trinity ENGAGE WITH AGILE MANUFACTURING

D8.6 TRINITY Report on Standardisation with Recommendations for Standardization Bodies

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WP Leader	**CECIMO (WP8)**
Authors	**O. Hunchak**
Contributors	**All partners**
Reviewers	**All partners**
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PP	Restricted to other programme participants (incl. Commission Services)	
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EXECUTIVE SUMMARY

This deliverable D8.6 “Report on standardization landscape and relevant standards” (M48) is the first deliverable for Task 8.5 “Standardization” within Work Package 8 (WP8) “Dissemination, Exploitation and Standardization”.

Standards play an important role in ensuring the safety of products and in supporting the introduction of new technologies, products and services in the market. It is therefore important to consider relevant standardization work being carried out by the different standardization bodies to be able to consider it in the context of the use case demonstrations to be carried out and to provide feedback to the standardization bodies where relevant.

In this regard, the main objective of this task is to facilitate the acceptance and market uptake of the solutions developed under the TRINITY project. Other objectives are to provide background information for other WPs, ensure compatibility and interoperability with what already exists in the market through standards, as well as to use the standardization system as a tool for dissemination of the project results and interaction with the market stakeholders.

The standardization activities planned under this task to fulfil the objectives will be considered under two specific parts, which are mutually linked: 1) the identification and analysis of related existing standards and 2) the contribution to the ongoing and future standardization developments from the results of the project. The participation of CECIMO, representing the European Association of the Machine Tool Industries, as the leader of WP8 “Dissemination, Exploitation and Standardization” activities can count on an extensive network of national and European associations and manufacturing companies with a strong experience and direct involvement in standardization activities.

Therefore, this report provides a comprehensive analysis of the available and applicable standardization landscape, collecting background information for other WPs about existing standards that can be related, as well as the relevant Standardization Bodies and Committees involved, to ensure compatibility and interoperability of TRINITY and thus facilitate the acceptance and market uptake of the developed solutions.

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1 INTRODUCTION

1.1 Summary and Scope of the Deliverable

The purpose of this report D8.6 is to provide information on the standardization landscape, by identifying relevant standards to the TRINITY project, and to provide an overview of standards under development by their respective Standardization Committees. The report will thus provide background information for the WPs that can ensure compatibility and interoperability with already existing solutions by identifying relevant standards – published or under development – at the International and European level in the fields of: *Robotics, Human-Robot Collaboration, Automation, Advanced Manufacturing, Industrial Cybersecurity, Interoperability, Internet of Things, Artificial Intelligence, Safety and Virtual Reality / Augmented Reality.*

1.2 Overview of the TRINITY Project

The TRINITY project is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement 825196. Its proposal title "Digital Technologies, Advanced Robotics and increased Cyber-security for Agile Production in Future European Manufacturing Ecosystems" (TRINITY). The duration of the project will be 54 months 1 January 2019.

The main objective of TRINITY is to create a network of multidisciplinary and synergistic local digital innovation hubs (DIHs) composed of research centres, companies, and university groups that cover a wide range of topics that can contribute to agile production: advanced robotics as the driving force and digital tools, data privacy and cyber security technologies to support the introduction of advanced robotic systems in the production processes. The result will be a one-stop shop for methods and tools to achieve highly intelligent, agile, and reconfigurable production, which will ensure Europe's welfare in the future.
The network will start its operation by developing demonstrators in the areas of robotics we identified as the most promising to advance agile production, e.g. collaborative robotics including sensory systems to ensure safety, effective user interfaces based on augmented reality and speech, reconfigurable robot workcells and peripheral equipment (fixtures, jigs, grippers, …), programming by demonstration, IoT and secure wireless networks, among others.

These demonstrators will serve as reference implementation for two rounds of open calls for application experiments, where companies with agile production needs and sound business plans will be supported by TRINITY DIHs to advance their manufacturing processes. Besides technology-centred services, primarily laboratories with advanced robot technologies and know-how to develop innovative application experiments, TRINITY network of DIHS will also offer training and consulting services, including support for business planning and access to financing.

Services of participating DIHs and dissemination of information to wider public will be provided through a digital access point that will be developed in the project. Another important activity of the project will be the preparation of a business plan to sustain the network after the end of the project funding.

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1.3 Background on Standardization

Standards are voluntary technical documents that set out requirements for a specific item, material, component, system or service, or describes in detail a method, procedure or best practice. Standards are developed and defined through a process of sharing knowledge and building consensus among technical experts nominated by interested parties and other stakeholders - including businesses, consumers and environmental groups, among others. These experts are organized in Technical Committees (TCs), which are subdivided in Subcommittees (SCs) or Working Groups (WGs). These TCs are included in the structure of the Standardization Organizations (National, European and International, with the respective mirror committees) and Working Documents following their internal regulations.

The Standardization Bodies operate at National (UNE, UNI, DIN, AFNOR, BSI, etc.), Regional (CEN, CENELEC, ETSI) or International (ISO, IEC, ITU) level. Sometimes there are different Standardization Bodies at the same level but covering different fields. This is the case of ISO (general), IEC (electrical) and ITU (telecommunications) at international level, or CEN, CENELEC and ETSI at European level in the same way. The Standardization Bodies, such as ISO, IEC, CEN, DIN or UNE, consists of many Technical Committees (TC), which deal with different areas of interest, and each TC may have a few SC or WG according to its need.

There are also different kinds of standardization documents. The most widespread is the standard, which has a different code depending on the organization under it was developed, e.g., EN for European Standards, ISO for International standards. Other types of documents are Technical Specifications (TS), Technical Reports (TR) and Workshop Agreements (CWA). Further Amendments to the standards are identified by adding A1, A2, etc. at the end of the standard code.

The formal definition of a standard is a “document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context”. These include requirements and/or recommendations in relation to products, systems, processes or services. European Standards (ENs) are documents that have been ratified by one of the three European Standardization Organizations (ESOs), CEN, CENELEC or ETSI; recognized as competent around voluntary technical standardization as for the EU Regulation 1025/2012.

At European level, all the members of CEN shall adopt EN standards as national standards and must withdraw any existing national standard which could conflict with them. European and International Standardization Organizations (e.g. CEN and ISO) (have signed formal agreements to avoid duplication of efforts and promote global relevance of standards, which allows to adopt or develop in parallel each other’s standards with the same content and code.

The technical collaboration between ISO and CEN was formalized through the Vienna Agreement (VA).
European standards developed through the Vienna Agreement have EN ISO codification while International Standards developed through the Vienna Agreement remain only with ISO code. CENELEC has close cooperation with its international counterpart, the International Electrotechnical Commission (IEC) through the Frankfurt Agreement (FA).

As a result, new electrical standards projects are jointly planned between CENELEC and IEC, and where possible most are carried out at international level. This means that CENELEC will first offer a New Work Item (NWI) to its international counterpart. If accepted, CENELEC will cease working on the NWI. If IEC

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refuses, CENELEC will work on the standards content development, keeping IEC closely informed and giving IEC the opportunity to comment at the public enquiry stage. CENELEC and IEC vote in parallel (both organizations are voting at the same time) during the standardization process. If the outcome of the parallel voting is positive, CENELEC will ratify the European standard and the IEC will publish the international standard. Close to 80% of CENELEC standards are identical to or based on IEC publications.

1.4 EU Policy Background

The European Union (EU) safety legislation poses general rules that can apply to robots. There are mandatory safety requirements involving technical specifications in order to meet EU laws or European harmonised standards. The manufacturer is responsible for these safety measures to be complied with and implemented in the design and production phase of developing the product. CE marking is issued after the relevant EU legislation has been adhered to. The legislation can differ depending on what type of robot is in question.

