Report D1.6

"OntoCommons

Standardisation Impact Report v1"

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Task	T1.6	OntoCommons Standardisation Impact Report v1
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0.3	15/09/2021	Rita Giuffrida, Francesco Osimanti, Patricia Nugent	OntoCommons.eu contribution to Standards
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List of Acronyms

Item	Description
BFO	Basic Formal Ontology
CEN	European Committee for Standardisation
CENELEC	Comité Européen de Normalisation Électrotechnique
CNR	Consiglio Nazionale delle Ricerche
CSAs	Coordination and Support Actions
CWA	CEN Workshop Agreement
DOLCE	Descriptive Ontology for Linguistic and Cognitive Engineering
DOME4.0	Digital Open Marketplace Ecosystem
EAB/EAG	External Advisory Board/Expert Advisory Group
EMMO	European Materials Modelling Council
ENIT	École Nationale d'Ingénieurs de Tarbes
EOSC	European Open Science Cloud
e-SDF	E-SCIENCE DATA FACTORY
ESO	European Standard Organisation
ESS	European Standardisation System
ETSI	European Telecommunications Standards Institute
EUOS	EU Observatory for ICT Standardisation, aka the Standards Observatory.
FAIR	Findable, Accessible, Interoperable and Reusable
ICF	Industry Commons Foundation
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineers
iiRDS	Intelligent Information Request and Delivery Standard
ISO	International Organisation for Standardisation
JRC	Joint Research Centre
MODA	Multimedia Ontology Driven Architecture
MSP	Multi-Stakeholder Platform
NMBP	Nanotechnologies, Advanced Materials, Biotechnology, and Advanced Manufacturing and Processing
OCES	OntoCommons Ontology EcoSystem
OSS	Open-Source Software
OWL	Web Ontology Language
RDA	Research Data Alliance

RIA	Research and Innovation Action
SAREF	Smart Applications REFerence
SDO	Standard Developing Organisation
TC	Technical Committee
TWG	Technical Working Group
UPM	Universidad Politecnica de Madrid
W3C	World Wide Web Consortium
WGs	Working Groups

Keywords

Standardisation, ICT Standards, Digital Industrial Transition, Coordination, Harmonisation, Interoperability

Disclaimer

Executive Summary

This report, the first of two iterations of the OntoCommons Standardisation Impact report, provides a state of the art of **European contributions to Ontologies and semantic interoperability in the international standards arena and how, thanks to those, OntoCommons.eu has contributed to progressing on the the harmonisation of data documentation and interoperability of data across materials and manufacturing domains**. It goes on to outline how the Ontocommons.eu demonstrators, the Expert Advisory Group (EAG), consortium partners and related activities and projects all serve to progressing activities in the standardisation landscape, by providing important user requirements for standardisation and the materials and modelling domain perspective, with the objective of making standards more harmonised and applicable across different domains.

OntoCommons.eu cooperates with industrial players to develop thematic demonstrators, in order to prove the effectiveness of the OntoCommons Ecosystem adoption in the industrial domain. The team has started to conduct an analysis of the standards considered by each of the OntoCommons demonstrators, and the benefits of using ontologies in support of such standards.

The information emerged in the scope of the analysis conducted could open the door to future reflections and future recommendations for standardisation. These that can ultimately feed the OntoCommons Roadmap (D1.16).

In the next iteration of this deliverable, the analysis of standards used by the demonstrators will be extended to the new OntoCommons demonstrators adopted in the course of the project (besides the initial set of 11 use cases), as well as to the demonstrators of related projects. The collaboration with related initiatives will also be more strictly linked to the demonstration cases and the organisations linked to the standards that they are currently using. At the time of writing, some Consortium calls are also being set up in order to align the WP1 (Cooperation) and WP5 (Demonstration) activities together, and use the demonstrators' feedback to gather requirements to improve standards, and, therefore, the possibility of communication and understanding across these domains.

The more important impacts, among others, reported by each demonstrator, that have emerged from this analysis are:
- decreased development time and improved industrial system reliability and efficiency,
- better automation and information traceability,
- better representation of equipment,
- capturing and representation of expertise,
- routine and processes thanks to the use of data and models to optimise production, decreased time to perform certain type of operations,
- improved communication between organisational units,
- reduced number of hours spent on complex and repeatable work,
- enriched data bases and easier data retrieval, **reduced time thanks to standardisation of processes** and **reduced manufacturing costs and environmental footprint**.

The complete analysis is reported in Table 2.

D1.6 also accounts for the achievement of the project's milestone MS5: *"Cooperation with Standardisation Working Groups and the Technical Committees status"*, due in M12, verified through monitoring of the progress on the support and cooperation with Standardisation WGs and the international Technical Committees.

Ontologies can contribute to the competitiveness of European Innovation, by helping to tackle challenges such as the harmonisation of standards, identified in the European Standardisation System Roadmap. Different projects, associations, described in detail under Section 6, as well as focused Coordination and Support Actions (CSAs) such as Ontocommons.eu, Dome 4.0, Ontotrans, StandICT.eu to name a few in Europe are collaborating with Standards Developing Organisations (SDOs) to bring the users' perspective and contribute to a **more agile process for standardisation** and to provide valuable guidelines and recommendations.

Standards used to organise data related to Engineering properties and materials information, as well as ICT Standards (which are fundamental for exploitation), can benefit from the work of conceptualisation, **better categorisation of information and process efficiency that ontologies can offer**. OntoCommons has the objective of ensuring that efforts are channelled in the same direction among related initiatives, and that the materials and manufacturing community is adequately represented by these efforts.

Representatives from Ontocommons.eu have had exchanges with European Commission officials of DG GROW, DG CONNECT, who lead the ICT Rolling of Standardisation[1] have offered an opportunity to the project to provide contributions to a new chapter introduced to the Rolling plan edition of 2022, entitled **the Data Economy**, in its final phases of revision for introduction to the 2022 Rolling Plan for ICT Standardisation. Contributions around ontologies and semantic interoperability are welcomed. The content would undergo peer review acceptance nevertheless, the opportunity to have this dialogue is extremely positive and puts us in a good position to have a continued dialogue with the Mutlistakeholder Platform contributors in the following months.

In the scope of the OntoCommons Cooperation work package, **Task 1.2: "Specifications, Support to International Standardisation TCs & WGs & Cooperation"**, the OntoCommons team has started to identify and engage with relevant stakeholders in the international standardisation field, focusing its effort on different levels: first, a continuous **mapping** of all EU and international standardisation initiatives on ontology-based standardisation of data documentation in NMBP related domains has been carried out (listed in the Table 1 of this document), in order to understand the current landscape and coordinate the efforts through the cooperation with this activities.

Secondly, concrete actions are being undertaken to carry out the **collaboration** with some of these initiatives: OntoCommons.eu has expressed its interest in joining the StandICT2023.eu's EUOS in the form of a Technical Working Group (TWG) on Ontologies and involve representatives from the materials and manufacturing domains. In fact, in November 2021 it was decided that ENIT, as the technical coordinator of OntoCommons.eu, will chair this TWG with his representative Arkopaul

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Sarkar, which will provide a landscape and gap analysis report on Ontologies on a global scale and provide recommendations for future work. This report will have a foreword written by an EC DG senior officer. Moreover, the project is collaborating with FAIR initiatives to integrate and test FAIR Semantics recommendations, and with RDA and its group to elaborate recommendations for standardised data documentation based on ontologies and taxonomies. Further collaborations include the direct liaison with European and international initiatives and SDOs, and the contributions to the Metadata and Ontologies challenge of EOSC.

