smart manufacturing standards map (SM2) – Part 2: Catalogue**". The catalogue is the result of a joint initiative of IEC and ISO via the joint "**Smart Manufacturing Standards Map Task Force**" (SM2TF) which aims at creating a standards catalogue modelled on the existing Smart Grid for the bodies involved in Smart Manufacturing, in order to facilitate the search for standardized criteria.

3.3 Systems and characteristics

Recommendation for action Roadmap V4 **2.3-1 Consistently use and standardize the AAS concept**	To support the processes described above, such as maintenance functions and storage of knowledge in a life cycle record, the assets must be able to exchange data with production systems and plant operators via standardized interfaces with standardized semantics. This is achieved via the AAS concept, if the AAS or their generic submodels, as well as their communication between Industrie 4.0 components, are defined in standards (see Chapter 1). It is recommended to support and advance the activities of **IEC/TC 65/WG 24** IEC 63278-1 **"Asset administration shell for industrial applications – Part 1: Administration shell structure"**.
Progress assessment	Work on IEC 63278-1 has advanced with strong support from Germany, and the standard is being developed with the aim of publishing it in 2023. With the submission of the New Work Proposals IEC 63278-2: „**Information meta model"** and IEC 63278-3 „**Security provisions for Asset Administration Shells**" the further foundations are to be laid to continuously use and standardize the concept of the AAS hell. Among other things, an extension of the Common Data Dictionaries (CDD) for the representation of submodels is being prepared. All relevant Technical Committees (TC) are called upon to create and describe submodels. The InterOpera funding project is making a direct contribution to the description of submodels in the environment of standardization.
Recommendation for action Roadmap V4 **2.3-2 Internationalization of further parts of the AAS standards series**	It is proposed that the approach to the further structure of the series of standards be based on the national work of Platform Industrie 4.0/AG 1. In this context, reference is also made to the coordination with the activities of **ISO/IEC/JWG 21 Task Force 8 "Digital Twin and Asset Administration Shell"** and **IEC/TC 65/WG 24**. An elaboration of the digital life cycle record in accordance with work on DIN 77005-1 is taken up below in Recommendation for action 2.3-15.
Progress assessment	With the establishment of the standardization bodies **ISO/IEC JTC1/SC 41/WG 27 "Digital Twin – Strategy"** and **ISO/IEC JTC1/SC 41/WG 6 "Digital Twin – Standardization"**[8] the recommendations were implemented to set up the internationalization of further parts of the standards series. In addition, the Industrial Digital Twin Association (IDTA)[9], a user organization, was founded to bring together the various developments of the Industrial Digital Twin and to develop it together with industry as an open technology solution based on theAAS . Standardization in the context of the work within **IEC/TC 65/WG 24** is coordinated via the **IDTA "WG Submodels"**.

8 Note: in Liaison via JTC1/SC41/AG20 "Industrial Sector" – on IEC TC65 WG23 and TC65/WG24 as well as **JWG21**

9 See: IDTA

Recommendation for action Roadmap V4 **2.3-5 Characteristics and properties**	Characteristics of conceptual assets such as planning documents should be included in standardized dictionaries such as the **IEC SC 3D "Common Data Dictionary (CDD)"**, e.g. the specifications in VDI 2770. Additionally, planning documents should be communicable between humans and machines/Industrie 4.0 components.
Progress assessment 	The Industrial Digital Twin Association (IDTA) is currently working on an adaptation of VDI 2770. Possible implementation in international standardization remains to be clarified. In addition, extensive harmonization of VDI 2770 with the **intelligent information Request and Delivery Standard** (iiRDS) was achieved. This was submitted as a Publicly Available Specification (PAS) to **IEC/TC3 Documentation, graphical symbols and representations of technical information**.
Recommendation for action Roadmap V4 **2.3-8 Characteristics and properties**	Preparatory activities for the standardization of submodels of the AAS should be initiated. The integration should be done in coordination with **IEC/TC 65/WG 24**. A submodel must be standardized in its basic properties, which means that there must be both basic/obligatory properties and basic/obligatory functions that can be extended by an Industrie 4.0 partner via individual properties and functions. This means that, for example, the same mandatory properties and functions must be available for different assets when considering energy, so that, requirements, e.g., for all components of a system or systems of a plant can be easily consolidated or controlled in the same way. Specific additions remain possible.
Progress assessment 	As already noted for recommendation for action 2.3-1, preparatory activities for the standardization of submodels in standardization have been created or are in progress. Next, what is needed above all is a deepening and broadening of methodological knowledge, to which the InterOpera funding project should contribute. With the achieved project results, Technical Committees (TC) and other committees are to be approached in standardization based on their relevance in order to create further specific submodels.
Recommendation for action Roadmap V4 **2.3-9 Characteristics and properties Conditions for functional requirements**	Conditions must be created so that functional requirements (e.g. role and expected function) and their fulfilment (e.g. supported role, provided function) can be included in standardized dictionaries so that the execution of production processes by production systems can be planned.
Progress assessment 	In the meantime, there are extensive efforts to set up capability descriptions in a standardized way. Capabilities are technology-neutral descriptions of functions, i.e. independent of the way in which they are implemented ("capability" or "skill" as the description of the implemented capability). The core task here is to describe these capabilities on the one hand as requirements in the process description, and on the other hand also as capabilities of the devices. Ideally, these should be automatically compared and brought into line with each other. This also applies to the already running production process, e.g. in a transformable matrix production.

Recommendation for action Roadmap V4 **2.3-11 Digital nameplate**	The approaches for a digital nameplate in accordance with DIN SPEC 91406 (PAS) and VDE V 0170-100 are to be continued and implemented internationally in a suitable form.
Recommendation for action Roadmap V4 **2.3-12 Digital nameplate**	Adaptations in all application standards for machine-readable marking based on VDE V 0170-100 together with DIN SPEC 91406.
Progress assessment for 2.3-11 to 2.3-12 	IEC/SC 65E **"Devices and integration in enterprise systems"** is a committee that has implemented both recommendations. VDE V 0170-100 has been brought into international standardization as IEC 63365 **"Digital nameplate – Digital product marking"** and DIN SPEC 91406 as IEC 61406 **"Identification Link – Unambiguous biunique machine-readable identification"**.
Recommendation for action Roadmap V4 **2.3-13 Model of the digital life cycle record**	The model of the digital life cycle record based on DIN 77005-1 is to be considered as a submodel of the AAS. The specification of the AAS metamodel, available since the end of 2018, provides the necessary basis for this. It is recommended that the submodel for the life cycle record be further elaborated and incorporated into international standardization work on the AAS in **IEC/TC 65/WG 24**. (see Rec. for action 2.3-1, 2.3-2)
Progress assessment 	The information model for the digital life cycle record in DIN 77005-2, which is currently being developed, is based on the specifications in DIN 77005-1. A national draft standard is expected to be available once the commenting phase is complete. Subsequently, internationalization of the standard and closer coordination with the AAS will be sought. Due to the size of the model, designing it as a submodel of the AAS will be very challenging.
Recommendation for action Roadmap V4 **2.3-19 Maintainability**	Investigation into the internationalization of VDI 2770 Part 1 on minimum requirements for digital manufacturer information
Progress assessment 	In preparation for possible internationalization, a translation of VDI 2770 Part 1 into various languages is currently being examined. It is intended to submit a New Work Proposal to ISO for the internationalization of VDI 2770 Part 1 in 2022.

Recommendation for action Roadmap V4 **2.3-22 Validation and testing**	Operational models and appropriate tools are needed for a simulation. Tools and models need common semantics for machine execution and for a comprehensible representation of the characteristics of the considered system in its environment.
Progress assessment 	Some promising basic work has been started to initiate simulation models. By means of supporting use cases, submodels are created in the AAS Explorer in the open source procedure in projects such as the **ZVEI Working Group "Simulation and Industrie 4.0"**. Harmonization with other submodels of the AAS will then take place.
Recommendation for action Roadmap V4 **2.3-23 Industrial cloud platforms**	Standardization activities for a flexible and extensible architecture for future requirements of cognitive services, real-time applications and data marketplaces should be taken up in the relevant committees. As core elements, hybrid cloud platforms, IIoT applications and cyber-physical architectures should be investigated. Uniform life cycle management of all IT resources, means of production and technical building equipment are just as much a Part of this as the creation of an integrated infrastructure for real-time capable, cross-domain value-added networks for the AI-supported, autonomous production of the future.
Progress assessment 	Currently, **ISO/IEC/JTC 1/SC 38 "Cloud computing and distributed platforms"** is developing several standards that focus on multi-cloud concepts, in particular on the interoperability of multiple cloud services and data sharing frameworks. Nevertheless, the issue of technical cooperation at the platform level has so far remained open in the area of standardization. Such collaboration must fundamentally be built on a flexible and extensible rule-based framework architecture. This should enable a universally accepted framework for current and future requirements for cognitive services, real-time applications, data sovereignty, marketplaces and many other requirements in a digital ecosystem. To this end, the Gaia-X ecosystem makes its normative contribution to regulatory, industry, and technical standards, known as the **"architecture of standards"**[10], available to participants in such an ecosystem. This set of rules, formulated in a Gaia-X architecture[11], among other things, promises a high level of interoperability and security.