The main legislative framework for the safety of machinery is the Machinery Directive 2006/42/EC, to be replaced by the upcoming Machinery Regulation, which is the blanket framework for all machinery being placed onto the European product market. Almost all robots would have to adhere to this regulation first and foremost. Another applicable framework is the EU Cybersecurity Act, which aims to introduce an EU-wide cybersecurity certification framework for ICT products, services and processes. Robotics companies doing business in the EU will benefit from having to certify their ICT products only once and see their certificates recognised across the European Union.

There are several other directives that may apply to a robot being placed on the European market, including the pending updated legal framework that will apply to artificial intelligence products, commonly known as the Artificial Intelligence Act. It is essential that robotics companies are clear on the directives and regulations that will apply to their products in the design phase to avoid any unwanted issues.

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2 METHODOLOGY

For an analysis of the standardization landscape and the identification of existing standards and standard documents under development relevant to the project, the following methodology has been designed and applied to understand the key concepts of the project and to assess the main standardization areas.

List of Key Concepts
A list of key concepts has been prepared to act as a starting point for the identification of standardization areas. For the selection of the key concepts, the aims and goals of the TRINITY project were considered, together with the technical aspects of the use cases.

The final list of key concepts used for the report is shown below in Table 2.1:
Table: List of Key Concepts as a starting point for the identification of standardization areas

INDUSTRIAL ROBOTS
Robot / Robotics
ADVANCED MANUFACTURING
Automation Systems and Integration Additive Manufacturing Industrial Automation System, Process Measurement and Control
INDUSTRIAL CYBER SECURITY
Industrial Cyber Security
INTEROPERABILITY
Interoperability
INTERNET OF THINGS
Internet of Things
ARTIFICIAL INTELLIGENCE
Artificial Intelligence
HEALTH AND SAFETY OF WORKERS
Health and Safety Protective Equipment
SAFETY OF MACHINERY
Safety of Machinery
VIRTUAL REALITY / AUGMENTED REALITY
Virtual Reality (VR), Augmented / Mixed Reality (AR / MR)

Relevant Technical Committees
The first of part of the Report's standardization analysis, as laid down in Chapter 3.1, consisted in the identification of all the relevant standardization Technical Committees (TCs) in order to accurately provide a comprehensive overview of the standardization landscape in relation to the TRINITY project.

In Chapter 3.1, the TCs and their respective standardization activities have been effectively grouped in accordance with the list of key concepts, outlined in Table 2.1, that are of particular relevance to the project to facilitate the analysis of the standardization landscape.

Published and Under Development Standards
Existing standards, both published and under development, relevant to the project were identified for each standardization area, together with the responsible Technical Committee covering the respective standards.

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In this regard, the report covers all relevant published and under development standards developed by the European Committee for Standardization (CEN), the European Committee for Standardization in the Electrical Field (CENELEC), the International Electrotechnical Commission (IEC) and the International Standardization Organization (ISO).

Analysis of Relevant Standards for the TRINITY project and DIH network as a whole
The second part of the Report's standardization analysis, as laid down in Chapter 3.2, consisted in the identification of the published standards that are most relevant to the TRINITY project within the wide range of standards that were comprehensively outlined in Chapter 3.1.

This part of the analysis will be instrumental for the TRINITY consortium partners to carefully consider the relevant standardization work that is being carried out by the different standardization TCs and consequently consider it in the context of the use case demonstrations.

Information on the standards used and any possible needs for new standards or improvements on existing standards identified as a result of the use case demonstrations carried out will be collected towards the end of the project in a report with the aim of providing standardization bodies with inputs and recommendations.

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3 RELEVANT STANDARDIZATION TECHNICAL COMMITTEES AND ACTIVITIES

3.1 Industrial Robots

International standardization in robotics paves the way to the market for new robotic products, assists to overcome technical barriers in international commerce, and fosters market growth. While safety standards form the primary basis to establish specific types of robotic products in helping create new markets through reducing safety risks for users as well as reducing liability risks for manufacturers, other standards can help to dismantle trade barriers such as standards on terminology, coordinate systems, performance benchmarking and inter-operability based modular design. As the market for industrial robots constantly grows, the demand for standards in this area also constantly rises.

3.1.1 ISO/TC 299 – Robotics

ISO/TC 299 has the goal to develop high quality standards for the safety of industrial robots and service robots to enable innovative robotic product to be brought onto the market. In addition, ISO/TC 299 has the goal to foster the growth of the robotic market by introducing standards in fields like terminology, performance measurement and modularity. The scope of ISO/TC 299 reads "Standardization in the field of robotics, excluding toys and military applications.*"*

All relevant standard development takes place in ISO/TC 299 and is organized in several working groups:

Working Group 1 (WG1) – Vocabulary and Characteristics

The main task of WG1 is to define fundamental terms to review the existing vocabulary for traditional robots and adding new terms, especially for the realm of service robots.

Published standards:

- ISO 8373:2021 Robotics – Vocabulary
- ISO 14539:2000 Manipulating industrial robots – Object handling with grasp-type grippers – Vocabulary and presentation of characteristics.
- ISO 9787:2013 Robots and robotic devices – Coordinate systems and motion nomenclatures
- ISO 11593:2022 Robots for industrial environments – Automatic end effector exchange systems – Vocabulary.

Working Group 2 (WG2) – Safety

The main task of WG2 is the study of the need to develop new service robot safety standards. The areas under consideration, which are the performance criteria, coordinate systems, mobile robot characteristics, modularity in hardware / software and robotic software for service robots.

Published standards:

- ISO 13482:2014 Robots and robotic devices – Safety requirements for personal care robots
- ISO/TR 23482-1:2020 Robotics – Application of ISO 13482 – Part 1: Safety-related test methods
- ISO/TR 23482-2:2019 Robotics – Application of ISO 13482 – Part 2: Application guidelines.

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Standards under development:

- ISO/AWI 13482 Robotics – Safety requirements for service robots
- ISO/CD 18646-2 Robotics – Performance criteria and related test methods for service robots – Part 2: Navigation
- ISO/DIS 31101 Robotics – Application services provided by service robots – Safety management system requirements.

Working Group 3 (WG3) – Industrial Safety

The WG3 deals with industrial robots, addressing the safety of industrial robots on one hand, while on the other hand addressing the safety of industrial robot systems and their integration in manufacturing environments.

Published standards:

- ISO 10218-1:2011 Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots
- ISO 10218-2:2011 Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration
- ISO/TS 15066:2016 Robots and robotic devices – Collaborative robots
- ISO 9283:1998 Manipulating industrial robots – Performance criteria and related test methods
- ISO/TR 13309:1995 Manipulating industrial robots – Informative guide on test equipment and metrology methods of operation for robot performance evaluation in accordance with ISO 9283
- ISO 9409-1:2004 Manipulating industrial robots – Mechanical interfaces – Part 1: Plates
- ISO 9409-2:2002 Manipulating industrial robots – Mechanical interfaces – Part 2: Shafts
- ISO 9946:1999 Manipulating industrial robots – Presentation of characteristics
- ISO 11593:2022 Robots for industrial environments – Automatic and effector exchange systems – Vocabulary.

Standards under development:

- ISO/FDIS 10218-1 Robotics – Safety requirements – Part 1: Industrial robots
- ISO/FDIS 10218-2 Robotics – Safety requirements – Part 2: Industrial robot systems, robot applications and robot cells
- ISO/AWI PAS 5672 Robotics – Collective applications – Test methods for measuring forces and pressures in quasi-static and transient contacts between robots and human.

Working Group 4 (WG4) – Service Robots

The WG4 deals with service robot standards, investigating the standardization needs specific to service robots, without however, having provided any relevant standards yet.