Strengthening the collaboration among these initiatives is fundamental, and even more important, this collaboration should also result in enhanced cooperation on standardisation: as different standards might use different semantics for similar concepts, **standards alignment, integration and conformance, through the use of ontologies**, can make a real difference in getting the materials domain and the manufacturing domain to communicate and be able to exchange information, setting the basis for a common ground of understanding.

The role played by standards has in fact been heavily recognised in particular in the industrial ecosystem as a means of improving performances and process efficiency. At the same time, ontologies can support industries in the adoption of standards, for example by **improving their machine-readability** and thus the possibility of better and even automated implementation.

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1.Introduction

Europe's competitiveness in the domain of materials and manufacturing depends, among other factors, on its ability to embed digital capabilities (e.g., IoT and AI) in the operations of competitive industries and services, and consequently on its work on harmonisation and standardisation of data documentation, which ontologies can greatly contribute to. **Data standards** are vital in order to increase performance while guaranteeing other crucial attributes such as FAIRness, interoperability, trust, security and reliability in data sharing. Their application in our society offers potential to ensure that data users from the manufacturing domain have access to information on what data means in the material domain (and vice versa). As a matter of fact, data standards promote common understanding and agreement on access to information.

Due to the critical role played by standards, efforts to improve cooperation in standardisation activities in data both at a European and global level are already in place within OntoCommons.eu. From the user perspective, the project aims to strengthen the cooperation with relevant SDOs with the European Standard Organisations ESOs, ETSI, CEN-CENELEC, as well as with ISO, iiRDS and EU-funded projects and initiatives operating in the standardisation area, like StandICT.eu 2023 and DOME4.0, just to mention a few. OntoCommons.eu's objective, in this case, is to work closely with ongoing standardisation initiatives with a view to detecting emerging standards in ontology while keeping abreast of existing efforts to promote FAIR data and FAIR ontologies as part of activities foreseen under Task 1.1. Monitoring developments and coordinating cooperation. In this context, ontologies play a relevant role in implementing standards as the latter can adopt ontologies to better establish and define themselves, making standards and ontologies strongly interconnected. Existing ontologies, such as BFO, DOLCE, EMMO are used by the OntoCommons.eu project for this purpose.

Ultimately, the efforts carried out by OntoCommons.eu's Working Group on Cooperation in Standardisation will pave the way to innovation across NMBP domains (Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing) by ensuring that recommendations, roadmaps and specific actions within these domains are inclusive of requirements for standardised and FAIR documentation on ontologies, and the following chapters outline a few coordinated efforts that go into that direction of activity.

1.1 Purpose and scope

The scope of the present deliverable, which has public dissemination level, is to provide an initial overview of EU contributions to international standardisation activities in the ontology domain and how OntoCommons.eu has contributed to progress on the impact in this domain in the first year of the project.

This is provided at M13, as opposed to M12, in order to include inputs from the OntoCommons.eu First Horizontal Workshop, called "Global Workshop: Ontology Commons addressing challenges of the Industry 5.0 transition", which included a session entirely dedicated to ontologies and standardisation. Details of this session are included in Chapter 5 of this deliverable.

This report also accounts for the achievement of the project's milestone MS5: *Cooperation with Standardisation Working Groups and the Technical Committees status*, due in M12, verified through monitoring of the progress on the support and cooperation with Standardisation WGs and the international Technical Committees.

Finally, the report outlines the next steps to be taken to follow up on the work that has been carried out so far.

1.2 Related Deliverables

This deliverable is released in two iterations. The second version of this deliverable is the **D1.7: OntoCommons Standardisation Impact Report, v2**, which will be released in M24. Given the more advanced state of the project in that period of time, we expect the following iteration of this deliverable to include evolved results on the ongoing collaborations of the OntoCommons.eu Consortium and Demonstrators with global standardisation initiatives and on the impact of such collaborations on the standardisation of data documentation across the materials and manufacturing industrial domains.

The **deliverable D3.9** is the **Report on the first focused workshop on domain ontologies**, dedicated to the focused workshop "[Domain Ontologies for Research Data Management in Industry Commons of Materials and Manufacturing](https://www.ontocommons.eu/)" (DORIC-MM 2021), which happened in two sessions in May, and June 2021 and was co-located with the 18th European Semantic Web Conference (ESWC). The event gathered some feedback and insights from the OntoCommons community about the semantic landscape in the field of materials and manufacturing, as well as various insights regarding standardisation and ontologies. The workshop highlighted the **importance of the standardisation of ontologies to enable data reusability** and the challenges to achieve it, such as reaching the necessary agreement to build a good framework and the lack of long term and community vision.

The workshop highlighted that **domain-specific metadata standards, including ontologies are a necessary component of solutions for FAIR research data management with industrial applications**, and the OntoCommons Demonstrators use cases will contribute to prove the importance and effectiveness of such ontologies.

From the workshop discussions, another important feature emerged: namely, that the standardisation level can vary among the different Material and Modelling domains: some of them rely on ISO level standards, others rely on technical documents, such as CEN Workshop Agreement (CWA). To foster interoperability and data reusability between the various Material and Modelling domains, it is therefore important to invest in the standardisation process across all domains.

1.3 Structure of the document

Chapter 2 of this document provides an overview of the current **State of the Art** and the need for standardised digital information, as well as the present challenges and barriers and the potential for OntoCommons.eu to positively influence the standardisation landscape and help tackling many of the **challenges** identified in the EU Standardisation System.

In particular, this chapter focuses on the current challenges in the use of standards in the **ICT** domain, which the materials and manufacturing community is directly affected by as a user, and in the **Product Engineering** domain, as well as on the potential for ontologies to contribute to the effectiveness of **Open Source and Open Standards**.

The **framework set up and initial steps** carried out to achieve the project's objectives of Cooperation in Standardisation is presented in **Chapter 3**. In the first 12 months of the project, effort on the task 1.2 "Specifications, Support to International Standardisation TCs & WGs & Cooperation" has been focused on different levels: a continuous mapping of EU and global initiatives related to ontology-based standardised data documentation, the collaboration with several related initiatives and in particular with EOSC, RDA, European and international projects linked to standardisation, SDOs and FAIR related initiatives.

Different standards might use different semantics or terms for explaining the same or very similar concepts. From one side, this aspect increases the complexity of establishing common rules that could be applied in industrial and research areas. On the other hand, this complexity can be overcome by highlighting the double role played by ontologies in the standardisation environment: in **Chapter 4**, the impact of ontology standardisation in the industrial ecosystem is analysed through the standards currently considered by the OntoCommons.eu set of **industrial demonstrators**.