10 See: Architecture of standards :Gaia-X_Architecture_Document, December 21

11 Gaia-X Architecture Document 21.12 Release

3.4 Interoperability

Recommendation for action Roadmap V4 **2.4-3 Conformity with the ISO/IEC 21823 series**	DIN NA 043-01-41 IoT and other relevant bodies and committees should carefully review the current standards of the ISO/IEC 21823 series with regard to their direct reference to industry and report back to the mirror committee. Further DIN/DKE committees on semantics are to be included.
Progress assessment 	With regard to the consistency of standards concerning the AAS , current work on the ISO/IEC 21823 series, in particular ISO/IEC 21823-1 **"Interoperability for IoT Systems"**, is currently being carried out by IEC/TC 65/WG 24. In coordination with **ISO/IEC JTC 1/SC 41 "Internet of things and digital twin"**, the context of "interoperability" in the drafts such as that of IEC 63278-1 is to be examined and, if necessary, adapted. At national level, this activity is supported by mirror committees such as **DIN NA 043-01-41** and **DKE/AK 931.0.16**.
Recommendation for action Roadmap V4 **2.4-4 Duplications in terminologies**	Duplications in terminologies, in particular with regard to their identical or synonymous application, should be identified, checked, differentiated and/or adapted in the competent bodies in order to avoid their erroneous application in further normative documents. It is recommended to consolidate the terms with current international standards such as ISO/IEC 20924 and ongoing terminology activities in **IEC/TC 65 WG 23** on vocabulary.
Progress assessment 	For the consolidation of terms on an international level, the **Joint Project Team 3** (JPT 3) has been established in **IEC/TC 1** whose task is the further development of the International Electrotechnical Vocabulary (IEV). This is the authoritative source for **"standardized IEC terminology"** and deals with terminology for intelligent and digital systems. A major concern of the JPT3 is synchronization and avoidance of duplication, especially for basic terms. This is relevant, among other things, with regard to ISO/IEC 20924 and the ongoing activities on terminology in **IEC/TC 65/WG 23**. **IEC/TC 65/WG 23/TF "Smart manufacturing terms and definitions"** will implement the measures recommended by the JPT 3 accordingly.

3.5 Integration

Recommendation for action Roadmap V4 **2.5-1 Supplement existing standards (ISO 13585-1 or IEC 61360) on semantics**	The data formats required in the information world are taken from ISO 13585-1 or IEC 61360. The properties of ECLASS are also coded on this basis. However, AAS or submodels require additional property types for operational use compared to the purely descriptive characteristics of an asset. These are states and parameters of the assets as well as their measured and actuator values (dynamic data) Commands and entire functions (often called business functions) must also be described using the same concepts. The concept of properties in today's standards is to extend such semantics in the data models to be able to represent dynamic values correctly. For example, this can be done with corresponding new attributes in the ISO 13585-1 and IEC 61360 data model. Models for functions/commands are to be developed or existing ones defined in standards.
Progress assessment	The importance of a standardized dictionary as one of the fundamental aspects of creating meaningful AAS has increased over the past year. Essential concepts for this are described in the white paper **"Modelling the semantics of data of an AAS ll with elements of ECLASS".**[12] The document identifies the missing structures in the ECLASS conceptual data model that are necessary to meet the requirements of theAAS . Furthermore, the white paper also lists suggestions for the further development of the ECLASS data model and describes the cases in which necessary elements of the AAS metamodel are not supported by either IEC 61360 or ECLASS. Proposals for the extension of the ECLASS data model are being formulated for the identified gap. In parallel with the activities at ECLASS, **IEC/TC 3/SC 3D** is also investigating necessary extensions to the data model. First prototypical submodel templates of the AAS have already been realized in the **IEC Common Data Dictionaries (CDD)**.

12 White paper "Modelling the Semantics of Data of an Asset Administration Shell with Elements of ECLASS": https://www.plattform-i40.de/IP/Redaktion/DE/Downloads/Publikation/Whitepaper_Plattform-Eclass.html

Recommendation for action Roadmap V4 **2.5-2** **Sustainable and consistent harmonization of properties between ECLASS and CDD**	Given the fundamental importance of standardized semantics for Industrie 4.0 components, a multiple coexistence of different standards for the same semantics is not acceptable, since it prevents the overlapping interaction between Industrie 4.0 components. Parallel developments as in certain places today in IEC, ISO and ECLASS must be coordinated: The activities to harmonize the properties must be accelerated in the ECLASS and IEC committees involved. In particular, the existing properties should be brought to the same semantic and syntactic level and adapted. Standardized mechanisms and procedures for specifying new properties must be synchronised between ECLASS and CDD to avoid further differences in properties. Ideally, the publishers of properties (and other structural elements, e.g. classes, values and units) have interlocked their standards after the harmonization steps to such an extent that semantically identical elements have the same name and code, i.e. mean the same thing. Common content should be kept and processed identically in all databases or managed in a common database in order to structurally prevent the content from being divergent. The main publishers are IEC, ECLASS and in future probably also ISO. The results should be made publicly available.
Progress assessment 	At the end of 2020, ECLASS and IEC, together with ISO, initiated the COMDO (**One COMmon Data RepOsitory for Smart Manufacturing**) project to create a single common data repository. Again, progress was made on current implementation approaches for a common repository to develop a plan for implementation across relevant use cases. The next step is to submit a feasible proposal for implementation to the technical steering committees of the project partners (IEC/SMB, ISO/TMB, ECLASS Board).

3.6 Industrial communication

Recommendation for action Roadmap V4 **2.6-1** **Seamless transition between local industrial networks and industrial mobile radio networks**	New standards for global mobile network technologies should be configured or existing standards expanded in such a way as to enable a seamless transition between local industrial networks and industrial mobile radio networks. Starting points for the standardization of such heterogeneous, industrial networks can be the documents of the 5G-ACIA for the integration of Ethernet, TSN and OPC-UA in 5G.
Progress assessment	The profile currently under development for **IEC/IEEE 60802** is the connecting element of heterogeneous, industrial networks. This is shown in the 5G-ACIA white paper **"Integration of 5G with time-sensitive networking for industrial communications,"**[13] which identifies 5G and TSN technology as being key to future industrial communications. In the technical paper **"OPC UA for Field eXchange (FX)"** of the OPC Foundation, IEC/IEEE 60802 is also assigned an important role in **"Converged Networks"**.
Recommendation for action Roadmap V4 **2.6-6** **Summary of parameters and methods for the evaluation of industrial real-time communication systems**	Parameters and methods for the evaluation of industrial real-time communication systems (wired and wireless) are to be summarized and uniformly defined in a standard.
Progress assessment	A uniform approach to the evaluation of industrial real-time communication systems has been introduced into international standardization and is being further developed in **IEC/TC 65/AG 4 "Coordination of properties and CDD"**.
Recommendation for action Roadmap V4 **2.6-7** **Provision of test specifications**	Communication standards for Industrie 4.0 shall provide test specifications that can be used to demonstrate the performance, conformity and interoperability of products.
Progress assessment	With the standardization project for IEC 61802, a standard for test specifications based on IEC/IEEE 60802 **"TSN for industrial automation"** is being developed in **IEC/SC 65C/WG 18 "Time-sensitive networking for industrial automation"** to ensure provision.

13 White paper Integration of 5G with Time-Sensitive Networking for Industrial Communications: https://5g-acia.org/whitepapers/integration-of-5g-with-time-sensitive-networking-for-industrial-communications/

Recommendation for action Roadmap V4 **2.6-8** **Worldwide harmonization of frequency spectra for industrial automation applications**	Efforts to obtain a worldwide harmonization of frequency spectra for industrial automation applications should be actively assisted by experts in measurement and automation technology. Industry associations and Plattform Industrie 4.0 should formulate arguments and requirements for administrations (e.g. BNetzA in Germany) for consideration in frequency use planning. These should be internationally coordinated. The regulation applicable to Germany for frequency allocations for local frequency use in the 3,700–3,800 MHz frequency range should apply worldwide in the interests of international harmonization. It is also recommended to harmonize the concepts for non-public industrial network operation and for cooperative network operation with a public network operator.
Progress assessment	Worldwide harmonization of spectrum aspects is addressed in the 5G-ACIA white paper **"5G for connected industries and automation."**[14] The paper proposes the achievement of harmonization by means of a joint initiative of all relevant players in the emerging 5G ecosystem in manufacturing.
Recommendation for action Roadmap V4 **2.6-9** **Non-public networks**	New standards for global mobile network technologies should be configured or existing standards expanded in such a way that the use of a non-public local industrial network is also possible. The starting point should be the 5G ACIA's **"White paper 5G non-public networks for industrial scenarios"**.
Progress assessment	An updated version of the 5G ACIA's **"White paper 5G non-public networks for industrial scenarios"**[15] is available. This paper describes four industrial (IIoT) deployment scenarios for 3GPP-defined, non-public 5G networks. In addition, key aspects are considered, particularly service characteristics that can help highlight the differences between these scenarios.
Recommendation for action Roadmap V4 **2.6-11** **Uniform standardization of industrial location management**	Industrial location management requires the uniform standardization of the following aspects: (1) technologies for determining location data; (2) formats for location data; (3) agreements on data storage (central/decentralized); (4) protocols for data transport; (5) applications and visualization tools.
Progress assessment	**Omlox**[16] is a technology standard that enables technology- and manufacturer-independent provision of location data. Efforts for harmonization in the context of the industrial environment can add value and, for example, reduce the technical complexity of location systems. Standardized interfaces facilitate the integration of the systems at the customer's site and enable later expansion.