Working Group 6 (WG6) – Modularity for Service Robots

The WG6 explores the standardization needs in the field of modularity for service robots, covering both **Software modularity** and **Hardware modularity.**

Published standards:

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- ISO 22166-1:2021 Robotics – Modularity for service robots – Part 1: General requirements.

Standards under development:

- ISO/CD 22166-201 Robotics – Modularity for service robots – Part 201: Common information model for modules
- ISO/AWI 22166-202 Robotics – Modularity for service robots – Part 202: Information model for software modules.

3.1.2 CEN/TC 310 – Advanced Automation Technologies and their Applications

CEN/TC 310 covers standardization in the field of automation systems and technologies and their application and integration to ensure the availability of the standards required by industry for design, sourcing, manufacturing and delivery, support, maintenance and disposal of products and their associated services.

Areas of standardization may include enterprise modelling and system architecture, information and its supporting systems, robotics for fixed and mobile robots in industrial and specific non-industrial environments, automation and control equipment and software, human and mechanical aspects, integration technologies and system operational aspects.

These standards may utilize other standards and technologies beyond the scope of TC 310, such as machines, equipment, information technologies, multi-media capabilities, and multi-modal communications networks.

Published standards:

- EN ISO 13482:2014 Robots and robotic devices – Safety requirements for personal care robots
- EN ISO 11354-1:2011 Advanced automation technologies and their applications – Requirements for establishing manufacturing enterprise process interoperability – Part 1: Framework for enterprise interoperability.
- EN ISO 10218-1 :2011 Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots
- EN ISO 10218-2:2011 Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration
- EN ISO 19440:2007 Enterprise integration – Constructs for enterprise modelling
- EN ISO 19439:2006/AC:2007 Enterprise integration – Framework for enterprise modelling
- EN ISO 19439:2006 Enterprise integration – Framework for enterprise modelling.

Standards under development:

- EN ISO 8373 Manipulating industrial robots – Vocabulary.
- EN ISO 10218-1 Robotics – Safety requirements – Part 1: Industrial robots
- EN ISO 10218-2 Robotics – Safety requirements for robot systems in an industrial environment – Part 2: Robot systems, robot applications and robot cells integration.

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3.2 Advanced Manufacturing

The development of an inclusive European digital society calls for the uptake of innovative technologies by the European industry. CEN/TC 310 'Advanced automation technologies and their applications', CEN/TC 438 'Additive manufacturing' and CLC/TC 65X 'Industrial-process measurement, control and automation' will continue to collaborate with ISO and IEC (ISO/TC 184 'Automation systems and integration' and IEC/TC65 'Industrial-process measurement, control and automation') in order to develop European Standards that support the digital transformation of European industry.

3.2.1 ISO/TC 184 Automation Systems and Integration

ISO/TC 184 covers standardization in the field of automation systems and their integration for design, sourcing, manufacturing, production and delivery, support, maintenance and disposal of products and their associated services. Areas of standardization include information systems, automation and control systems and integration technologies.

<u>Published standards:</u>

- ISO 23570-1:2005 Industrial automation systems and integration – Distributed installation in industrial applications – Part 1: Sensors and actuators
- ISO 11354-2:2015 Advanced automation technologies and their applications – Requirements for establishing manufacturing enterprise process interoperability – Part 1: Framework for enterprise interoperability.
- ISO 11454-2:2015 Advanced automation technologies and their applications – Requirements for establishing manufacturing enterprise process interoperability – Part 2: Maturity model for assessing enterprise interoperability.
- ISO 22549-2:2020 Automation systems and integration – Assessment on convergence of informatization and industrialization for industrial enterprises – Part 1: Framework and reference model
- ISO 22549-2:2020 Automation systems and integration – Assessment on convergence of informatization and industrialization for industrial enterprises – Part 2: Maturity model and evaluation methodology.

3.2.2 CLC/TC 65X Industrial Process Measurement, Control and Automation

CLC/TC 65X aims to contribute, support and coordinate the preparation of international standards for systems and elements used for industrial process measurement, control and automation at CENELEC level.

This standardization work is to be carried out for equipment and systems and closely coordinated with IEC/TC 65 and its subcommittees with the objective of avoiding any duplication of work while honouring standing agreements between CENELEC and IEC.

<u>Published standards:</u>

CLC 62714 series *Engineering data exchange format for use in industrial automation systems engineering – Automation markup language*

CLC 62439 series *Industrial communication networks – High availability automation networks*

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CLC 61069 series *Industrial-process measurement, control and automation – Evaluation of system properties for the purpose of system assessment*

Standards under development:

- EN IEC 62714-2:2022 Engineering data exchange format for use in industrial automation systems engineering – Automation Markup Language – Part 2: Role class libraries
- EN IEC 62381 Automation systems in the process industry – Factory acceptance test (FAT), site acceptance test (SAT), and site integration test (SIT).

3.3 Industrial Cyber Security

The technological revolution fostered by industry 4.0 has brought new life to the manufacturing sector, increasing the level of digitization of processes and connection between machines. This evolution continues to bring countless advantages, but it exposes companies to several risks.

The new manufacturing ecosystem has increased the number of connections between different players all linked in the value chain. Therefore, cybersecurity has become an essential issue to address, not only for the individual company but also as a collective guaranteed measure of mutual benefit for the sector's value chain.

Industrial Cyber Security

3.3.1 ISO/IEC JTC 1/SC 27 Security, Cybersecurity and Privacy Protection

ISO/IEC JTC 1/SC 27 is focused on the development of standards for the protection of information and ICT. This includes generic methods, techniques and guidelines to address both security and privacy aspects, such as:

- Security requirements capture methodology.
- Management of information and ICT security, in particular information security management systems, security processes, and security controls and services
- Cryptographic and other security mechanisms, including but not limited to mechanisms for protecting the accountability, availability, integrity and confidentiality of information.
- Security management support documentation including terminology, guidelines as well as procedures for the registration of security components.
- Security aspects of identity management, biometrics and privacy
- Conformance assessment, accreditation and auditing requirements in the area of information security management systems
- Security evaluation criteria and methodology.

SC 27 engages in active liaison and collaboration with appropriate bodies to ensure the proper development and application of SC 27 standards and technical reports in relevant areas.

Published standards:

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ISO 27000 series *Information technology – Security techniques — Information security management systems — Overview and vocabulary*

3.3.2 ISO/TC 22/SC 31 Data Communication

ISO/TC 22/SC 31 is focused on the technical aspects of data communication for vehicle applications:

- Data buses and protocols (Including dedicated sensor communication)
- V2X communication (Including V2G)
- Diagnostics
- Test protocols
- Interfaces and gateways (including those for nomadic devices)
- Data formats
- Standardized data content

Published standards:

ISO 15118 series *Road vehicles - Vehicle to grid communication interface*

3.4 Interoperability

Interoperability has become a common challenge within the manufacturing field in recent years particularly due to legacy systems, and the integration of manufacturing processes under the directive of promoting Industry 4.0.

The current pressing challenge for interoperability is closely linked to that of standardization and the implementation of best practices, which have prevented the driving of I4.0 to link manufacturing throughout the supply chain. Research into the current challenges have indicated that there is a gap within the IT and application landscapes of manufacturing enterprises, which present challenges for the linking of systems and flow of data.