Chapter 5 describes the session dedicated to Standardisation that took place in the first Horizontal Workshop in M12 (November 2021). The session, called "Enabling intra-ontology interoperability through shared terminology", was a great chance to collect feedback from the panel of experts that engaged in fruitful discussions. Barry Smith, from the National Center for Ontological Research, member of the OntoCommons.eu External Advisory Board, Boonserm Kulvatunyou, from NIST, member of the OntoCommons.eu External Advisory Board, Ulrike Parson, from the iiRDS Consortium engaged in collaborations with OntoCommons.eu, and Nicolas Figay, from the Airbus Defence and Space at Elancourt and involved in one of the OntoCommons.eu demonstrators, have presented their inputs talks moderated by Silvana Muscella, CEO at Trust-IT, answered questions from the attendees, and finally engaged in an interactive discussion that provided valuable input for the OntoCommons Roadmap.

Chapter 6 is divided in two sections, dedicated to the collaboration with relevant projects and with SDO. For each of those, a short description, insights on the type of collaboration, standards involved and impact of the collaboration are provided, as well as the possible next steps to guarantee a continuous engagement.

The conclusive chapter, **Chapter 7**, includes some recommendations from the analysis carried out so far, and lists future actions to be carried out within the timeframe of OntoCommons.

2. State of the Art and Landscape Analysis

The European Standardisation System (ESS) supports the overall competitiveness of EU industries. The Standardisation strategy Roadmap[2] has identified the following challenges to address, among others, in order to achieve an **effective and harmonised standardisation**:

- to modernise and consolidate the ESS, ensuring it is better oriented towards meeting EU's priorities, notably the **Green Deal/Digital Industrial Transition**
- to address bottlenecks within the standardisation system
- to incentivise **coordination**, efficiency and flexibility in the timely delivery **of European Standards**
- to **make full use of the EU industrial resources** to contribute to (pre-) standardisation activities, including research and innovation activities.

Ontologies can help tackle many of the challenges identified in the roadmap by contributing to the standards harmonisation and interoperability.

Manufacturing has in fact adopted technologies such as automation, robotics, industrial IoT, and big data analytics in order to improve productivity, efficiency, and capabilities.

The following paragraphs provide an overview of the current challenges and opportunities in the use of standards related to **engineering properties and materials information standards**, and **ICT standards**.

2.1 Engineering properties and materials information standards

The increased digitisation in several domains and in particular in Product Engineering and Materials 4.0, is accompanied by new opportunities as well as new challenges.

Each engineering software system might have different representations of data and different digital information, that, therefore, cannot be re-used by other systems, resulting in extra costs.

In order to achieve **digital interoperability and through-life management of information** in the Materials 4.0 domains, non-proprietary, computer-understandable information models are needed, to describe the characteristics and properties of the objects of study in each specific domain and ensure that these can be understood by the receiving system even when this becomes obsolete[3].

International Standards allow for consensus of the digital representation of all engineering product data, in a form that is independent from proprietary software, well established and reliable.

The information models specified in the ISO standards could provide new opportunities and new business models for the application and presentation of materials information. Moreover, a

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[2] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13099-Standardisation-strategy_en
[3] MATERIALS 4.0 | A ROLE FOR STANDARDS, Henry Royce Institute

significant advantage is that several standards can be combined to form integrated systems and provide new business opportunities or new methods of work.

When it comes to the application of standards, however, and in particular ISO 10303-235 (AP235), the current implementations of this information model are relatively outdated and need to be brought to ontology level: in fact, the key to this model is that, any property definition, **requires the processes by which that property value is determined**. The MODA work as well as the EMMO ontology work contribute to this information model, that in fact needs to be brought to ontology level.

This is the direction in which OntoCommons.eu and the related initiatives are working towards. One barrier, which can be turned into an opportunity, would be that of entering the ISO/TCs that are actually working on updating/advancing the ISO 10303 Application Protocols.

2.2 ICT Standards

In modern ICT the service value of a device relies on the possibility (and capacity) to communicate with other devices (best known as "network effect"). This rule affects and is pivotal in all areas of ICT. Specifications ensure that products made by different manufacturers are able to **interoperate**, and that (end) users are given the chance to pick among different suppliers, products or services.

There are few barriers to be overcome to attain a full interoperability and enable ICT Standards to achieve a tangible impact, as outlined below:

- Accessibility - Accessible Information and Communication Technology is technology that can be used by people with a wide range of abilities and diverse backgrounds. Each user is able to interact with the technology in ways that work best for him/her.
- Approval Procedure - The average cycle to achieve the final Standard's approval (in view of the publication and reception) is time consuming, especially in the context of a globally competitive standards system and this can result in an impediment to EU's overall competitiveness.
- Awareness - There's a need, especially among small businesses and industries, to understand the critical importance of ICT Standards to play a key-role in every market's domain, mostly in ICT. Technological standards offer significant benefits to both industry and consumers and thus, play an essential role for the ICT sector. They ensure full interoperability and guarantee the smooth development and exploitation of new technologies.
- Engagement - It is sometimes complicated for non-standardisation experts (despite being fully operational in a sudden field, as Ontology) to interact with correlated SDOs and their inner scheme of Working Groups and/or Technical Committee (due to lack of funding for time and travel or simply unawareness of the functioning of Standards development). This may prevent them to have a say or bring valuable contributions to the development of ICT Standards (like emphasizing potential gaps or priorities to be closely taken into account).

- Intellectual Property Right(s) - The attempt of bringing R&I into standards often requires permission for SDOs and an IPR agreement under RAND rules.

The pro-active efforts in cooperating in technical working Groups within StandICT.eu or become part of the Communities of Practice within RDA all serve to break down barriers.

2.2.1 OntoCommons role in the Rolling Plan for ICT Standardisation:

The Rolling Plan for ICT Standardisation, which is drafted on a yearly basis by the European Commission in collaboration with the European Multi-Stakeholder Platform on ICT Standardisation, provides an overview of all known areas where ICT standardisation could support EU policy objectives. It also details the requirements for ICT standardisation, translates them into actions and provides a follow-up mechanism for the actions.

The 2021 edition focuses on four main priority areas: (1) Key Enablers and Security, (2) Societal Challenges, (3) Innovation for the digital single market, and (4) Sustainable Growth, each subdivided into technological or application domains. For each priority domain, policy and legislation objectives are defined in Part A of the plan and accompanied by a set of future requested actions in Part B, as well as overview of relevant standardisation activities being carried out by SDOs and other Standard Setting Organisations in Part C. From these four thematic areas, about 180 actions are included under the 37 technological or application domains.

A challenge, and at the same time opportunity OntoCommons.eu has envisaged, is that the Rolling Plan **does not currently include a specific section on ontologies** per se. However, ontologies are transversal to multiple technological and application domains and indeed find mention in the 2021 edition as part of standardisation activities underway in sections related to Big Data, Open Data IoT and Public Sector Information, as well as part of the requested actions and activities underway for Smart Cities and Communities/ Technologies and Services for Smart and Efficient Energy Use, Robotics and Autonomous Systems, to Construction - Building Information Modelling, Water Management Digitisation and the Circular Economy. Indeed, ontologies can help tackle many of the challenges identified in the European standardisation system by contributing to the standards harmonisation, alignment and interoperability.