14 See: 5G for Connected Industries and Automation (Second Edition)

15 See: 5G Non-Public Networks for Industrial Scenarios

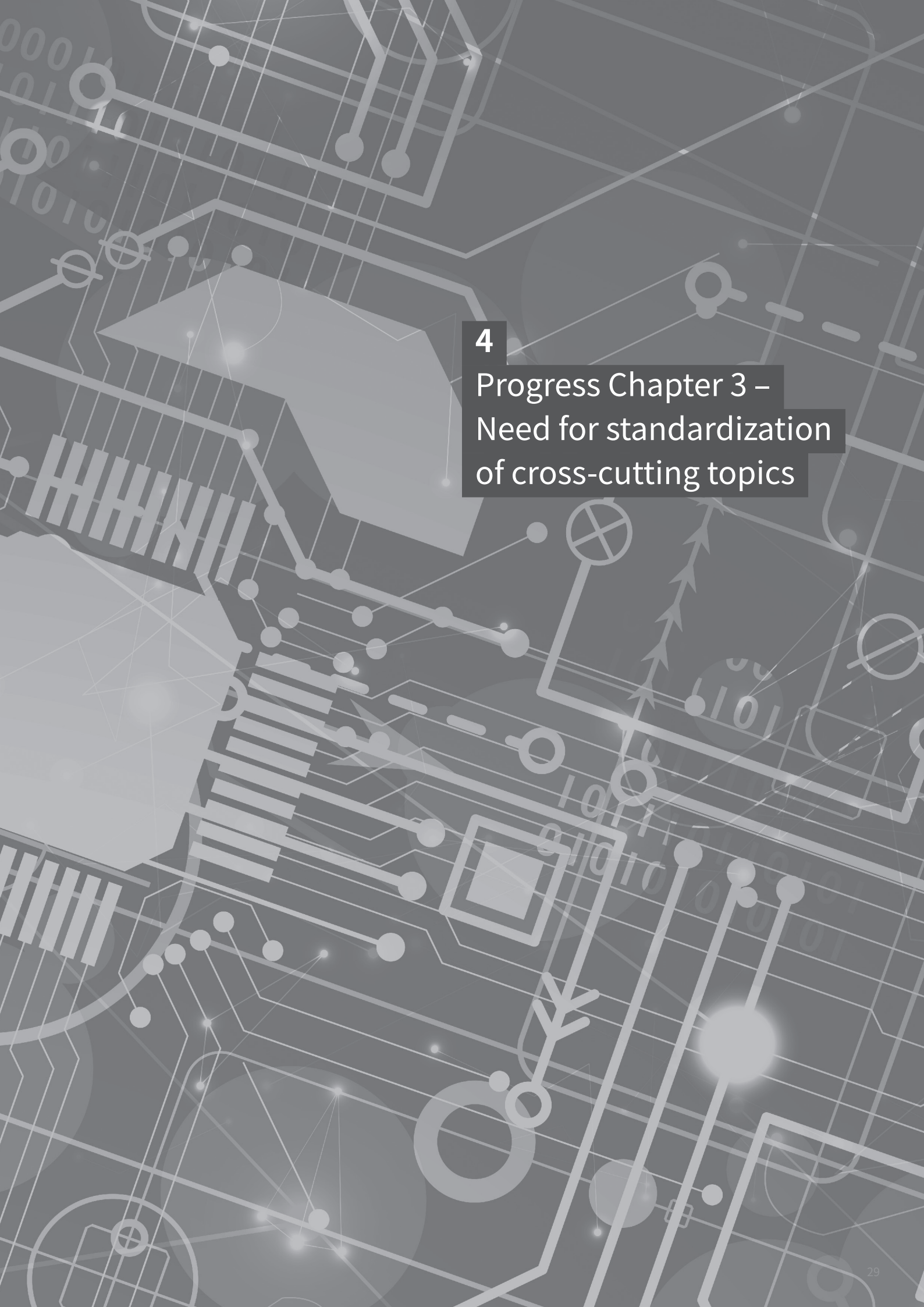
16 Omlox

3.7 Humans and work in Industrie 4.0

Recommendation for action Roadmap V4 **2.7-1**	The formulation of minimum standards for the consideration of socio-technical aspects is to be examined in various generic standards on ergonomics and work design. The relevant statements regarding the design of work systems are currently scattered across numerous standards. This means that operational planners find it more difficult to find them and to take sufficient account of them when planning Industrie 4.0 solutions. To this end, the overview of the relationships in ergonomics standardization should also be improved.
Recommendation for action Roadmap V4 **2.7-2**	Against this background it is recommended that operational planners be provided with a document containing a summary of all process-relevant statements regarding Industrie 4.0. This should first be implemented in a guide to work system design for Industrie 4.0 solutions.
Progress assessment **2.7-1 – 2.7.2** 	The same assessment applies to both recommendations for action. **DIN NA 023-00-06 AA "Ergonomics for work structure and product design in Industrie 4.0"** has taken up this recommendation, and a project on this is in the initiation phase.
Recommendation for action Roadmap V4 **2.7-8**	The progressive automation and mechanization of work organization can lead to a reduction in interaction processes between people. Care must be taken to identify and assess aspects of social isolation in terms of their potential impact on the mental stress of employees. There is a need to supplement or amend the following standard: DIN EN ISO 10075-2.
Progress assessment 	For the need for additions or changes described in the recommendation for action, the corresponding work on DIN EN ISO 10075-2 is in progress. The recommendation for action referred to in the Roadmap V4 was introduced by DIN NA 023-00-06 AA "Ergonomics of work and product design in Industrie 4.0".
Recommendation for action Roadmap V4 **2.7-13**	In the medium term, aspects of lifelong learning and digital literacy will gain in importance. New possibilities of technical support for employees' qualifications enable them to perform other and more varied tasks. This results in a need to modify some central standards, e.g. the draft DIN EN ISO 27500, and further standards such as DIN EN ISO 9241-11, DIN EN ISO 9241-20, -100, -171 and -210, DIN EN ISO 26800, DIN EN ISO 10075-2.
Progress assessment 	The previously formulated need to integrate aspects of lifelong learning and digital literacy to a greater extent was translated in a concrete step with the implementation of DIN EN ISO 27500.

Recommendation for action Roadmap V4 **2.7-17**	Assistance systems can specify the sequence in which tasks are to be processed or the system behind it, in terms of operational organizational objectives such as route optimization, time savings, order of tasks, etc. The interface design should allow the employee to decide when to accept the next job, how to carry out the next job, etc. The employee must have control over the process and be able to decide. DIN EN ISO 614-2 and DIN EN 10075-2, C standards for machines for example, require amendment.
Progress assessment 	With DIN EN ISO 10075-2, the design principles for ergonomic principles with regard to mental workload are currently being worked on; the previously formulated recommendations for action were brought into the process by **DIN NA 023-00-06 AA**.
Recommendation for action Roadmap V4 **2.7-26**	The process of teaching collaborative robots by employees should be ergonomically designed (e.g. expectation-compliant, error-tolerant and self-describing). ISO/TS 15066, DIN EN ISO 10218-2 require revision, for example.
Recommendation for action Roadmap V4 **2.7-27**	Requirements for exoskeletons must be made more concrete in standards. No relevant standards are yet available, new projects should be initiated.
Progress assessment for 2.7-26 to 2.7-27 	The same assessment applies to both recommendations for action. In 2021, the joint working committee **DIN NA 023-00-08 GA "Exoskeletons"** was founded within the DIN Standards Committee Ergonomics. The goal of the committee is to first conduct a review of the need for standardization in the process of teaching collaborative robots.