3.4.1 IEC/SC 65E Devices and Integration in Enterprise Systems

IEC/SC 65 E aims to prepare international standards specifying:

1. Device integration with industrial automation systems. The models developed in these standards address device properties, classification, selection, configuration, commissioning, monitoring and basic diagnostics.
2. Industrial automation systems integration with enterprise systems. This includes transactions between business and manufacturing activities which may be jointly developed with ISO TC184

Published standards:

IEC 62541 -100:2015 *OPC unified architecture – Part 100: Device Interface.*

IEC 62264 series *Enterprise-control system integration*

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Standards under development:

- IEC 62264-2 ED3 Enterprise-control system integration – Part 2: Object and attributes for enterprise-control system integration
- IEC 62264-4 ED2 Enterprise-control system integration – Part 4: Objects models attributes for manufacturing operations management integration
- IEC 62264-5 ED3 Enterprise-control system integration – Part 5: Business to manufacturing transactions.
- IEC 62264-7 ED1 Enterprise-control system integration – Part 7 Alias Service Model.

3.5 Internet Of Things

The Internet of Things (IoT) can connect various manufacturing devices equipped with sensing, identification, processing, communication, actuation, and networking capabilities. Network control and management of manufacturing equipment, asset and situation management, or manufacturing process control allow IoT to be used for industrial applications and smart manufacturing. IoT intelligent systems enable rapid manufacturing and optimization of new products, and rapid response to product demands.

3.5.1 ISO/IEC JTC 1/SC 41 Internet of Things and Digital Twin

ISO/IEC JTC 1, entitled "Information technology", is a joint technical committee (JTC) under ISO and IEC. Its purpose is to develop, maintain and promote standards in the field of information and communications technology (ICT).

JTC 1 has been responsible for many critical IT standards, ranging from the Joint Photographic Experts Group (JPEG) image formats and Moving Picture Experts Group (MPEG) audio and video formats to the C and C++ programming languages.

Published standards:

- ISO/IEC 20924:2021 Information technology – Internet of Things (IoT) – Vocabulary
- ISO/IEC 21823-1:2019 Internet of Things (IoT) – Interoperability for IoT systems – Part 1: Framework
- ISO/IEC 21823-2:2020 Internet of Things (IoT) – Interoperability for IoT systems – Part 2: Transport interoperability
- ISO/IEC 21823-3:2021 Internet of Things (IoT) – Interoperability for IoT systems – Part 3: Semantic interoperability
- ISO/IEC 21823-4:2022 Internet of Things (IoT) – Interoperability for IoT systems – Part 4: Syntactic interoperability
- ISO/IEC TR 22417:2017 Information technology – Internet of Things (IoT) use cases
- ISO/IEC 29161:2016 Information technology – Data structure – Unique identification for the Internet of Things (IoT).

Standards under development:

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- ISO/IEC AWI 30149 Internet of Things (IoT) – Trustworthiness framework
- ISO/IEC AWI 30172 Digital twin – Use cases
- ISO/IEC AWI 30172 Digital twin – Concepts and terminology.

3.6 Artificial Intelligence

Industrial artificial intelligence covers all aspects related to the application of artificial intelligence to industry. Unlike general artificial intelligence which is a frontier research discipline to build computerized systems that perform tasks requiring human intelligence, industrial AI is more concerned with the application of such technologies to address industrial pain-points for customer value creation, productivity improvement, cost reduction, site optimization, predictive analysis and insight discovery.

3.6.1 CEN-CENELEC JTC 21 "Artificial Intelligence"

CEN and CENELEC have established the new CEN-CENELEC Joint Technical Committee 21 **'Artificial Intelligence**', based on the recommendations presented in the CEN-CENELEC response to the EC White Paper on AI, the CEN-CENELEC Focus Group Road Map on Artificial Intelligence, and the German Standardization Roadmap for Artificial Intelligence. The Joint Technical Committee, whose Secretariat is held by DS, the Danish Standardization Body, is responsible for the development and adoption of standards for AI and related data, as well as provide guidance to other Technical Committees concerned with AI.

In particular, CEN-CLC/JTC 21 identifies and adopts international standards already available or under development from other organizations like ISO/IEC JTC 1 and its subcommittees, such as SC 42 Artificial Intelligence. Furthermore, CEN-CLC/JTC 21 focuses on producing standardization deliverables that address European market and societal needs, as well as underpinning EU legislation, policies, principles, and values.

High-Level Expert Group on Artificial Intelligence (AI HLEG)

The overall work of the AI HLEG has been central to the development of the Commission's approach to Artificial Intelligence. The concept of trustworthiness and the 7 key requirements, introduced by the Ethics Guidelines are guiding the upcoming legislative steps in AI. The group's recommendations have served as resources for policymaking initiatives taken by the Commission and its Member States. Among those initiatives, there was the Communication on Building Trust in Human Centric Artificial Intelligence, the White Paper on Artificial Intelligence: a European approach to excellence and trust and the updated Coordinated plan on AI.

The AI HLEG has worked closely with the European community of AI stakeholders through the AI Alliance. The European AI Alliance is an online forum with over 4000 members representing academia, business and industry, civil society, EU citizens and policymakers. The members of the AI Alliance offered detailed feedback for the Ethics Guidelines for Trustworthy AI. Moreover, a set of materials such as policy documents, academic papers and discussions published on the forum, helped define the other deliverables of the AI HLEG.

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3.6.2 ISO/IEC JTC 1/SC 42 Artificial Intelligence

ISO/IEC JTC 1, entitled "Information technology", is a joint technical committee (JTC) under ISO and IEC. Its purpose is to develop, maintain and promote standards in the field of information and communications technology (ICT).

JTC 1 has been responsible for many critical IT standards, ranging from the Joint Photographic Experts Group (JPEG) image formats and Moving Picture Experts Group (MPEG) audio and video formats to the C and C++ programming languages.

Published standards:

- ISO/IEC TR 20547-1:2020 Information technology – Big data reference architecture – Part 1: Framework and application process
- ISO/IEC TR 20547-2:2018 Information technology – Big data reference architecture – Part 2: Use cases and derived requirements
- ISO/IEC 20547-3:2020 Information technology – Big data reference architecture – Part 3: Reference architecture
- ISO/IEC 20547-5:2018 Information technology – Big data reference architecture – Part 5: Standards roadmap
- ISO/IEC 23053:2022 Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)
- ISO/IEC 24027:2021 Information technology – Artificial Intelligence (AI) – Bias in AI systems and AI aided decision making.
- ISO/IEC TR 24028:2020 Information technology – Artificial Intelligence (AI) – Overview of trustworthiness in artificial intelligence
- ISO/IEC TR 24029-1:2021 Artificial Intelligence (AI) – Assessment of the robustness of neural networks – Part 1: Overview
- ISO/IEC TR 24030:2021 Information technology – Artificial Intelligence (AI) – Use cases
- ISO/IEC 22989 :2022 Information technology – Artificial Intelligence (AI) – Artificial intelligence concepts and terminology.

Standards under development:

- ISO/IEC DIS 24029-2 Artificial Intelligence (AI) – Assessment of the robustness of neural networks – Part 2: Methodology for the use of formal methods.
- ISO/IEC CD 5259-1 Artificial Intelligence (AI) – Data quality for analytics and Machine Learning (ML) – Part 1: Overview, terminology, and examples
- ISO/IEC AWI 5259-2 Artificial Intelligence (AI) – Data quality for analytics and Machine Learning (ML) – Part 2: Data quality measures
- ISO/IEC CD 5259-3 Artificial Intelligence (AI) – Data quality for analytics and Machine Learning (ML) – Part 3: Data quality management requirements and guidelines
- ISO/IEC CD 5259-4 Artificial Intelligence (AI) – Data quality for analytics and Machine Learning (ML) – Part 4: Data quality process framework.

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3.7 Health And Safety of Workers

All workers are entitled to work in environments where risks to their health and safety are properly controlled. Under health and safety law, the primary responsibility for this is down to employers. Employers have a duty to consult with their employees, or their representatives, on health and safety matters.