The possibility, as already mentioned, is currently being explored to provide input to a new chapter, **Data Economy**, in the final phases of revision for introduction to the 2022 Rolling Plan, where there may be a possibility to add relevant content on ontologies. This would obviously be a tremendous step forward to ensure that future standardisation policy objectives and recommendations are inclusive and duly representative of the requirements for standardised and FAIR documentation on ontologies promoted by the OntoCommons.eu initiative.

OntoCommons.eu is also working directly with SDOs and other Standards Setting Organisations, with a view to improving cooperation between industry and research standards and providing relevant guidelines, as detailed in Section 6. This will favour an active dialogue to establish more agile processes, while exploiting the potential offered by ontologies and standards. The full list of cooperative institutions can be found in Table 1 and practical examples are provided in Section 5 of this deliverable.

2.2.2 Open Source and Open Standards:

Standards and Open-Source development are both processes widely adopted in the ICT industry to develop innovative technologies and facilitate their adoption in the market.

Open Standards can play a critical role in ICT technologies by enabling the achievement of paramount objectives in view of a more digitized and competitive European industry sector:

- Standards allow industry to provide software and services capable to match customer's needs and requirements (both today and in the future).
- Standards ensure a full interoperability and allow technologies to be connected or integrated and work seamlessly together.
- Standards can boost innovation by providing an agreed and trusted basis on top of which innovation can thrive.
- In a networked ecosystem, Open-Source Software and Standards can fulfil the burning need for end-to-end solutions with pieces of software from different vendors to work and function together.

To date, Open-Source components are the pivotal building blocks of the digital transformation, comprising an estimated 60-90 percent of the code base in modern software applications: Open-Source software components are developed and adopted by big industry, SMEs and communities, making better code available for sharing and reusing to everyone, so long as they comply with license requirements.

The potential economic impact of Open-Source Software (OSS) on European Industry is massive: it is estimated that companies based in the EU territory and member states invested around €1 billion in OSS in 2019, which resulted in an impact on the European economy spanning between €65 and €95 billion (source: "*The impact of Open-Source Software and Hardware on technological independence, competitiveness and innovation in the EU economy*"). A widespread and faster adoption of Open-Source Software would result in lowering barriers to participation, enabling experimentation and contribution to development of de facto standards for a wide array of Industrial Stakeholders and speeding up the completion of a fully-fledged "*Digitising European Industry*" strategy.

In the case of Open Source and Open Standards, ontologies have the potential to enable better categorisation of information and increase efficiency in the open-source development process[4].

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[4] https://link.springer.com/chapter/10.1007/0-387-34226-5_7

3.Framework set-up to capture EU contributions in Standards

In the scope of the task 1.2 "Specifications, Support to International Standardisation TCs & WGs & Cooperation" OntoCommons.eu leverages relevant ongoing efforts and works closely with standardisation initiatives to ensure alignment and, where possible, influence work on emerging ontology standards, as well as on the existing work toward FAIR data and FAIR ontologies.

In order to achieve this objective, the OntoCommons.eu team is consolidating its dialogue with relevant stakeholders in the international standardisation field over the course of the first twelve months from its launch. In particular, in order to get in contact with relevant players of the standardisation ecosystem, the team has focused its effort on the actions described in the following sections.

3.1 Mapping of EU and international standardisation initiatives

The table below lists the relevant EU and international initiatives currently mapped, related to ontology-based standardisation of data documentation in NMBP domains. The mapping is a continuous activity which is still in progress:

Number	Organisations related to Standards efforts	Type of collaboration
1	BDVA - Big Data Value Association/DAIRO	• TEKNIKER and ATB (part of the OntoCommons consortium) are members. • OntoCommons will join the BDVA event, such as the European Big Data Value Forum (EBDVF) • OntoCommons will liaise with BDVA to utilise their outputs.
2	CEN - European Committee for Standardization	• Dimitris Kiritsis (WP1 leader) participated in a meeting on a new standard on Zero Defect Manufacturing (ZDM) organized by DIN/CEN/CENELEC. The participants have the intention to work with ontologies in this domain and the idea is to create a WG on ZDM in IOF.
3	CFPC - Carbon Fibres & Advanced High-Performance Cluster	• TEKNIKER (part of the OntoCommons consortium) has contacts with this working group through the EUMAT Platform. • OntoCommons will liaise with CFPC to utilise their outputs.
4	CO-LaN	• Michel Pons attended the OntoCommons Doric Kick-off event on 15th March 2021.

		• OntoCommons will liaise with CO-LaN to utilise their outputs
5	DDI - Data Documentation Initiative	• Joachim Wackerow attended the TLO/MLO workshop in March/April 2021. • OntoCommons will liaise with DDI to utilise their outputs
6	ECLASS or eCl@ss-Standard for Master Data and Semantics for Digitalization	• First contact initiated • Collaboration scope not defined yet
7	EMMC - The European Materials Modelling Council	• There is a close connection with OntoCommons via individuals and organisations participating in both. • EMMC has disseminated OntoCommons events. • OntoCommons and CNR (part of the OntoCommons consortium) joined the EMMC International Workshop, March 2021. • EMMC will join OntoCommons' s Focus Areas on "Interoperability" and "Digitalisation". • The Ontology EMMO (governed by EMMC) is used by various OntoCommons demonstrators.
8	EOSC - European Open Science Cloud	• OntoCommons identified three relevant EOSC Task Forces to either establish close working relationships on technical and semantic interoperability of data and FAIR metrics. • There is a close connection with OntoCommons via individuals and organisations participating in both. • Members of EOSC joined the OntoCommons Event: "Creating a Knowledge Exchange Space for data management and documentation – KexS". OntoCommons joined the EOSC Symposium with a session on the Alignment and harmonisation between EU marketplaces and synergies and collaboration opportunities between EOSC and OntoCommons.
9	ETSI (including developments of SAREF - Smart Applications REFerence Ontology, and extensions)	• Mauro Dragoni, Research Scientist at Fondazione Bruno Kessler is one of the main developers of SAREF and contributed in the panel discussion of the webinar "What can ontologies do for standardisation? OntoCommons.eu project in the standardisation ecosystem", and in the first OntoCommons Horizontal Workshop. • Patrick Guillemin, Technical Officer SmartM2M, CABLE, eHealth, ISG CIM and IoT/Smart Cities Coordinator, former AIOTI WG03 IoT Standardisation Chairman, AIOTI

		Steering Board Member, is member of the OntoCommons External Advisory Board. • OntoCommons liaises with ETSI SAREF to analyse their outputs. • UPM (OntoCommons consortium) has developed several SAREF extensions and the SAREF latest versions. • OntoCommons will liaise with SAREF to utilise their outputs.
10	EUDAT Collaborative Data Infrastructure (EUDAT CDI)	• First contact initiated • Collaboration scope not defined yet
11	European Multi Stakeholder Platform on ICT Standardisation	• The Ontocommons consortium will contribute content to the new chapter "Data Economy" within the ICT Standardisation rolling plan 2022 by November 2021.
12	IAOA - International Association for Ontology and its Applications	• There is a close connection with OntoCommons via individuals and organisations participating in both. • Members of IAOA attended the OntoCommons Doric Kick-off on 15th March 2021. • Members of IAOA attended the TLO/MLO workshop March/April 2021. • IAOA President Laure Vieu gave a talk during the 1st OntoCommons Horizontal Workshop. • Co-organization of the FOMI 2021 workshop in September 2021. • Discussion with co-chairs of the IAOA Industry and Standards Technical Committee for the organization of events in the coming years. • OntoCommons will liaise with IAOA to utilise their outputs.
13	IDSA - International Data Spaces Association	• TEKNIKER (part of the OntoCommons consortium) is a member. • OntoCommons will liaise with IDSA to utilise their outputs and contribute to their groups
14	iiRDS – The International Standard for intelligent information Request and Delivery	• The iiRDS ontology can be harmonised and made interoperable with the other ontologies involved in the OntoCommons project (e.g. EMMO, DOLCE, BFO). • iiRDS has applied to become an OntoCommons demonstrator with a use case that aims to enrich technical documentation content with iiRDS metadata to enable the digital representation of documentation in industry 4.0 scenarios.