Recommendation for action Roadmap V4 **2.7-29**	When constructing and designing the technical systems, and in particular when designing human-machine interfaces, aspects of the design that will facilitate learning must be taken into account. It is a case of looking ahead and taking account of the operational processes (control and information processes, and communication and feedback processes).
Recommendation for action Roadmap V4 **2.7-30**	Procedures that will enable the establishment of lifelong learning should be defined as Part of the continual improvement process (and/or existing specialist knowledge should be updated by means of incremental learning).
Progress assessment für 2.-7-29 bis 2.7-30 	The same assessment applies to both recommendations for action. Work design that promotes learning is an important field of action in companies in order to efficiently and effectively meet the requirements for competence maintenance and development in the digitalized world of work and to exploit the learning potential of work systems. For both of the previously formulated recommendations for action, reference is made to the ongoing standardization activities for work design conducive to learning within the framework of VDI/VDE MT 7100 and DIN EN ISO 10075-2. VDI/VDE-MT 7100 Part 1 outlines the benefits for companies, employees and society, as well as the goals of work design that promotes learning. Key drivers and necessities are outlined; these include the speed and scope of the digital transformation, the global competitive situation, increase in dynamics and complexity of value creation, as well as demographic change and the change in expectations of the workforce. As already mentioned, DIN EN ISO 10075-2 deals with the design principles for ergonomic principles (2.7-17) with regard to mental workload. Here, too, the recommendations for action were taken on by DIN NA 023-00-06 AA.



4 Progress Chapter 3 – Need for standardization of cross-cutting topics

4.1 Open Source

Recommendation for action Roadmap V4 **3.1-1: Continuation and enhancement of agile standardization projects**	It is recommended to further develop agile standardization through pilot projects and thus to strengthen the cooperation of standardization with open source. Specifications (e.g. DIN SPEC or VDE SPEC) within the framework of Industrie 4.0 can offer a good opportunity for piloting.
Progress assessment 	The foundation for the further implementation of the recommendation for action has been laid. It has been confirmed that the role of open source solutions is important for standardization and vice versa. In the current discourse, this results in the development towards decoupling the terms **"agile approaches to standardization"** and **"open source solutions"** in standardization. This initially results in two separate directions. → **Agile approaches to standardization:** In the area of agile standardization, the interaction of SCI 4.0 and LNI 4.0 has already demonstrated how an agile approach can be enabled and, for example, functional gaps can be reported back to standardization. Building on this, standardization can react very quickly and in a targeted manner. A concrete example for this form of implementation is the test bed **"AAS"**[17]. A further example of this approach is DIN SPEC 92222 **"Reference architecture for industrial cloud federation"**[18]. Here, concrete use cases were validated in collaboration with the **Cloud2Cloud test bed**[19] of Labs Network Industrie 4.0 (LNI 4.0), so that the results of the tests could be directly fed back into the standardization project. Work on the technological implementation of the Industrial Cloud Federation by means of OPC-UA is being continued in a Joint Working Group between DIN and the OPC Foundation, with the necessary standardization requirements being derived on the basis of specific use cases in the form of demonstrators within the framework of a test bed. These procedures are examples of this agile standardization approach – one that allows for the practical preparation of concrete action recommendations. **Supporting open source activities from the standardization environment:** With the establishment of the DIN/DKE Joint Open-Source-Program Office (Joint OSPO), a contact point is now being set up which deals with questions about the successful interaction between standardization and open source solutions in various constellations.

17 See LNI4.0: Testbed AAS

18 See: https://www.beuth.de/en/technical-rule/din-spec-92222/346097997

19 See: https://lni40.de/cloud-kommunikation-ohne-grenzen/

Recommendation for action Roadmap V4 **3.1-2: Example of implementation through open source**	In order to accelerate the spread of Industrie 4.0, the development of sample implementations as open source should be promoted even more strongly. With the help of license recommendations and legal opinions it has to be ensured that the use and especially participation in open source projects is easily possible.
Progress assessment 	The topic of open source is being advanced both at the European level in the **CEN-CENELC (DITSAG) Project 4: "Open Source Solutions"** as well as on a national level with the upcoming foundation of the DIN/DKE Joint OSPO. The results obtained are being coordinated with each other and validated in pilot projects.

4.2 Industrial security

Recommendation for action Roadmap V4 **3.2-1: Harmonization of the EU Cybersecurity Act and the New Legislative Framework**	A constructive and comprehensive coordination between authorities, legislators and standardization organizations regarding the interplay of the two regulatory approaches of the EU Cybersecurity Act[20] and the New Legislative Framework[21] should take place in a timely manner.
Progress assessment 	Due to the complexity and the associated cost factors, it is very important that all affected stakeholders participate in the standardization process for industrial security. This includes component manufacturers, equipment manufacturers, integrators, certifiers, and operators/users. In addition, the regulatory level should be involved at an early stage, particularly on a European basis (EU, ENISA), in order to ensure the feasibility of future regulations (Cyber Security Act and Cyber Resilience Act) in the sense of the "**New Legislative Framework**".

20 See: Cyber security and Cyber resilience Act: Cyber Resilience Act | Shaping Europe's digital future (europa.eu)

21 See: New legislative framework (europa.eu)

Recommendation for action Roadmap V4 **3.2-2: Security infrastructure for secure inter-domain communication**	Secure communication requires secure identities (identifiers and attributes) and anchors of trust. Generating and administering secure identities and securing their trustworthiness require a secure infrastructure. The requirements for this include factors such as scalability, resilience, profitability, long-term fitness for purpose, and (user-defined) trustworthiness beyond local legal jurisdictions and independent of local jurisdictions. Cross-domain governance structures to support secure Industrie 4.0 communication must be defined and standardized. This will require the close cooperation of all industrial stakeholders. The possible use and integration of national and regional solutions (for example eIDAS)[22] must be examined with the help of the regulatory authorities and tested in field trials/pilot projects.
Progress assessment 	There has also been decisive activity in the area of research needs for security in industrial environments. This concerns the definition and implementation of infrastructures for secure identities for communication in global value networks, as well as ensuring the trustworthiness of the components and systems involved. In the past year, solutions such as eIDAS have come to the fore.
Recommendation for action Roadmap V4 **3.2-5: Access, roles and authorization mechanisms for Industrie 4.0**	Access to and use of data and resources within the framework of Industrie 4.0 cooperations requires standardized rules. Existing concepts such as IEC 62351 **"Power systems management and associated information exchange – Data and communications security"** can serve as a starting point. Boundary conditions governing implementation include scalability and the potential for representation in the form of specific vertical requirements.
Progress assessment 	As Part of the standardization activities of the New Work Item Proposal IEC 63278-3: Part 3: **"Security provisions for Asset Administration Shells"** the definition of access mechanisms to data and resources for Industrie 4.0 is being introduced at **IEC/TC 65/WG 24.**

22 See: eIDAS Regulation: eIDAS Regulation | Shaping Europe's digital future (europa.eu)

Recommendation for action Roadmap V4 **3.2-6: Security standards for the exchange of type and instance information of AAS**	Online and offline options are provided for the exchange of type or instance information. A data format for transfer files is proposed. Mechanisms for ensuring authenticity and confidentiality must be defined and established as global standards. Access APIs are to be defined. This must be coordinated with the concepts for secure identities (see [Recommendation for action 3.2-2]) and access control (see [Recommendation for action 3.2-5]).
Progress assessment 	In **IEC/TC 65/WG 23** and **WG 24**, work on security requirements and concepts was started in the context of the **"Smart Manufacturing Framework and System Architecture"** and the work on the **"Digital Administration Shell"** in the sense of security-by-design (see IEC TR 63283-3: **"Challenges for cybersecurity"** and IEC 6378-3: Part 3: **"Security provisions for Asset Administration Shells"**). The next step is to establish a Joint Advisory Group between **IEC/TC 65** and **ISO/IEC/JTC 1/SC 27 "Information security, cybersecurity and privacy protection"** to ensure consistent work.
Recommendation for action Roadmap V4 **3.2-7: Standardized security development process for integrators and operators**	IEC 62443-4-1 **"Secure product development lifecycle requirements"**defines a security engineering process for component suppliers; this must be expanded to take into account the other parties that form Part of the value added network, such as machinery construction companies, operators and integrators, in order to make it possible to implement comprehensive and consistent security architectures within the sense of **"security engineering"**.
Progress assessment 	The IEC 62443 **"Security for industrial automation and control systems"** series of standards supports IACS cybersecurity with a holistic approach for operators, integrators and manufacturers. The goal is to provide and ensure the integrity and availability of components and systems by defining security guidelines for implementation, integration and operation. This is also of great importance for the security of Industrie 4.0. **IEC/TC 65/WG 10 "Security for industrial process measurement and control – Network and system security"** is working on updates and completion in cooperation with ANSI/ISA 99. In addition, approaches to the horizontalization of the IEC 62443 series are being discussed.