3.7.1 ISO/PC 283 Occupational Health and Safety Management Systems

ISO/PC 283 is responsible for the on-going development of the new ISO standard ISO 45001 *Occupational health and safety management systems - Requirements with guidance for use,* and the development of supporting guidance and standards. ISO 45001 defines good practices in OH&S management and specifies requirements for a management system. The standard applies to all forms and sizes of organization, performing any types of activities.

Published standards:

- ISO 45001:2018 Occupational health and safety management systems – Requirements with guidance for use
- ISO 45003:2021 Occupational health and safety management systems – Psychological health and safety at work – Guidelines for managing psychological risks.

Standards under development:

- ISO/DIS 45002 Occupational health and safety management systems – General guidelines for the implementation of ISO 45001:2018
- ISO/WD 45004 Occupational health and safety management – Guidelines for performance evaluation.

3.7.2 CEN/TC 122 Ergonomics

CEN/TC 122 covers standardization in the field of ergonomics, in particular:

- General ergonomics principles
- Anthropometry and biomechanics
- Ergonomics of human-system interaction
- Ergonomics of the physical environment and - ergonomics of personal protective equipment addressing
- Human characteristics and performance
- Methods for specifying, designing and evaluating products, systems, services, environments and facilities.

Published standards:

- EN ISO 27501:2019 The human-centred organization – Guidance for managers
- ISO 9241-210:2010 Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems provides requirements and recommendations for human-centred design principles and activities throughout the life cycle of computer-based interactive systems. This standard has been revised by ISO 9241-210:2019.

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- EN 1005-3:2002+A1:2008 Safety of machinery – Human physical performance – Part 3: Recommended force limits for machinery operation
- EN 1005-5:2007 Safety of machinery – Human physical performance – Part 5: Risk assessment for repetitive handling at high frequency
- EN 13861:2011 Safety of machinery – Guidance for the application of ergonomics standards in the design of machinery

Standards under development:

- EN ISO 14738 Safety of machinery – Anthropometric requirements for the design of workstations for industries and services

3.8 Safety Of Machinery

Machines can help improve production efficiency in the workplace. However, their moving parts, sharp edges, and hot surfaces can also cause serious workplace injuries such as crushed fingers or hands, amputations, burns, or blindness. Safeguards are essential to protect workers from injury. Any machine part, function, or process that might cause injury should be safeguarded. When the operation of a machine may result in a contact injury to the operator or others in the area, the hazard should be removed or controlled.

3.8.1 ISO/TC 199 Safety of Machinery

ISO/TC 199 covers standardization of basic concepts and general principles for safety of machinery incorporating terminology, methodology, guards and safety devices within the framework of ISO / IEC Guide 51 and in cooperation with other ISO and IEC technical committees, excluding product safety standards, as defined in ISO / IEC Guide 51, and which are explicitly covered by the work of other ISO or IEC technical committees.

3.8.2 CEN/TC 114 Safety of Machinery

CEN/TC 114 produces standards and other documents on general principles for the safety of machinery, including terminology and methodology. These standards are often referred to in the standards dealing with a specific type of machinery. Nearly 100% of the standards published by CEN/TC 114 are developed in cooperation with ISO/TC 199, and most of them support the Machinery Directive (2006/42/EC). Among portfolio of CEN/TC 114 is EN ISO 12100:2010 **“Safety of machinery – General principles for design – Risk assessment and risk reduction”**, which translates the requirements of the Directive on machinery (2006/42/EC) into a hazard-based approach. The TC has also developed the documents on the impact of cyber-security and Artificial Intelligence for machines.

Published standards:

- EN ISO 12100:2010 Safety of machinery – General principles for design – Risk assessment and risk reduction
- EN ISO 13849-1:2015 Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design
- EN ISO 13849-2:2012 Safety of machinery – Safety-related parts of control systems – Part 2: Validation

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- EN ISO 11161:2007 Safety of machinery – Integrated manufacturing systems – Basic requirements
- EN ISO 11161:2007/A1:2010 Safety of machinery – Integrated manufacturing systems – Basic requirements – Amendment 1
- EN ISO 13851:2019 Safety of machinery – Two-hand control devices – Principles for design and selection.

Standards under development:

- EN ISO 13855 Safety of machinery – Positioning of safeguards with respect to the approach of the human body
- EN ISO 14119 Safety of machinery – Interlocking devices associated with guards – Principles for design and selection.
- EN ISO 21260 Safety of machinery – Mechanical safety data for physical contacts between moving machinery and persons.

3.8.3 IEC/TC 44 Safety of Machinery: Electrotechnical Aspects

IEC/TC 44 covers standardization in the field of the application of electro-technical equipment and systems to machinery (including a group of machines working together in a coordinated manner, excluding higher-level systems aspects) not portable by hand while working, but which may include mobile equipment. The equipment covered commences at the point of connection of the electrical supply to the machinery. Standardization of interfaces (excluding local area networks and fieldbus) between control equipment and the electro- technical equipment of machinery. Standardization of electrotechnical equipment and systems relating to the safeguarding of persons from hazards of the machinery, its associated equipment and the environment. To coordinate with ISO all matters concerning the safety of machinery.

Published standards:

- IEC 62061:2021 Safety of machinery – Functional safety of safety-related control systems
- IEC 60204:2022 SER Safety of machinery – Electrical equipment of machines – All parts
- IEC 60204-1:2016+AMD1:2021 CSV Safety of machinery – Electrical equipment of machines – Part 1: General requirements
- IEC 60204-1:2016 Safety of machinery – Electrical equipment of machines – Part 1: General requirements
- IEC 60204-1:2016 RLV Safety of machinery – Electrical equipment of machines – Part 1: General requirements
- IEC 60204-1:2016/AMD1:2021 Amendment 1 – Safety of machinery – Electrical equipment of machines – Part 1: General requirements
- IEC 60204-11:2018 RLV Safety of machinery – Electrical equipment of machines – Part 11: Requirements for equipment voltages above 1000 V AC or 1500 V DC and not exceeding 36 kV
- IEC 60204-11:2018 Safety of machinery – Electrical equipment of machines – Part 11: Requirements for equipment voltages above 1000 V AC or 1500 V DC and not exceeding 36 kV
- IEC 60204-31:2013 Safety of machinery – Electrical equipment of machines – Part 31: Particular safety and EMC requirements for sewing machines, units and systems.
- IEC 60204-32:2008 Safety of machinery – Electrical equipment of machines – Part 32: Requirements for hoisting machines

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- IEC 60204-33:2009 Safety of machinery – Electrical equipment of machines – Part 33: Requirements for semiconductor fabrication equipment
- IEC/TS 60204-34:2016 Safety of machinery – Electrical equipment of machines – Part 34: Requirements for machine tools.

Standards under development:

- IEC 62046/AMD1 ED1 Safety of machinery – Application of protective equipment to detect the presence of persons.
- IEC/TS 62998-3 ED1 Safety of machinery – Safety-related sensors used for the protection of persons – Part 3: Sensor technologies and algorithms.
- IEC 62061/AMD1 ED2 Amendment 1 – Safety of machinery – Functional safety of safety-related control systems
- IEC/TS 63074 ED1 Safety of machinery – Security aspects related to functional safety of safety-related control systems.

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4 LIST OF MOST RELEVANT STANDARDS IDENTIFIED FOR THE TRINITY PROJECT

This chapter provides a comprehensive outline of the most relevant standards that should be considered based on the TRINITY internal and external third-party use case demonstrators. This chapter reflects upon specific standards used in the TRINITY project, specifying the general background information and the scope of the identified standards.