		• iiRDS will provide insights and recommendations to shape the OntoCommons Roadmap. • Members of iiRDS attended an OntoCommons webinar and a session of the 1st OntoCommons Horizontal Workshop. • OntoCommons is liaising with iiRDS to to discuss the technical potential of the different Ontology levels. • Members of iiRDS are considering to apply to the StandICT.eu Open calls to help support the work they are doing with IIRDS. Should the application be successful they will provide content that will contribute to the OntoCommons.eu roadmap. • OntoCommons will liaise with iiRDS to utilise their outputs.
15	INCITS - International Committee for Information Technology Standards	• Hedi Karray (OntoCommons technical coordinator) is a member. • OntoCommons will liaise with INCITS to utilise their outputs.
16	IOF - Industrial Ontology Foundry	• OntoCommons is contributing to the development of a standardised set of open industrial ontologies that spans the entire domain of traditional manufacturing. • Members of the OntoCommons EAB are members of the Industry Ontology Foundry (Barry Smith, Boonserm Kulvatunyou). • Dimitris Kiritsis, WP1 leader, is one of the IOF Technical Oversight Board vice chairs. • Hedi Karray, OntoCommons technical coordinator, is member of the IOF Technical Oversight Board. • The IOF Working Group is developing the ZDM (Zero Defects Manufacturing) ontology, related to quality improvement and that could be implemented by some of the OntoCommons demonstrators. • OntoCommons will use the IOF core as the MLO for OntoCommons.
17	ISO - International Organization for Standardization	• Hedi Karray is collaborating with ISO/TC 184/SC4. • Fahad Khan, Markus Stumptner, David Price attended the TLO/MLO workshop in March/April 2021. • OntoCommons is considering the involvement (supported by Barry Smith, member of EAB) in ISO/IEC JTC 1 in particular the working group concerned with top-level ontology standards. • OntoCommons will liaise with ISO to utilise their outputs.

18	Mat-o-Lab	• Members of Mat-o-Lab attended the OntoCommons Doric event on 7th June 2021. • OntoCommons is liaising with Mat-o-Lab to discuss a possible cooperation. • OntoCommons will liaise with Mat-o-Lab to utilise their outputs, in particular Matportal.
19	NCOR - National Center for Ontology Research	• NCOR is headed by Barry Smith, EAB member of OntoCommons. • Hedi Karray, OntoCommons technical coordinator, is associate researcher at NCOR. • OntoCommons will liaise with NCOR to utilise their outputs.
20	NIST - National Institute of Standards and Technology	• Members of NIST attended both OntoCommons Doric event on 15th of March 2021 and 7th June 2021. • Serm Kulvatunyou gave a talk during the 1st OntoCommons Horizontal Workshop. • OntoCommons will liaise with NIST to utilise their outputs.
21	OGC - Open GeoSpatial Consortium	• First contact initiated • Collaboration scope not defined yet
22	OISPG - Open Innovation Strategy and Policy Group	• OISPG is part of the Industry Commons Foundation (OntoCommons consortium).
23	oneM2M - Standards for M2M and the Internet of Things	• First contact initiated • Collaboration scope not defined yet
24	OPC Foundation - The Industrial Interoperability Standard TM	• First contact initiated • Collaboration scope not defined yet
25	OPEN INDUSTRY ALLIANCE 4.0	• First contact initiated • Collaboration scope not defined yet
26	RDA - Research Data Alliance	• OntoCommons gave a presentation about the project during RDA's 17th Plenary Meeting in April 2021. • RDA proposes to provide support to identify and get in contact with the relevant stakeholders with the RDA galaxy of Interest Groups and Working Groups. • The OntoCommons multi-stakeholder collaboration Knowledge Exchange Space (KExS) already involves

		Interest Groups interested in ontologies such as the RDA Chemistry IG and the Vocabulary and Semantic Service IG.
		• RDA will help OntoCommons to identify the relevant recommendations for the project and its stakeholders.
		• OntoCommons is considering to create an RDA Community of practice for data documentation in materials and manufacturing.
		• OntoCommons is considering to create an Industry Commons group within RDA.
		• OntoCommons will liaise with RDA to utilise their outputs.
27	SSHOCRo	• First contact initiated • Collaboration scope not defined yet
28	StandICT.eu	• OntoCommons.eu will provide key insights on appropriate and pertinent gaps, recommendations and priorities in ICT Standardisation around ontologies for StandICT.eu's future Open Calls. • OntoCommons.eu may publicise the opportunities offered to its stakeholders by the StandICT.eu Open Calls and encourage applications. • OntoCommons.eu may also take part in webinars and events organised by StandICT.eu 2023 and vice versa. • StandICT.eu is about to launch a new Technical Working Group on Ontologies which will include experts from OntoCommons.eu and ultimately yield a Gaps Analysis Report for ICT standardisation activities in the Ontology domain and generate timely and pertinent content to feed directly into the StandICT.eu EUOS. (European Standards Observatory)
29	UK National Digital Twin Programme	• OntoCommons is using UK National Digital Twin Programme's resources. • UK National Digital Twin Programme members attended the OntoCommons TLO/MLO workshop. • OntoCommons will liaise with the UK National Digital Twin Programme to utilise their outputs.
30	W3C - World Wide Web Consortium	• UPM (OntoCommons consortium) is involved in W3C groups. • OntoCommons will liaise with the W3C to utilise their outputs.

Table 1 - List of relevant initiatives in the NMBP standardisation area

3.2 Expressing interest in joining the European Observatory for ICT Standardisation (EUOS):

In alignment with the challenges presented in Section 2.2, OntoCommons.eu has liaised with StandICT.eu and expressed the interest to join the European Observatory for ICT Standardisation (EUOS), led by the CSA H2020 project StandICT.eu, and **to support the creation of a Technical Working Group (TWG) focused on standardisation applied to ontologies**.

The StandICT.eu 2023's EUOS is an interactive platform, the key-goal of which is to monitor the global ICT Standardisation landscape, with its ultimate objective to provide the community of experts with the most accurate coverage of relevant and timely Standards, priorities and needs that might affect key domains of the Digital Single Market and the EU ICT Rolling Plan for Standardisation. The group of experts to join the TWG on ontologies has been identified and set-up by the StandICT.eu team. ENIT, as the technical coordinator of OntoCommons.eu, is chairing this TWG with representative Arkopaul Sarkar. The TWG is composed of diverse partners that have both ICT and industrial backgrounds. Given the versatility of the ontologies, the group has started to work on analysis that concerns both ICT and materials and manufacturing-oriented standards.