Recommendation for action Roadmap V4 **3.2-8:** **Generic interface for security elements in embedded systems**	The implementation of cryptographically based security functions in Industrie 4.0 devices must be protected against attacks. High security levels can be achieved by integrating suitable security hardware. However, the diversity and complexity of the assemblies available on the market with their special boundary conditions leads to high integration costs and thus to a relatively high application threshold for manufacturers and integrators, especially for SMEs. A **"generic trust anchor API"**, which would be supported by many hardware manufacturers as a uniform programming interface, can provide help.
Progress assessment	For a uniform programming interface, the standard ISO/IEC TS 30168 **"Internet of Things (IoT) – Generic trust anchor application programming Interface for Industrial IoT"** was initiated at **ISO/IEC JTC 1/SC 41/WG 3 "IoT Foundational Standards"**, the processing of which is progressing. In the future, this will facilitate the integration of hardware-based security into industrial products and thus promote the implementation of cybersecurity, especially for critical infrastructures.
Recommendation for action Roadmap V4 **3.2-9:** **5G Security for Industry**	The fifth generation of mobile communications (5G) is intended to meet a wide range of availability, security and capacity requirements. Data and its transport between data source and data sink can be dynamically modified and processed. The network is thus becoming intelligent. In the ISO-OSI model the 5G technology can therefore be located at all levels 1 to 7. 5G technology and its use can be clustered in → the installation of 5G components as Part of product development, → local use of 5G on site and operation by organizations, and → the use of 5G services provided by mobile providers. New features and possibilities of 5G require the possibility of dynamic, flexible and scalable security architectures. On the basis of suitable industrial use cases, it must be possible to derive the security requirements taking into account existing security standards such as ISO/IEC 27001 and IEC 62443 within the framework of the 5G standards. → Industrial security guidelines must be implementable, especially for Industrie 4.0-based cross-company communication. → Application of IEC 62443 and ISO/IEC 27001 must be possible, especially in in-house operations. → The protection of metadata of the communication of devices, machines and plants must be guaranteed. This applies in particular to data that can be collected by the telecommunications provider via the signalling channel. → Industry compatible security requirements should be actively incorporated into the 5G standardization process.
Progress assessment	Special security aspects in the application of 5G communications in industrial environments are now being introduced into 3GPP via 5G ACIA. The goal is to support the easy integration of 5G into industrial domains. Initial results are integrated and available in 3GPP TS33.501.

4.3 Data protection/privacy

Recommendation for action Roadmap V4 **3.3-1: Trustworthiness of value networks**	The definition of process standards for the protection of personal data within value-added networks up to the protection of personal data required for individualized products with batch size 1, among other things: → Rules for classifying data and information, also in the respective context (contexts are very relevant because they massively influence the sensitivity and meaningfulness of data, e.g. an article number in an Internet order seems harmless until it can be linked to e.g. a drug product database, which then shows that the product is e.g. a cancer drug or a psychotropic drug. The knowledge that the format of the article number indicates a medical device is also significant). → Rules for the exchange of classified data and information (which data may be passed on where under which circumstances? → What may the recipient do with it? When must it be deleted, if necessary?); → Methods of evaluating the trustworthiness of cooperation partners. Examples of mechanisms are manufacturer declarations, certificates, auditing.
Recommendation for action Roadmap V4 **3.3-2: Privacy compliant auditing**	Definition of standards for privacy-compliant auditing processes that process personal data and/or work at risky interfaces in a manner compatible with data protection, including → Methods for data-saving (e.g. aggregated) logging, or → methods for local processing and evaluation of sensitive data so that they can be aggregated or deleted afterwards.
Recommendation for action Roadmap V4 **3.3-3: Relationship between data protection standards and Industrie 4.0 scenarios**	The fitness for purpose of existing standards that relate to Industrie 4.0 scenarios must be clarified. → In the case of automated communication across domain boundaries (e.g. as the boundaries between jurisdictions), the relevant data protection requirements and associated security requirements derived from them must be harmonized. → Access control standards must be able to manage resources in a domain-oriented manner in order to ensure that the respective level of data protection is taken into account, especially for cross-border data transfers in the value chain, for example from the EU to third countries whose level of data protection has or has not been recognized as equivalent to that of the EU, especially since such recognition can be granted or withdrawn. The domain-oriented administration of access control standards must functionally cover these recognition dynamics. Data protection standards must apply to “intelligent” home appliances (household appliances, toys, etc.) produced in Industrie 4.0 processes and their communication needs (including back to the manufacturer).

Progress assessment for 3.3-1 to 3.3-3

The first relevant standards on the trustworthiness of value networks are being developed. In doing so, the field is being approached from side topics, such as information security management in organizations and consumer protection in IoT devices. With the publication of ISO/IEC 27701 **"Extension to ISO/IEC 27001 and ISO/IEC 27002 for privacy information management – Requirements and guidelines"**, many users of information security management certification to ISO/IEC 27001 and ISO/IEC 27002 are broadening their perspective on privacy. The tests associated with the certifications and questions about the technical and organizational implementation of the necessary measures generate a need for implementation of the relevant standards on data protection and identity management[23] in the Industrie 4.0 sector as well. Other relevant standards are being developed by **ISO/IEC/JTC 1/SC 27/WG 5 "Identity management and privacy technologies"**, such as ISO/IEC DIS 27556 **"User-centric privacy preferences management framework"**, ISO/IEC DIS 27557 **"Organizational privacy risk management"**, ISO/IEC DIS 27559 **"Privacy enhancing data de-identification framework"**, ISO/IEC AWI TS 27560 **"Consent record information structure"**, ISO/IEC AWI TS 27561 **"Privacy operationalization model and method for engineering (POMME)"**, ISO/IEC DTR 27563 **"Impact of security and privacy in artificial intelligence use cases"**.

Requirements for auditors and certifiers of information security management systems have also been formulated by **ISO/IEC/JTC 1/SC 27/WG 5** and, due to urgent market demand, have been provisionally published as ISO/IEC TS 27006-2 **"Requirements for bodies providing audit and certification of information security management systems – Part 2: Privacy information management systems"**. At present the TS is being developed into a full International Standard.

Because IoT devices very often process personal data, they are the focus of the ISO/DIS 31700 project **"Consumer protection – Privacy by design for consumer goods and services"** of ISO/PC 317 of the same name. The Industrie 4.0 scenario, in which devices can still be in contact with the manufacturer after delivery ("calling home") and possibly transmit personal usage data, is also being taken into account.

Other standards on IoT Security and Privacy are being developed in the projects ISO/IEC 24700, ISO/IEC 24702 and ISO/IEC 24703 by **ISO/IEC/JTC 1/SC 27/WG 4 "Security controls and services"**.

23 Among others (e.g. ISO/IEC 29100, ISO/IEC 24760, ISO/IEC 29134, ISO/IEC 29184, ISO/IEC 27555)

4.4 Trustworthiness of value creation processes in Industrie 4.0

Recommendation for action Roadmap V4 **3.4-1: Definition of process standards for the trustworthiness of collaboration within an I4.0 value-added network**	These include: → the standardization of "trustworthiness capability profiles" → methods of evaluating the trustworthiness of cooperation partners. Examples of mechanisms include manufacturer declarations, certificates, auditing → rules for the exchange of classified data and information → minimum security requirements for B2B → integration of processes and components → compliance with regulatory provisions
Progress assessment 	Currently, the definition of process standards for trustworthiness in the trustworthiness environment is being contributed and addressed by **ISO/IEC/JTC 1/WG 13 "Trustworthiness"**. These IoT-related results are referenced and anchored in **ISO/IEC/JTC 1/SC 41** as well as in **ISO/TC 292 "Security and resilience"** on the topic of supply chain security.

4.5 Functional safety in Industrie 4.0

Recommendation for action Roadmap V4 **3.5-1**	The implementation of the Industrie 4.0 concepts leads to a further modularization of plants and components with great effects also on the engineering process. It should be considered how Industrie 4.0 concepts can also take into account plant safety and functional safety issues. This can be done by extending the concept of the AAS to a "Safe AAS".
Progress assessment 	The topic of the impact of Industrie 4.0 on the safety life cycle is being considered in the **"Task force recommendations for safety"** of the DKE working group 931.0.14 **"Smart manufacturing and Industrie 4.0"**. A description of safety properties by means of semantic features is regarded as being central to a digital (machine-interpretable) documentation of the individual steps of the safety life cycle (e.g. risk analysis). For this purpose, a standardized format of a semantically interoperable (machine-interpretable) description is needed. The task force mentioned above proposes a project to develop a standardized description of hazards and safety measures. The topic of risk analysis should be considered, for example, at the level of ISO 12100 **"Safety of machinery – General principles for design"** (or, for example, the HAZOP method). Minimum requirements for machine interpretability are also to be described. The results of this project should be incorporated into the concept of the AAS and the description of aspects of assets in submodels. In the framework of a German-Chinese standardization cooperation, the concept of a **"Safety data dictionary"** (see also Recommendation for Action 3.5-2) is currently being developed.