ISO 10218-1:2011 Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots

ISO 10218-1:2011 specifies requirements and guidelines for the inherent safe design, protective measures and information for use of industrial robots. It describes basic hazards associated with robots and provides requirements to eliminate, or adequately reduce, the risks associated with these hazards.

ISO 10218-1:2011 does not address the robot as a complete machine. Noise emission is generally not considered a significant hazard of the robot alone, and consequently noise is excluded from the scope of ISO 10218-1:2011.

ISO 10218-1:2011 does not apply to non-industrial robots, although the safety principles established in ISO 10218 can be utilized for these other robots.

ISO 10218-2:2011 Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration

ISO 10218-2:2011 specifies safety requirements for the integration of industrial robots and industrial robot systems as defined in ISO 10218-1, and industrial robot cell(s). The integration includes the following:

- The design, manufacturing, installation, operation, maintenance and decommissioning of the industrial robot system or cell
- Necessary information for the design, manufacturing, installation, operation, maintenance and decommissioning of the industrial robot system or cell
- Component devices of the industrial robot system or cell

ISO 10218-2:2011 describes the basic hazards and hazardous situations identified with these systems and provides requirements to eliminate or adequately reduce the risks associated with these hazards. ISO 10218-2:2011 also specifies requirements for the industrial robot system as part of an integrated manufacturing system. ISO 10218-2:2011 does not deal specifically with hazards associated with processes (e.g. laser radiation, ejected chips, welding smoke). Other standards can be applicable to these process hazards.

ISO/IEC 20922: 2016 Information technology — Message Queuing Telemetry Transport (MQTT) v3.1.1

ISO/IEC 20922: 2016 is a client Server publish/subscribe messaging transport protocol. It is light weight, open, simple, and designed so as to support the communication between the different software components, devices and control system. These characteristics make it ideal for use in many situations, including constrained environments such as for communication in Machine to Machine (M2M) and Internet of Things (IoT) contexts where a small code footprint is required and/or network bandwidth is at a premium.

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However, ISO/IEC does not have a specific standard for MQTT. The MQTT protocol is defined and maintained by the Organization for the Advancement of Structured Information Standards (OASIS) MQTT Technical Committee

ISO/TS 15066:2016 Robots and robotic devices – Collaborative robots

ISO/TS 15066:2016 specifies safety requirements for collaborative industrial robot systems and the work environment and supplements the requirements and guidance on collaborative industrial robot operation given in ISO 10218-1 and ISO 10218-2.

ISO/TS 15066:2016 applies to industrial robot systems as described in ISO 10218-1 and ISO 10218-2. It does not apply to non-industrial robots, although the safety principles presented can be useful to other areas of robotics.

ISO/TR 20218-1:2018 Robotics — Safety design for industrial robot systems — Part 1: End-effectors

ISO/TR 20218-1:2018 provides guidance on safety measures for the design and integration of end-effectors used for robot systems as well as safety guidance on the integration of robot systems. The integration includes the following:

- the manufacturing, design and integration of end-effectors
- the necessary information for use

Specifically, the standard establishes a common approach and structure for developing and documenting use cases, which are representations of functional requirements in the context of automation systems. Use cases describe interactions between users (human or system) and the automation system, illustrating the intended behaviour and functionality.

ISO 10303-1:2021 Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and fundamental principles

ISO 10303-1:2021 provides product information along with the necessary mechanisms and definitions to enable product data to be exchanged. The exchange is among different computer systems and environments associated with the complete product lifecycle, including product design, manufacture, use, maintenance, and final disposition of the product.

The standard aims to facilitate the interoperability and exchange of product data between different computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE) systems. It provides a common language and structure for describing product information, enabling seamless data exchange throughout the product lifecycle.

IEC 62541-100:2015 OPC unified architecture – Part 100: Device Interface.

This part of IEC 62541 is an extension of the overall OPC Unified Architecture standard series and defines the information model associated with Devices. This part of IEC 62541 describes three models which build upon each other as follows:

- The (base) Device Model is intended to provide a unified view of devices irrespective of the underlying device protocols.

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- The Device Communication Model adds Network and Connection information elements so that communication topologies can be created;
- The Device Integration Host Model finally adds additional elements and rules required for host systems to manage integration for a complete system. It allows reflecting the topology of the automation system with the devices as well as the connecting communication networks.

IEC 62264 - Enterprise-control system integration

The IEC 62264 series focuses on the integration of various aspects of enterprise and control systems in industrial automation. It provides a framework and guidelines for integrating business and control systems within an organization. It aims to enhance the interoperability, efficiency, and effectiveness of operations by defining common models and terminology for communication and information exchange between different systems.

The standard addresses topics such as data exchange, data modelling, information management, and system integration architecture. It promotes the use of international standards and best practices to ensure seamless integration and collaboration between business and control systems. IEC 62264 is applicable to various industries and sectors where integration of enterprise and control systems is necessary, including manufacturing, process industries, utilities, and its series are:

- IEC 62264-1:2013: Models and terminology
- IEC 62264-2:2013**:** Object and attributes for enterprise-control system integration
- IEC 62264-3:2016 Activity models of manufacturing operations management
- IEC 62264-4:2015 Objects and models attributes for manufacturing operations management integration
- IEC 62264-5:2016 Business to manufacturing transactions.

ISO 12100:2010 Safety of machinery – General principles for design – Risk assessment and risk reduction

ISO 12100:2010 specifies basic terminology, principles and a methodology for achieving safety in the design of machinery. It specifies principles of risk assessment and risk reduction to help designers in achieving this objective. These principles are based on knowledge and experience of the design, use, incidents, accidents and risks associated with machinery. Procedures are described for identifying hazards and estimating and evaluating risks during relevant phases of the machine life cycle, and for the elimination of hazards or sufficient risk reduction. Guidance is given on the documentation and verification of the risk assessment and risk reduction process.

ISO 12100:2010 is also intended to be used as a basis for the preparation of type-B or type-C safety standards. It does not deal with risk and/or damage to domestic animals, property or the environment.

ISO 13849-1:2015 Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design

ISO 13849-1:2015 provides safety requirements and guidance on the principles for the design and integration of safety-related parts of control systems (SRP/CS), including the design of software. For these parts of SRP/CS, it specifies characteristics that include the performance level required for carrying out safety functions. It applies to SRP/CS for high demand and continuous mode, regardless of the type of technology and energy used (electrical, hydraulic, pneumatic, mechanical, etc.), for all kinds of machinery.

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It does not specify the safety functions or performance levels that are to be used in a particular case. This part of ISO 13849 provides specific requirements for SRP/CS using programmable electronic system(s).

It does not give specific requirements for the design of products which are parts of SRP/CS. Nevertheless, the principles given, such as categories or performance levels, can be used.

ISO 13849-2:2012 Safety of machinery – Safety-related parts of control systems – Part 2: Validation
ISO 13849-2:2012 specifies the procedures and conditions to be followed for the validation by analysis and testing of the specified safety functions, the category achieved, and the performance level achieved by the safety-related parts of a control system (SRP/CS) designed in accordance with ISO 13849-1.

EN ISO 13855:2010 Safety of machinery - Positioning of safeguards with respect to the approach speeds of parts of human body
EN ISO 13855:2010 provides guidelines for the design and implementation of safety distances to prevent access to hazardous zones of machinery. It specifies parameters based on values for approach speeds of parts of the human body that should be maintained to ensure the safety of individuals near machinery, supplementing the SFS-EN ISO 12100. Safeguards considered on this Standards include:

- Electro-sensitive protective equipment (Light curtains and Laser scanner)
- Pressure-sensitive protective equipment (Pressure-sensitive mats)
- Two-hand control devices
- Interlocking guards without guard locking

The standard is currently under development.