The outcome of the collaborative work carried out by the experts will be a dedicated **Landscape Report**, that will feed into the OntoCommons Roadmap, as well as into the next iteration of this deliverable.

3.3 Involvement in related standardisation initiatives

Another objective of the OntoCommons.eu project is to engage with the following European and international standardisation initiatives:

- To create joint liaisons and contribute to international standardisation and semantic implementations of existing materials testing interoperability standards and creation of dedicated working groups through the EC-JRC, with European and international initiatives and SDOs;
- To contribute and support work in taxonomy, ontology development and semantic interoperability in dedicated working groups: AIOTI, IOF, CEN-CENELEC, ETSI and ISO/IEC JTC 1, in which the OntoCommons.eu team, supported by the EAB Barry Smith, is also a member of the working group linked to top-level ontology standards;
- To establish a collaboration with IEEE with the development of a dedicated working group on Industry Commons;
- To collaborate with FAIR initiatives (FAIRsFAIR, GoFAIR, FAIRSharing) to integrate and test FAIR Semantics recommendations and with RDA and its groups to elaborate recommendations for standardised data documentation based on ontologies and taxonomies;
- To contribute to the Metadata and Ontologies challenge of EOSC, addressing the needs of individual communities and sub-communities for an overarching, coordinated approach to metadata and ontologies, that can be reached by filling the gap of interoperability.

The paragraph 3.1 and the overall section 6 of this deliverable illustrate the activities already underway to engage in the collaboration with each of these initiatives.

4.OntoCommons.eu contribution to Standards

The following paragraphs outline the relation among standards and ontologies, focusing on the analysis of the standards used in the industrial demonstrators. The OntoCommons.eu Consortium relies on the guidance provided by its External Advisory Group in order to understand what are the fundamental requirements and needs in terms of ontological perspectives. In particular, the following members of the External Advisory Group of OntoCommons are directly involved in important international standardisation initiatives:

- **Prof. Barry Smith** is a prominent contributor to both theoretical and applied research in ontology: SUNY Distinguished Professor and Julian Park Chair of Philosophy, is the Director of the National Center for Ontological Research, as well as of the Center for Brain and Behaviour Informatics, at the University of Buffalo. He is also Adjunct Professor in the Departments of Neurology and Computer Science.
- **Dr. Serm Kulvatunyou** has been working with industry and research communities to improve the efficiency and effectiveness of systems integration and interoperability: he is a computer engineer at the National Institute of Standards and Technology (NIST). Before joining NIST he was also a Standards and Products Architecture for Oracle Applications Integration Solutions. Moreover, he has been working with industry standard development organisations such as OASIS, UN/CEFACT, AIAG and the Open Application Group (OAG) to develop and improve standards for electronic business.
- **Dr. Patrick Guillemin** is working for ETSI as a Technical Officer and Senior Research Officer, specialised in the development of new standardisation initiatives, with 22 years of ICT Standardisation experience.
- **Dr. Nina Jeliazkova,** founder and co-owner of Ideaconsult Ltd, received the Blue Obelisk Award in 2010 for achievements in promoting Open Data, Open Source and Open Standards.

4.1 Standards for ontologies and ontologies for standards

Standardisation efforts have led to the emergence of conceptual models in many sectors.

Standards reflect consensus on the semantics of terms; however, different standards might use different semantics or terms for explaining the same or very similar concepts. From one side, this aspect increases the complexity of establishing common rules that could be applied in industrial and research areas. On the other hand, this complexity can be overcome by highlighting the double role played by ontologies in the standardisation environment: standards can use ontologies to establish themselves, and ontologies can be used to better define standards. This need shows the strong interconnection between these two entities, that is starting to become more and more relevant in several domains.

The OntoCommons project cooperates with relevant initiatives to contribute to standards integration and conformance, through the use of ontologies. The standards integration concerns the explicit representation of overlapping sets of concepts in standards and the difference in their semantics is needed to ensure consistency.

Moreover, to support this dialogue, OntoCommons.eu is interested in strengthening the collaboration with relevant players in the standardisation area. The initiatives identified so far are available in Table 1. However, this list is continuously updated by the project members, and the table represents a snapshot by M12.

4.2 Ontology standards and the industrial ecosystem

At a moment when industry is moving towards a tighter cross-domain collaboration, standardisation processes demand stronger integration of multi-domain stakeholder clusters with streamlined, digitally-supported workflows for greater efficiency.

Global information and communications technology standards create additional value and aggregate markets through technology diffusion, increased productivity, and interoperability. A more agile standards ecosystem is essential to match (and adequately serve) nowadays growing, ever-evolving global technology environment, in order to allow both innovators and product developers to choose the best solution to fulfil their needs and to freely revise that choice in response to inevitable changes in technology and market conditions.

Industry 5.0 is driven by digital data, connectivity, and cyber systems (like Industry 4.0), but it extends these concepts adding also environmental and social factors. Industry 5.0 aims to help to frame how the industrial ecosystem and emerging societal trends and needs can co-exist[5]. The advent of this new business facilitates the adoption of new technologies and the increasing of data exchanged in organisations. To guarantee reliable and secure interactions between systems, a coherent approach for the semantic communication in multiple intelligent systems is vital.

In this context, the role played by standards has been heavily recognised in the industrial ecosystem as a means of improving performances and efficiency of companies' ways of working.

At the same time, ontologies support industries to improve the adoption of standards as they make them more machine readable and, as a consequence, they can be automatically implementable. Ontologies also help to connect information between different standards and represent a solution to formalise the smart manufacturing knowledge in an interoperable way.

As a matter of fact, big corporations can benefit from the adoption of ontologies because they represent the critical enablers to standardise data. This is, for example, applicable in the manufacturing area as ontologies adoption in standards facilitates the exchange of information between production plants built in different countries, which follow different rules and ways of working.

In the OntoCommons.eu context, the project team is cooperating with industrial players to develop thematic demonstrators that prove the effectiveness of adopting ontologies in the industrial domain. In order to improve the interoperability in data documentation, the team has started to conduct an analysis on the standards used to build the demonstrators. The work around standards supports the implementation of interoperability and FAIRness principles for the OntoCommons demonstrators.

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[5] https://ec.europa.eu/info/news/industry-50-towards-more-sustainable-resilient-and-human-centric-industry-2021-jan-07_en

The following table shows the outcome of the preliminary analysis done for the existing 11 demonstrators. In the next deliverable iteration, the analysis will be extended also to new OntoCommons demonstrators that will be identified by the project team and use cases of related projects.