Recommendation for action Roadmap V4 **3.5-2**	Standardized procedures and methods should be developed to enable on-time risk management throughout the life cycle without compromising the confidentiality of the technical documentation. In accordance with the most recent German-Chinese agreements, a guideline should first be developed (**"Sino-German White Paper on Functional Safety for Industrie 4.0 and Intelligent Manufacturing"**[24]), which sensitizes the stakeholders with regard to the possible repercussions (increases in risk or compromise of risk-reducing measures) of different Industrie 4.0 application scenarios on plant safety.
Progress assessment 	The above-mentioned white paper, **"Sino-German White Paper on Functional Safety for Industrie 4.0 and Intelligent Manufacturing"**, published in July 2020, addressed the increasing complexity and interconnectedness between systems and outlined how the entire infrastructure has become more vulnerable to internal failures and cyber-attacks. In this respect, the paper analyzed existing standards and specifications, and made recommendations to achieve safety for Industrie 4.0. As already mentioned, the concept of **"digital safety life cycle management"** is currently being investigated within the framework of the German-Chinese standardization cooperation (DCKN). Further concrete approaches in the direction of **"digital safety life cycle management"** are currently being developed within the framework of the **"Report on safety recommendations for Smart Manufacturing"** of the DKE/AK 931.0.14 **"Task force safety"**.
Recommendation for action Roadmap V4 **3.5-3**	The effects of the use of AI systems in an industrial environment on plant safety should be considered. Current findings of AI research and application, e.g. explainable AI, should be considered to what extent safety requirements can be met when using AI and how these requirements can be described in standards.
Progress assessment 	The project ISO/IEC TR 5469 **"Artificial intelligence – Functional safety and AI systems"** was initiated by **ISO/IEC/JTC 1/SC 42/WG 3 "Artificial Intelligence – Trustworthiness"** working together with **IEC/TC 65/SC 65A "System aspects"** This Technical Report describes properties, risk factors, and possible approaches for realizing safety-relevant functions with AI methods. The publication of the TR is planned sometime during 2022. The working group DKE/AK 914.0.11 **"Functional safety and artificial intelligence"** was founded at DKE for this purpose.
Recommendation for action Roadmap V4 **3.5-4**	The work on safety and security should be further deepened and made more concrete. This should be done as Part of the revision of IEC TR 63069 **"Industrial-process measurement, control and automation – Framework for functional safety and security"**. A further development towards publication as a Technical Specification (TS) or an International Standard (IS) should be discussed.
Progress assessment 	A revision of IEC TR 63069 is planned. However, a formal revision has not yet been initiated.[25]

24 Sino-German White Paper on Functional Safety for Industrie 4.0 and Intelligent Manufacturing (bundesregierung.de)

25 As of January 2022

4.6 Artificial intelligence in industrial applications

Recommendation for action Roadmap V4 **4.1-1 Standardized terminology of artificial intelligence for Industrie 4.0**	Definitions of terms in existing (international) standards with a focus on "**artificial intelligence**" are to be continuously checked for consistency with regard to their applicability in Industrie 4.0 and clarified where necessary. Identified inconsistencies and obstacles to application are to be dealt with in the corresponding standards committees.
Progress assessment	The standard ISO/IEC 22989 "**Information technology – Artificial intelligence – Artificial intelligence concepts and terminology**" (**ISO/IEC JTC 1/SC 42/WG 1**) defines terminology in this area. The national mirror work takes place in the **DIN/DKE Joint Committee Artificial Intelligence** in the NIA, in which representatives of the SCI 4.0 Expert Council Artificial Intelligence in Industrial Applications are also active as staff members in order to continuously check the consistency for Industrie 4.0 applicability.
Recommendation for action Roadmap V4 **4.1-2: Application scenarios and use cases**	Based on the preliminary work of Working Group 2 of the Plattform Industrie 4.0, nationally coordinated application scenarios and use cases for Artificial Intelligence in Industrie 4.0 are to be developed and introduced into bilateral and international working and expert groups, as well as standards committees The use of a uniform template and of the IIRA Viewpoints should be aimed at.
Progress assessment	Technical Report ISO/IEC TR 24030 "**Artificial Intelligence – Use cases von ISO/IEC/JTC 1/SC 42/WG 4 – Use cases and applications**" was published in 2021. The document also includes use cases from the Industrie 4.0 environment The Technical Report is currently being revised so that it will once again be possible to include and analyze additional Industrie 4.0-relevant use cases. Use cases were collected and analyzed as Part of the work of **IEC/TC 65/WG 23**. The use case collection will be published as Part of IEC TR 63283-2 "**Industrial-process measurement, control and automation – Smart Manufacturing – Part 2 Use cases**" in 2022 and will consequently contain use cases for the application of AI.
Recommendation for action Roadmap V4 **4.1-3: Standardized assessment framework for the application of AI methods**	A uniform location and assessment framework for AI methods should be developed by horizontal standardization bodies. Appropriate classifications of the autonomy of technical systems, necessary metrics for evaluation methods for Industrie 4.0 as well as further requirements, concepts and methodologies should be addressed by vertical standards committees and should be introduced in standards committees in an appropriate manner.
Progress assessment	At international level standards and specifications on horizontal AI methods and systems are being published, including ISO/IEC 5392 "**Information technology – Artificial intelligence – Reference architecture of knowledge engineering**" and ISO/IEC 42001 "**Artificial intelligence management system**". Through the national mirror work in the **DIN/DKE Joint Committee Artificial Intelligence**, the results of the standards and specifications developed in this way can be reviewed directly for Industrie 4.0 by the **SCI 4.0 Expert Council AI** and vertical standardization work can be initiated on this basis.

Recommendation for action Roadmap V4 **4.1-5: Trustworthiness of AI**	The importance of trustworthiness of artificial intelligence or systems in which AI processes, technologies or methods are used are to be investigated in detail (see also Recommendations for action 4.1-1, 4.1-2); in particular the fundamental reference to cross-sectional technologies such as IT security and functional safety are to be considered.
Progress assessment 	A series of standards on trustworthiness is being developed In **ISO/IEC JTC 1/SC 42/WG 3 "Artificial intelligence – Trustworthiness"**. An overview of trustworthiness in relation to AI is given in the published Technical Report ISO/IEC TR 24028 **"Information technology – AI- Overview of trustworthiness in artificial intelligence"**. In addition, the Technical Report ISO/IEC TR 24027 **"Information technology – Artificial intelligence (AI) – Bias in AI systems and AI aided decision making"** was published in 2021. With the VDE application rule VDE-AR-E 2842-61-1 **"Development and trustworthiness of autonomous/cognitive systems"**, an important preliminary standard on the subject of AI trustworthiness was published in July 2021.
Recommendation for action Roadmap V4 **4.1-6: Development and continuous updating of a standardization map and derivation of strategies for action**	In order to take advantage of the various recommendations for action described in the Standardization Roadmap Industrie 4.0 V4 for AI (see in particular Recommendations for action 4.1-1, 4.1-2, 4.1-4A, 4.1-5), the development and continuous updating of a standardization map for artificial intelligence in general, and for AI in industrial applications in particular, is recommended. In particular, the exchange with other international standardization activities of ISO, IEC and at European level (e.g. the Stand.ICT.eu project or the Artificial Intelligence Focus Group) should be actively promoted (see also Recommendation for action 4.1-7).
Progress assessment 	Work on standardization maps and action strategies regarding AI has been launched or published at national, European and international level. The results of the first edition of the Standardization Roadmap AI were already presented in 2020 and handed over to the German government. The identified normative recommendations for action, which were formulated in the first edition, are currently being implemented. The second edition of the DIN/DKE Standardization Roadmap AI, which has now been initiated, has the task of continuing and further developing the results of the first edition of the roadmap. In addition to Industrie 4.0, the second edition will address six other focus topics on relevant aspects of AI. In addition, new focal points are being set and, for example, subject areas such as socio-technical systems, financial services and energy/environment are being considered. At the European level, the **CEN-CLC JTC 21 "Artificial Intelligence"** was founded in June 2021, whose **WG 1 "Strategic Advisory Group"** has as one of its objectives the development of a standardization roadmap and strategy with a focus on Europe. At the international level, an Advisory Group at **ISO/IEC/JTC 1/SC 42 "Artificial Intelligence"** was established in the fall of 2021 to develop a standardization map and an overview of ongoing and published projects. Other working groups of the same SC are developing roadmap strategies for further projects in their thematic areas in ad hoc groups A continuously updated summary of the main standardization bodies and their structural organization in the context of AI in industrial applications can be found on the website of the SCI4.0 Expert Council Artificial Intelligence in Industrial Applications.