SFS-EN ISO 14120 Safety of machinery - Guards - General requirements for the design and construction of fixed and movable guards
SFS-EN ISO 14120 specifies general requirements for the design and construction of guards used on machinery. Guards are physical barriers or devices designed to protect individuals from hazards associated with machinery. Moreover, it provides guidance on various aspects related to guards, including their materials, design, strength, and interlocking or fastening mechanisms. It also addresses topics such as openings, distance from the hazard, and visibility requirements for guards. By following the requirements of SFS-EN ISO 14120, manufacturers can ensure that the guards they design, and construct provide effective protection to operators and other personnel working with or near machinery.

SFS-ISO/TR 14121-2:2012 Safety of machinery — Risk assessment — Part 2: Practical guidance and examples of methods
SFS-ISO/TR 14121-2:2012 is a Finnish Technical Report based on ISO/TR 14121-2:2012. It gives practical guidance on conducting risk assessment for machinery in accordance with ISO 12100 and describes various methods and tools for each step in the process. It covers topics such as hazard identification, risk estimation, risk evaluation, and risk reduction measures. The guidance provided in the document is intended to support decision-making processes related to machinery safety and facilitate the implementation of appropriate risk control measures.

Moreover, the standard gives examples of different measures that can be used to reduce risk and is intended to be used for risk assessment on a wide variety of machinery in terms of complexity and potential for harm. Its intended users are those involved in the design, installation or modification of machinery (for example, designers, technicians or safety specialists).

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EN ISO 13854:2019 Safety of machinery - Minimum gaps to avoid crushing of parts of the human body

EN ISO 13854:2019 provides guidelines for minimizing the risks associated with machinery and equipment. It specifies minimum gaps that should be maintained to prevent crushing hazards and ensure the safety of individuals operating or working near machinery. It takes into account factors such as the size and speed of moving parts, the force exerted, and the potential body parts that could be at risk.

By adhering to the requirements outlined in EN ISO 13854:2019, manufacturers and operators can minimize the risk of accidents and injuries associated with machinery operation, providing a safer working environment. This standard supplements SFS-EN ISO 12100.

CEN ISO/TR 22100-5:2022 Safety of machinery. Relationship with ISO 12100. Part 5: Implications of artificial intelligence machine learning

CEN ISO/TR 22100-5:2022 addresses how artificial intelligence machine learning can impact the safety of machinery and machinery systems. It describes how hazards being associated with artificial intelligence (AI) applications machine learning in machinery or machinery systems, and designed to act within specific limits, can be considered in the risk assessment process.

SFS-EN ISO 11161:2007 Safety of machinery — Integrated manufacturing systems — Basic requirements

SFS-EN ISO 11161:2007 specifies the safety requirements for integrated manufacturing systems (IMS) that incorporate two or more interconnected machines for specific applications, such as component manufacturing or assembly. It gives requirements and recommendations for the safe design, safeguarding and information for the use of such IMSs.

The standard doesn't cover safety aspects of individual machines and equipment that may be covered by standards specific to those machines and equipment. Therefore, it deals with those safety aspects that are important for the safety-relevant interconnection of the machines and components. Where machines and equipment of an integrated manufacturing system are operated separately or individually, and while the protective effects of the safeguards provided for production mode are muted or suspended, the relevant safety standards for these machines and equipment apply.

ISO 9241-210:2010 Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems

ISO 9241-210:2010 provides requirements and recommendations for human-centred design principles and activities throughout the life cycle of computer-based interactive systems. It is intended to be used by those managing design processes and is concerned with ways in which both hardware and software components of interactive systems can enhance human–system interaction.

The standard addresses the human-cantered design principles and processes for interactive systems, providing with understanding of user requirements, specifying the user interface, and evaluating the usability of the system. Moreover, the ISO 9241-210 promotes the design of interactive systems that are efficient, effective, and satisfying for users.

This standard has been revised by ISO 9241-210:2019.

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ISO 23247-1:2021 Automation systems and integration — Digital twin framework for manufacturing - Part 1: Overview and general principles

ISO 23247-1:2021 provides an overview and general principles for the implementation of a digital twin framework in the context of manufacturing, including:

- Terms and definitions
- Requirements of the digital twin framework for manufacturing.

The standard aims to guide organisations in understanding the concept of a digital twin and its applications in manufacturing processes, covering aspects such as data acquisition, representation, management, and analysis within the digital twin framework. The standard helps organisations develop a common understanding of digital twin concepts and enables interoperability and collaboration within the manufacturing domain.

ISO 15609-1:2019 Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding

ISO 15609-1:2019 specifies requirements for the content of welding procedure specifications for arc welding processes. Specifically, it focuses on arc welding processes and provides requirements and recommendations for the preparation and content of welding procedure specifications (WPS) for arc welding of metallic materials. It covers both manual and mechanized welding processes.

The standard includes information on essential variables, such as base materials, filler materials, welding parameters, and joint design, that need to be considered when creating a welding procedure specification. It also outlines the procedure qualification requirements to ensure the compatibility and quality of the welding procedures.

ISO 3691-4:2020 Industrial trucks — Safety requirements and verification — Part 4: Driverless industrial trucks and their systems

ISO 3691-4:2020 specifies safety requirements and the means for their verification for driverless industrial trucks (hereafter referred to as trucks) and their systems. It covers aspects such as functional safety, human-machine interface, navigation, obstacle detection, and more.

The purpose of ISO 3691-4 is to ensure the safe operation and interaction of driverless industrial trucks in various industrial environments. It provides guidelines for manufacturers, integrators, and users of these trucks to ensure compliance with safety requirements and to mitigate risks associated with their operation. A driverless industrial truck is a powered truck, which is designed to operate automatically, comprising the control system, guidance means and power system. Requirements for power sources are not covered in this document.

The condition of the operating zone has a significant effect on the safe operation of the driverless industrial truck. The preparations of the operating zone to eliminate the associated hazards. It deals with all significant hazards, hazardous situations or hazardous events during all phases of the life of the truck (ISO 12100:2010, 5.4), relevant to the applicable machines when it is used as intended and under conditions of misuse which are reasonably foreseeable by the manufacturer.

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CEN EN 1525:1997 Safety of industrial trucks - Driverless trucks and their systems

CEN EN 1525:1997 provides safety requirements and recommendations for driverless industrial trucks and their systems, including guidance on their design, construction, and use. The standard aims to ensure the safe operation of driverless trucks in various industrial applications. It applies to all trucks and their systems except:

a) trucks solely guided by mechanical means (rails, guides, etc);
b) trucks operating in areas open to persons unaware of the hazards.

For the purpose of this standard, a driverless industrial truck is a powered vehicle, including any trailers designed to travel automatically in which the safety of operation does not depend on an operator. Remote controlled trucks are not considered driverless trucks.

IEC 61000-4-4:2012 Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test

IEC 61000-4-4:2012 relates to the immunity of electrical and electronic equipment to repetitive electrical fast transients, which provides guidelines and procedures for testing the immunity of electrical and electronic equipment against electrical fast transient/burst disturbances.

The standard defines the test method for generating and applying electrical fast transient/burst (EFT/B) disturbances to the equipment under test. EFT/B disturbances are rapid voltage variations that can occur in electrical systems due to switching operations, power supply disturbances, or lightning strikes. The purpose of the test is to evaluate the equipment's ability to withstand these disturbances without experiencing malfunctions or performance degradation.

IEC 61000-4-4 specifies the waveform characteristics, test setup, test procedure, and performance criteria for conducting EFT/B immunity tests. It provides manufacturers, testing laboratories, and regulatory bodies with a standardized approach to assess the electromagnetic compatibility of equipment.