OntoCommons Demonstrator Description	Impact	Topic and Standards/Ontologies considered
IRIS - IndustRIal codesign Support (Airbus Design and Manufacturing): During the aircraft and industrial system design process, different domains engage in trade-offs and optimizations, with decisions impacting the design of other domains. A trade needs to be done between these domains, to find the most suitable design of the plant.	The use of ontologies will enable a collaborative design process between the aircraft and industrial system domains, overcoming bottlenecks concerning knowledge management, interoperability and decision making, which will: 1. Help to decrease the development time, and improve the industrial system reliability and efficiency 2. Foster a tool agnostic industrial design process. 3. Allow automation, cognitive processes and information traceability up to design choice.	**Topic**: Aerospace, Manufacturing **Standards**: • ISO/IEC 21838 **Ontologies**: • IOF-Core (OAGi) • QU4LITY Ontology • GRACE Ontology • Z-BRE4K Ontology
SeDIM - Semantic Data Integration for Manufacturing (BOSCH Manufacturing): **Show how the use of standardised ontologies can significantly simplify the data integration problem behind an analytical**	Knowledge Graphs, ontologies, and rules will enable the Digital Twin to correctly represent physical equipment, expertise, routines and processes with data and models to run	**Topic**: Manufacturing **Ontologies**: • BOSCH Ontology (In-house development)

scenario at a BOSCH factory. The analytics is needed as a part of the overall goal of factory automation.	reliable production simulation, process monitoring, analytics and optimization. This will allow BOSCH to decrease the time needed to perform certain operations.	
EngDemostrator (Aibel Procurement): Capturing of all relevant chemical, manufacturing requirements and mechanical properties related to each manufacturing grade ontology to compare material grades as listed in EN, ISO or ASTM standards	The use of ontologies will be used to enable adequate semantic definition of products to improve handover between organisational units and reduce hours spent on complex and repeatable work.	**Topic**: Process industry **Standards**: • ISO 15926-14 **Ontologies**: • Material-Core (In-house development) • Standards Ontology (In-house development) • ChEBI • SKOS
Tribomat (Materials' Tribological Characterisation): This use case is collaborating with experts from top European companies in tribology, in the context of the iTribomat H2020 project: https://www.i-tribomat.eu/ to shorten the time and the number/size of experiments required to identify the behaviour of a material or combination of them (e.g. metal, coating, lubricant) with respect to specific operating conditions. The results of this demonstrator could be the first steps to pave the way towards a standard in the tribology experiments characterization, which would improve interoperability and reduce the time and resources needed for the design and execution of experiments.	Tekniker will use ontologies for semantic representation of tribological experiments data and model the stored knowledge in a more meaningful way to: 1. Reduce new material design time by 20%. 2. Reduce new material design resources by 20%. 3. Achieve a better representation of materials' experiments. 4. Enrich existing data with additional background knowledge. 5. Ease data retrieval and navigation	**Topic**: Manufacturing **Ontologies**: • EMMO • TribAIn • VAR Ontology **Future Actions**: OntoCommons aims to introduce the results of this use case into an SDO working on Tribological Characterisation, such as ISO (ISO 7148-1, ISO 7148-2, ISO/AWI 7148-1, ISO/AWI 7148-2, ISO 19291:2016, ISO 14830-1)

	through related resources. 6. Set the ground for developing more application-independent solutions.	
EVMF - European Virtual Marketplace Framework (Digital Materials Marketplaces): **Facilitate the interoperability of platforms and services within an open European Virtual Marketplace Framework.**	This use will use ontologies to create documentation of Materials Modelling software and describe a use case for Materials Modelling, to: 1. Improve VIMMP Ontologies (the semantic basis of the VIMMP platform that will facilitate exchanges between providers and users in the area of materials modelling) thanks to the interactions with similar NMBP platforms. 2. Provide prototypical needs from digital marketplaces.	**Topic**: Nanotechnologies, biotechnologies **Ontologies**: • VIMMP Ontologies • EMMO • SWO • MODA (CEN-CENELEC CWA17284)
PSS - Product Service Systems (OAS Product Service System): **Boost logistics, production and to assure quality, in combining materials handling and weighting, in integrating weighing, dosing, mixing, logistics and control to form a unified system.** **This demonstrator works in close collaboration with ATB to apply the PSS ontology and provide valuable input to it, which might lead to a standard ontology for PSS (the PSS Ontology is an IOF working group ontology that intends to propose a**	OAS will use ontologies to identify what modules, workflow and actors need to be considered for a new yard management service (such as devices, software, stakeholders and customer sites and infrastructure) to: 1. Support the standardisation of yard management services to reduce the time and effort needed for the re-configuration of the	**Topic**: Equipment industry **Ontologies**: • Product Service System (PSS) • IOF Core • Material Ontology • Logistic Ontology • Supply Chain Ontology

set of standard industrial ontologies).	yard management system. 2. Effectively work together with the customers and their clients to find the best definition of workflow and rules.	
Feedstock Quality Assurance (Fraunhofer Quality): **Measurement of different feedstocks, correlation with other feedstocks quality and correlation with the quality of produced components.**	This use case will use ontologies to describe the type of materials involved in the mixing process, the aspect of quality assurance while mixing and the aspects of quality for finally mixed feedstock to: 1. Get a Digital representation of the whole mixing process. 2. Recognise previously unknown correlations. 3. Decide which process (machine) parameters have to be adjusted. 4. Achieve consistent feedstock quality.	**Topic**: Quality assurance of powder blends **Standards**: • ISO 13320 • DIN ISO 4497 • BET DIN 66131 • DIN ISO 3923-1 • DIN ISO 3923-2 • DIN 66137-1 • DIN 66137-2 **Ontologies**: • EMMO
NanoMaterials Characterisation (IRES Nano-Materials): **Performance of a series of field measurements in order to characterise the airborne particle number concentration (PNC) that results from additive manufacturing activities.**	IRESS will use ontologies to: 1. Automate the experimental data collection process. 2. Achieve the semantic integration of data from different experimental measurements. 3. Study the correlation between Material Characterisation and Safety Domain through reasoning.	**Topic**: Chemicals, 2D materials **Ontologies**: • OYSTER Mechanical Testing Ontology • eNanoMapper Ontology • Additive Manufacturing Ontology • EMMO • BFO
Ontology-based Maintenance	Laboratory for Applied Ontology ISTC-CNR is using	**Topic**: Equipment industry

(BLM Group Ontology-based maintenance): **Standardise the terminology of the maintenance process, focusing in particular on the diagnosis of technical malfunctioning, and leveraging on the knowledge extracted from service information flows and repair records.**	ontologies to cover terms related to the machine's parts and structure, design, functions and malfunctions to: 1. Reduce the costs and increase the quality of the maintenance processes. 2. Create comprehensive records of maintenance cases, frequency and solutions. 3. Perform an assessment of new anomaly cases and associated solutions. 4. Alignment of terminology across internal (and possibly external) personnel.	**Ontologies**: • DOLCE
Cu/Al Data (Elvahalcor Metal Industry): **Semantic representation of technical documentation throughout Halcor's entire value chain in order to achieve data harmonization, data interloperability and interconnectivity.**	ElvalHalcor is using ontologies to modify the company's data models in a way that ensures data integration and interoperability, and contribute to the development of a Smart Decision System based on raw material and production process data and specifications that will: 1. Optimise product quality. 2. Reduce manufacturing costs. 3. Reduce the environmental footprint.	**Topic**: Manufacturing **Standards/Ontologies**: currently N/A
Complex Equipments (Siemens Digital Manufacturing): **The main goal of the use case is to show how the use of ontologies**	Siemens is using ontologies to create a library of shared, reusable data models that: 1. Will be used as training material for	**Topic**: Manufacturing **Standards**: • ISO 15936

and reasoning can significantly improve flexibility in manufacturing, as well as increase transparency and trust of AI systems by using methods for explaining AI-based decision-making. This use case will provide a data layer as part of the IOT platforms of Siemens that reduces appli-cation/customer-specific data provisioning and integration costs. To that end, Siemens will develop an ontology library that covers various relevant domain onto-logies as well as ontology trans-formations of various industrial standards.	developers and other stakeholders. 2. Will create best practice for data model governance as well as modelling tools (also for domain experts).	**Ontologies**: • QuED • SSN • UMATI • eClass • OPC-UA (in-house transformation from the standard) • CFIHOS