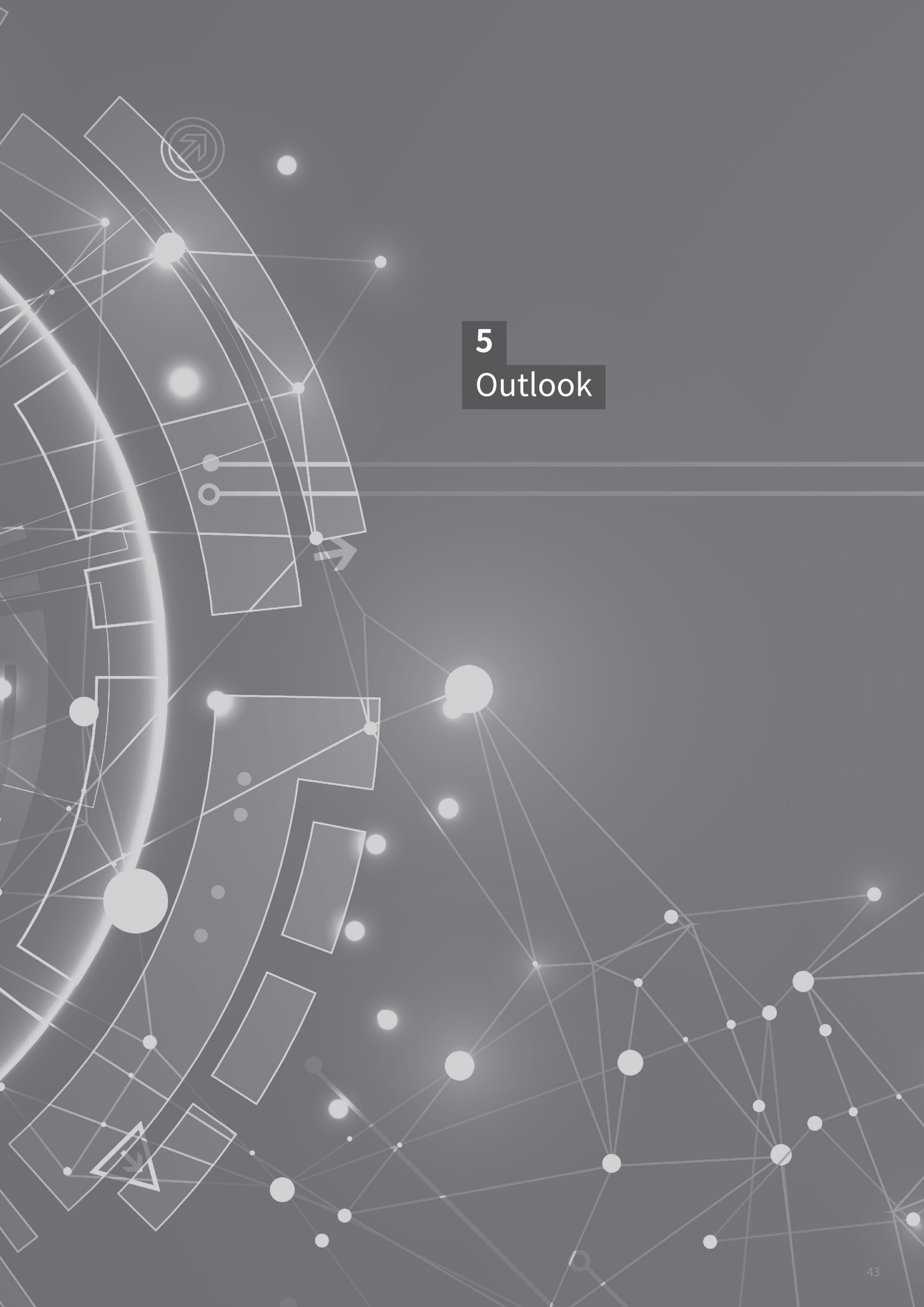
Recommendation for action Roadmap V4 **4.1-7: Synchronization, coordination and exchange with (national and international) standardization roadmaps and guidelines**	The cross-committee exchange between standardization activities in the context of artificial intelligence, the safeguarding and ensuring of the requirements of industrial automation in horizontal standardization committees, and the coordination and harmonization of requirements and standardization activities of Artificial Intelligence for Industrie 4.0 in the sense of vertical standardization must be strengthened. In particular, the exchange between horizontal standards bodies (such as ISO/IEC JTC/1 SC42) and vertical needs and requirements in Industrie 4.0 is necessary and can only be ensured by the participation of industrial representatives in these bodies and national, institutional representatives of vertical and horizontal standards organizations. This task should be entrusted to a body for the coordination and harmonization of standardization activities in the context of Industrie 4.0, which works in close coordination with horizontal standardization bodies and explicitly addresses the topic of artificial intelligence.
Progress assessment	The first edition of the German DIN/DKE Standardization Roadmap AI, which also includes a large section on Industrie 4.0, was made available and discussed both at European level in the AI Focus Group and further at **CEN-CLC JTC 21 "Joint Technical Committee Artificial Intelligence"**. **CEN-CLC JTC 21** was founded on the basis of the recommendations of the DIN/DKE Standardization Roadmap AI. In fall 2021 the newly established DIN/DKE Joint Committee on AI decided to submit the **DIN/DKE Standardization Roadmap AI** to the **ISO/IEC JTC 1/SC 42 "Advisory Group"** for the preparation of international standardization roadmap work. Further harmonization of AI-specific standardization aspects in Industrie 4.0 is currently being actively promoted through bilateral dialogues between different countries. In particular, within the framework of the I4.0[24] sub-working group of the German-Chinese standardization cooperation, the AI-specific standardization aspects are being elaborated in an overview and a comparison of national and international standardization activities of Germany and China.

26 German-Chinese Standardization Cooperation Commission, Subworking group I4.0

Recommendation for action Roadmap V4 **4.1-8A: Digitally formulated standards and specifications for automated evaluation**	Digitally formulated standards and specifications for automated evaluation Industrie 4.0 and especially the use of AI can play a pioneering role in the application of digitally formulated standards and specifications. This requires both the availability of digitally formulated standards and suitable evaluation procedures. The application of digitally formulated standards for automated evaluation should be investigated and promoted. For example, machine-interpretable standards can be used for automatic evaluation in the development of components, machines and systems in order to automatically check the conformity of developments to standards (see Recommendation for action 4.1-4A).
Progress assessment 	As early as 2017, DIN and DKE started work on the SMART Standards concept. In 2019, pilot projects were launched at European level with the participation of DIN and DKE, which were analyzed in 2020. As of July 2020, DIN has taken over the management of one of the CEN pilot projects **"New Work Item"** as Part of the strategic corporate project **"SMART Standards"**. The pilot project concluded at the end of 2021.[27] Further work on SMART standards is being carried out within the IDiS initiative.[28] Industrie 4.0-specific aspects, also in the context of artificial intelligence, are being considered in the context of Platform Industrie 4.0 – Working Group 2, among other things.

27 See: PROJECT REPORT „Standards of the future" Pilot Project 4 „New Work Item"

28 See: IDiS – Initiative Digitale Standards



5 Outlook

The new Standardization Roadmap Industrie 4.0 Version 5 will update and further develop the results of the fourth edition of the roadmap. In doing so, the current issue will set different priorities and will address recommendations for action and new cross-cutting topics such as industrial data spaces and ecological aspects in Industrie 4.0. Based on the progress assessments made previously, the following outlook can be made, also with regard to the upcoming Standardization Roadmap Industrie 4.0:

→ **Analyze and evaluate use cases for application and industry relevance:** The various use case activities in the working groups and committees will be continued on a decentralized basis, and the overall picture will be further focussed through a discussion of various cross-references. It is recommended that the emerging topic of data spaces in Industrie 4.0 be addressed more intensively and, in particular, that a consideration from the use case perspective be taken into account.

→ **Systemic implementation of Industrie 4.0:** There is the overarching challenge of systematically merging the different levels of abstraction of a business model and application perspective with the often very detailed technical considerations. Following the clarification of many detailed issues, the development and harmonization of many existing and emerging technology approaches, systemic development and the standardization of systems, are increasingly taking centre stage. Only the systemic implementation of Industrie 4.0 will bring the expected productivity benefits for companies.

→ **Uniform standards for greater interoperability:** Uniform standards for greater interoperability remain a fundamental prerequisite for applications such as the digital twin. This is also reflected in the assessments and outlooks described in this progress report. A tool is needed that establishes a standardized and seamless exchange of information between all stakeholders in a consistent manner. This tool for a standardized exchange is the Asset Administration Shell. Like a digital twin, it maps all objects and thus provides the interface for Industrie 4.0 communication. The AAS is therefore composed of many different submodels that describe the characteristics and properties in detail. Thus, standardized mechanisms and methods for the specification of new properties are now increasingly being synchronized between ISO, ECLASS and IEC. The upcoming edition will thereby investigate whether further divergences between ECLASS and CDD could be avoided. Further end-to-end use and standardization of the AAS will continue to be addressed by the SRI 4.0 version 5 to make it the central “integration plug” for digital ecosystems.

→ **Industrial communication:** With its referencing in further technical standards (e.g. OPC-UA, 5G-ACIA), the importance of the IEC/IEEE 60802 profile will increase. Supplemented by clauses on a security model, the profile follows a security by design approach. Another activity in IEEE 802 is an attempt to convert Cut-Through Forwarding (CTF) technology into an IEEE standard. CTF technology is already used in various imprints and reduces latency in networks, especially those with a linear topology. The development of a standard for industrial networks is mandatory for the application of the technology in the sense of “converged networks”.