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5 RECOMMENDATIONS

After analysing the collected data from internal and external third-party TRINITY demonstrators and coordinating with the TRINITY project partner from Work Package 3 “Use Case Demonstrations”, several recommendations have been formulated for standardization bodies. It is important to note that not all related standards have been identified for the specific use cases examined. In many instances, technical implementations tend to rely on common practices, with little knowledge of the specific standards that should guide the work. In light of these findings, the following recommendations have been identified for standardization bodies:

Update and expand the "Safety of Machinery" Standard: The standardization bodies should consider updating and expanding existing standards such as SFS-EN ISO 12100 "Safety of machinery" to address the unique risks associated with emerging technologies like artificial intelligence and cybersecurity. This can involve incorporating guidelines for data quality and integrity, decision-making principles; collaborating with industry experts and researchers to ensure the standard remains relevant and effective; and addressing potential risks specific to these technologies.

Develop AI-Related Standards for Safety of Machinery: Recognize the potential of AI in improving the safety of machinery. Standardization bodies should consider developing standards that specifically address the use of AI in safety systems of machinery. This can include guidelines for real-time monitoring, predictive maintenance, fault detection, autonomous operation, adaptive safety features, analysis of safety data, incorporation of principles for identifying potential safety risks and enablement of corrective actions to prevent accidents and injuries.

Emphasize Cybersecurity Standards: It is crucial for standardization bodies to place a strong emphasis on cybersecurity standards within the manufacturing industry. The potential consequences of cyber threats, including disruptions to factory operations and physical damages, highlight the criticality of robust cybersecurity measures. Encouraging the adoption of recognized cybersecurity standards like NIST 800-82 or NISTIR 8183 (developed by the National Institute of Standards and Technology - NIST in the United States) in use cases and demonstrations is essential for mitigating risks. Furthermore, enhancing awareness and education on cybersecurity within robotics standards and disseminating information about cybersecurity best practices will contribute to a more secure and resilient industry.

Foster Compliance with Digitalization-Related Standards: Standardization bodies should prioritize fostering compliance with digitalization-related standards to ensure the effective implementation of cybersecure and safe applications. It is crucial to emphasize the significance of standards pertaining to data transfer protocols, digital twins, system integration, and human-cantered design of interfaces. Promoting adherence to standards such as IEC 62541, ISO 23247-1, ISO 10303-1:2021, ISO 62264, ISO 9241-210:2010, and ISO/IEC 20922:2016 will provide guidance and best practices for implementing robust and secure digitalization solutions.

Regular Review and Updates: It is important for standardisation bodies to conduct regular reviews and updates of standards to keep them aligned with the evolving technology landscape. This can involve monitoring industry developments, identifying new risks, and addressing them through timely updates or the development of new standards.

Collaboration with Industry Experts: Standardisation bodies should collaborate with industry experts, researchers, and technology providers to gather insights and expertise in emerging technologies (AI,

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cybersecurity, automation etc.). This collaboration can help identify safety challenges, assess risks, and develop relevant standards that are up to date with technological advancements.

Address Fragmentation in Collaborative Robotics Standards: Standardisation bodies should consider incorporating collaborative robot system safety functions from ISO/TS 15066 into the updated ISO 10218 standard. This integration will enable comprehensive coverage of collaborative application development, verification, and validation. Additionally, it is important to integrate cybersecurity aspects and collaborative application requirements such as hand-guided control, power and force limiting, and speed and separation monitoring. Technical requirements from ISO/TR 20218 and RIA TR R15.806 should also be incorporated. By consolidating fragmented standards related to collaborative robotics into a single comprehensive standard, manufacturers, integrators, and health and safety bodies will have an essential tool to ensure consistent implementation of collaborative robotic systems.

Improve Awareness and Understanding of Standards: It is essential to focus on two key areas. First, there is a need to promote better knowledge and recognition of standards that guide technical implementations in use cases. This can be achieved through targeted training programs, workshops, and informational campaigns that highlight the importance and applicability of relevant standards. Second, stakeholders should be educated about the existence and relevance of standards, ensuring they are viewed as integral parts of daily work rather than optional guidelines. By enhancing awareness and understanding of standards, standardization bodies can foster a culture of compliance and promote the widespread adoption of standards across industries and sectors.

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6 CONCLUSION

This report provides a comprehensive analysis of the available and applicable standardization landscape, through the methodology outlined in Chapter 2, collecting background information for the TRINITY consortium partners about relevant standards, as well as the relevant Standardization Bodies and Committees involved, in order to ensure compatibility and interoperability of TRINITY with already existing solutions at the International and European level in the fields of: *Robotics, Human-Robot Collaboration, Automation, Advanced Manufacturing, Industrial Cybersecurity, Interoperability, Internet of Things, Artificial Intelligence, Safety and Virtual Reality / Augmented Reality.*

Through this analysis of the standardization landscape at the international and European level, the following conclusions may be drawn:

- There is a large number of European and international technical committees engaging in standardization on several fields related to the TRINITY project, and thus may be useful to consider for the project's development and dissemination of use case demonstrations. The most relevant technical committees identified in this report are ISO/TC 299 (Robotics), CEN/TC 310 (Advanced automation technologies and their applications), CEN/TC 114 (Safety of machinery), IEC/TC 65 (Industrial process measurement, control and automation), ISO/TC 184 (Automation systems and integration) and ISO/IEC JTC 1 (Information technology), which collectively cover most of the key technical fields of the TRINITY project – *Human-robot collaboration, safety* and *industrial cybersecurity* – and thus should be closely monitored by the members of the TRINITY consortium in the future.
- Despite the chronic challenges and inefficiencies of standard-setting processes, standardization bodies have successfully managed to codify and implement multiple standards that are fundamental for the robotics industry, especially in the fields of *robotics* and *safety*. These standards mainly include but are not limited to ISO 10218-1&2 (Safety requirements for robots), ISO 12100 / ISO 13849 (Safety of machinery), ISO 62443 series (Industrial automation and control systems), ISO 27000 series (Information security management), IEC 62451 (OPC UA) and IEC 62264 (Enterprise control system integration), and they provide a solid standardization framework for the TRINITY use case demonstrations.
- Standardization is either lagging or completely lacking in certain fields, particularly in the general sphere of emerging digital technologies and related aspects where standard-setting processes continue to lag behind innovation cycles. Due to the increasing variety of robot designs and industrial applications domains, recently developed standards are limited to certain production environments and industrial robot types, thereby partially or fully excluding some new robotic domains. In the fields of *human-robot collaboration, advanced manufacturing, industrial cybersecurity, internet of things* and *artificial intelligence,* there are significant gaps in the current standardization framework as we await numerous new standards or revisions that are currently under development, including but not limited to: IEC 62443 series, ISO 62439 series, ISO/ASTM DIS 52921, IEC 62264 series, IEC 62351 series, ISO/IEC AWI 30172 and ISO/IEC 5259 series, among others.
- Over recent years, industry has been reducing rather than increasing its participation in international standard-setting processes, mostly due to the significant direct and indirect costs that are incurred from the participation in these activities. This has led to an almost total exclusion of small-and-medium-sizes enterprises (SMEs) from standard-setting processes, who are increasingly unable to

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withstand the associated costs and thus are not able to exercise a legitimate influence in the relevant technical committees to protect their interests.

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- CEN website: https://www.cen.eu/
- CENELEC website: https://www.cenelec.eu/
- CEN/CENELEC Projex Online database: https://projex.cencenelec.eu/ (restricted to authorized users)
- ETSI website: https://www.etsi.org/

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