→ **Humans and work in Industrie 4.0:** The effects of the digital transformation, compounded by the effects of the pandemic, will be felt throughout the world of work. Inevitably, Industrie 4.0 also raises the question of what tasks employees should take on. Production work is becoming more demanding, varied and creative – and will continue to change. While the robots are working in the production hall, employees sit together in small groups and exchange ideas to further develop their processes and products. Where strenuous and physical work is eliminated, there is room for creativity and innovation work. In SRI 4.0 version 5, we will identify which standardization activities are needed to shape the innovation and productivity returns of Industrie 4.0 and, through the use of new technologies, the sustainability turnaround.

→ **Agile standardization by means of open source:** The great importance of open source and the development of open source reference implementations to accelerate the distribution of Industrie 4.0 have already been

highlighted. In the next edition, the topics of agile standardization (as a method) and open source (as a tool) will be considered separately in order to prevent the mixing of the two terms and to highlight the potential of both topics.

→ **Industrial Security:** For further digitalization, especially in the context of industrial production, industrial security is to be regarded as an important enabler. In the future, it will be important to describe necessary use cases from a data-driven context. This in turn requires the integration of security by design approaches to ensure the trustworthiness of a digital ecosystem for the stakeholders involved.

→ **Concretization of the concepts for Functional Safety in Industrie 4.0:** An important step for the coming months will be the further concretization of the developed concepts. This is a prerequisite for the transfer of these concepts into standards with corresponding normative specifications and requirements. The initiation of corresponding research projects can be a suitable measure to accelerate this development. The upcoming European AI regulation needs to be considered, especially to what extend it will set requirements for the use of AI systems in safety-critical industrial environments.

→ **Sustainability and ecological aspects of Industrie 4.0:** Industrie 4.0 and the technologies linked to it play a central role in reducing CO_2 emissions from production. Digital product passports (DPP) that map standardized information on energy and resource consumption are an important step for sustainable production. Industrie 4.0 makes it possible to tap additional potentials for resource efficiency. In combination with constructive and process-related approaches, material cycles can be closed over the entire product life cycle. Industrie 4.0 is a significant enabler for the circular economy and environmental and climate protection. The first concrete measures, such as the DPP, are already underway. The DPP is a data set that summarizes information on the components, materials and chemical substances, but also on repairability, spare parts or proper disposal of a product. The goal is to collect data across all phases of the product life cycle and make it available for various purposes at all these stages (design, manufacture, use, disposal). Structuring environmentally relevant data in a standardized, comparable format enables all actors in the value chain, supply chain and digital ecosystems to leverage potential in the area of environmental and climate protection and to work together towards a sustainable, circular economy. One specific requirement description from the field of Industrie 4.0 is to replace classic nameplates with electronic identification. There is also a need to provide further device information using modern information concepts such as the AAS in Industrie 4.0. Due to the different requirements for a digital nameplate, there are currently two forms at international level. These two standardization proposals have been submitted to the IEC, and the related activities have already started.[29]

In conclusion, close coordination of the various disciplines is required for the successful national setting of standards and specifications.This trend will continue to intensify. It is already foreseeable that topics such as semantic aspects of interoperability or collaborative industrial data spaces will become even more concrete. Hence, there is also the emerging challenge of creating national, European and international structures and formulating definitions for coordinated data models.

29 See Recommendation for action 2.3-12; IEC/SC 65E Devices and integration in enterprise: IEC 63365 ED1 Digital Nameplate – Digital Product Marking; IEC 61406 ED1 Identification Link – Unambiguous biunique Machine-Readable Identification)

Against this background, the fifth edition of the Standardization Roadmap Industrie 4.0 will address the existing and upcoming challenges on the basis of new findings and place them in the relevant normative context. It will provide an up-to-date picture of the standardization and stakeholder landscape, identify existing or potential gaps, and make appropriate recommendations for action. The expressed goal is to ensure and coordinate internationally the pervasiveness of an open and global Industrie 4.0 ecosystem .

With this in mind, we would like to call upon and motivate all interested parties to actively participate in the process of creating the new Standardization Roadmap Industrie 4.0.

Annex 1
Abbreviations

AA	Arbeitsausschuss (Working Committee)
AAS	Asset Administration Shell
AI	Artificial Intelligence
AK	Arbeitskreis (Working Group)
CDD	Common data dictionary
CEN	Comité Européen de Normalisation
CLC	Comité Européen de Normalisation Électrotechnique
CEN-CLC	CEN and CENELEC
COMDO	Common Data Repository for Smart Manufacturing
DIN	German Institute for Standardization
DKE	German Commission for Electrical, Electronic & Information Technologies
DTR	Draft technical report
ED	Edition
ETSI	European Telecommunications Standards Institute
EU CRA	European Cyber Resilience Act
GA	Gemeinschaftsausschuss (Joint Working Committee)
HE	Recommendation for action
IACS	Industrial Automation and Control Systems
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IS	International Standard
ISO	International Organization for Standardization
IT	Information technology
JTC	Joint Technical Committee

NA	Normungsausschuss (Standards Committee)
NIST	National Institute of Standards and Technology
OT	Operational technology
PAS	Publicly Available Specification
PKI	Public key infrastructure
PNW	New work item proposal
SMART Standards	Standards Machine Applicable Readable Transferrable
SM2TF	Smart manufacturing Standards Map Task Force
SC	Sub committee
SRI 4.0	Standardization Roadmap Industrie 4.0
TC	Technical committee
TR	Technical Report
TS	Technical Specification
TSN	Time Sensitive Network
WG	Working Group
W3C	World Wide Web Consortium
W3C	World Wide Web Consortium

Annex 2
Index of standards bodies listed

In Germany	
DIN NA 023-00-06 AA	Ergonomics for work structure and product design in Industry 4.0
DIN NA 023-00-08 GA	Exoskeletons
DIN NA 043-01-41 AA	Internet of Things
DIN/DKE NA 043-01-42 GA	DIN/DKE Joint Working Committee Artificial Intelligence
DKE/AK 914.0.11	Functional safety and artificial intelligence
DKE/K 931	System aspects of automation
DKE/AK 931.0.14	Smart manufacturing and Industrie 4.0
DKE/AK 931.0.16	Asset Administration Shell for Industrial Applications
In Europe	
CEN-CLC JTC 13	Joint Technical Committee Cybersecurity and Data Protection
CEN-CLC JTC 21	Joint Technical Committee Artificial Intelligence
ETSI	European Telecommunications Standards Institute
International	
IEC/SMB	Standardization Management Board
IEC/SMB/SG 12	Standardization Management Board/Digital Transformation
IEC/TMB	Technical Management Board
IEC/TC 1	Terminology
IEC/SC 3D	Classes, Properties and Identification of products – Common Data Dictionary (CDD)
IEC/TC 65	Industrial process measurement, control and automation

IEC/TC 65/AG 4	Coordination of properties and CDD
IEC/TC 65/SC 65A	System aspects
IEC/TC 65/SC 65C/WG 18	Time-sensitive networking for industrial automation
IEC/TC 65/SC 65E	Devices and integration in enterprise systems
IEC/TC 65/WG 10	Security for industrial process measurement and control – Network and system security
IEC/TC 65/WG 23	Smart Manufacturing Framework and Concepts for industrial-process measurement, control and automation
IEC/TC 65/WG 24	Asset Administration Shell for Industrial Applications
IEC/SyC SM	IEC System Committee Smart Manufacturing
ISO/TMBG/SMCC	ISO Technical Management Board/ Smart Manufacturing Coordinating Committee (SMCC)
ISO/TC 184	Automation systems and integration
ISO/TC 184/SC 4	Industrial data
ISO/TC 292	Security and resilience
ISO/IEC/JWG 21	Joint Working Group Smart Manufacturing Reference Model(s)
ISO/IEC/JWG 21/ TF 8	Task Force Digital Twin and Asset Administration Shell
ISO/IEC SM2TF	Smart manufacturing standards map Task Force
ISO/IEC/JTC 1/AG 8	Meta Reference Architecture and Reference Architecture for Systems Integration
ISO/IEC/JTC 1/WG 13	Trustworthiness
ISO/IEC/JTC 1/SC 27/WG 5	Identity management and privacy technologies
ISO/IEC JTC 1/SC 38	Cloud computing and distributed platforms
ISO/IEC/JTC 1/SC 41	Internet of things and digital twin

ISO/IEC/JTC 1/SC 41/AG 20	Sectorial Liaison Group (SLG 1) on Industrial sector
ISO/IEC/JTC 1/SC 41/WG 3	IoT Foundational Standards – Development of IoT foundational standards, including IoT and Digital Twin vocabulary
ISO/IEC/JTC 1/SC 41/WG 6	Digital twin
ISO/IEC/JTC1/SC41/WG27	Digital Twin – Strategy
ISO/IEC/JTC 1/SC 42	Artificial Intelligence
ISO/IEC/JTC 1/SC 42/WG 1	Foundational standards
ISO/IEC/JTC 1/SC 42/WG 3	Artificial Intelligence – Trustworthiness
ISO/IEC/JTC 1/SC 42/WG 4	Use cases and applications

Annex 3
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