Table 2 - Standards applied in the OntoCommons DemonstratorsThis preliminary analysis shows practical examples of implementing standards and ontologies in industrial systems. However, it also highlights the difficulty of adopting common standards or ontology rules in the manufacturing and materials ecosystems, issue that might be overcome thanks to the development of the OntoCommons Ontology EcoSystem (OCES). It consists of ontologies and tools following specific standardisation rules, that can be used as foundation for data documentation in the industrial domain to facilitate data sharing and valorisation and overcome the existing interoperability bottlenecks. Future recommendations on how to overcome this issue can also feed the OntoCommons Roadmap (D1.7)

5.OntoCommons.eu & Standards: workshop session

OntoCommons.eu has organised a session entirely dedicated to Standards, in the [Global Workshop "Ontology Commons addressing challenges of the Industry 5.0 transition](" on 2-5 November 2021.

The session was chaired by Silvana Muscella, CEO at Trust-IT, the partner which leads the OntoCommons Dissemination, Exploitation & Sustainability work package, as well as the specific task, in the Cooperation work package, dedicated to Specifications, Support to International Standardisation TCs & WGs & Cooperation. The workshop entitled: "Enabling intra-ontology interoperability through shared terminology" and was focused on the European and Global efforts for the cooperation on standards. It has been organised around four "Impulse Talks", of 15 minutes each, and a final panel discussion among the four panellists, with the objective to investigate on how OntoCommons.eu could build on existing solutions for ontology standardisation in the global setting, to enable intra-ontologies interoperability.

5.1 Ontology Standards in ISO

The first panel of the session concerned Ontology Standards in ISO, presented by Barry Smith, Director at the National Center for Ontological Research. Barry Smith, prominent contributor to both theoretical and applied research in ontology, outlined the current state of play with regard to the ISO/IEC 21838 standard: this standard is composed of several parts, two parts of which have already been approved and are currently in the publication stage.

Part 1 of this standard specifies requirements needed for a top-level ontology (TLO) to be classified as such, with the underlying idea that the TLO should be domain-neutral and therefore applicable to all domains, without restrictions. Part 2 of the ISO/IEC 21838 standard specifies BFO as a TLO conforming to these requirements, and parts 3 and 4 will specify DOLCE and TUPPER in a similar manner.

5.2 Improving the efficiency and effectiveness of systems integration and interoperability using ontology

In the next talk Boonserm Kulvatunyou, project manager for the infrastructure for data exchange standard development and use project in the Systems Integration Division at the National Institute of Standards and Technology (NIST), USA, talked about "Improving the efficiency and effectiveness of systems integration and interoperability using ontology", in fact, eighty percent of system integration cost is said to be attributed to resolving semantic ambiguity.

This talk was focused on the challenge of developing a consistent enterprise-wide data model, and on the fact that, if this model is ontology-based, it may also be more tractable thanks to the possibility of using a reasoner to assist in model consistency checking. For this reason, the Industrial Ontology Foundry (IOF) is working to provide the basic building blocks to build a consistent enterprise-wide data model.

Boonserm Kulvatunyou has been involved in R&D to address interoperability issues via standard for over 20 years and is currently the chair of the Semantic Refinement Method and Tools WG and of the Architecture Committee at the Open Applications Group, Inc. (OAGi) standard consortium. His group at NIST currently helps industry advance traditional standards through the R&D platform called Score (oagiscore.org). He holds board member positions in the Industrial Ontology Foundry (IOF) and also serves as advisors for the NIIMBL Big Data Standardization and the OntoCommons projects.

5.3 Industrial Standardisation in the IoT domain

The third speaker of this session, Ulrike Parson, is the current Steering Committee Chair of the iiRDS Consortium that develops and maintains a standard for the delivery of smart content: Ulrike Parson's presentation was focused on industrial standards in the internet of things, enabling interoperability and information exchange between components and services. It was focused as well on the role that ontologies play for the IoT standardization, creating a shared understanding of and terminology for technical capabilities, product features, and service properties, as well as enabling efficient machine-to-machine and human-to-machine communication. This impulse talk was closed with an overview of the challenges that must be faced when developing industrial ontologies, such as missing

reference architectures, the required level of ontology knowledge with subject matter experts and more.

5.4 Ontology Standards in Industry 5.0

The last impulse talk was presented by Dr Nicolas Figay, system architect at Airbus Defence and Space at Elancourt, France, and Airbus expert in the area of interoperability for PLM, involved as an international expert in the standardization community (ISO SC4 TC184, ASD Strategic Standardization Group, liaison OSLC ISO TC184 SC4), and in research within the area of Product Data Exchange and Sharing (RISESTEP, SAVE), Interoperability of Technical Enterprise Application for Networked Collaborative Product Development (ATHENA), Model Driven Architecture/Model Driven Engineering (OpenDevFactory) or Dynamic Manufacturing Network (IMAGINE).

Airbus has been continuously working on open manufacturing data standards in order to ensure interoperability between technical enterprise applications, for supporting effective collaboration between people and organization. For such a continuous operational interoperability, both open standards and ontologies, in conjunction with Model Driven Architecture, Service Oriented Platform and Enterprise modelling, are important and connected enablers. Through the analysis of past and current experience, the presentation pointed out some important challenges to consider for implementing the roadmap about common European Ontologies.

5.5 Impact of the discussions

The inputs collected from the speakers' presentations and discussions during this session of the workshop will feed into the chapter dedicated to standardisation of the OntoCommons.eu Roadmap.

The discussions have provided significant inputs that can guide the future efforts and can be summarised as follows:

- There is a lot going on in the standardisation landscape, and one of the current challenges is that of keeping track of the ongoing efforts. OntoCommons.eu plays an important role as it can help aggregate the information and pool it together in the work related to Cooperation on Standardisation.
- The industrial domain values the endorsement from ISO, and ISO references are said to be available in open source & for public use;
- EU efforts & ESOs are working on SMART Standards, so it is useful to create a link with our initiative
- The OntoCommons.eu Consortium is creating a connection with the EC DG GROW & DG Connect, in order to explore the possibility of setting up a dedicated chapter on Ontologies & Semantic interoperability within the 2022 edition of the ICT Rolling Plan of Standardisation.
- Dedicated efforts on developing SMART standards that are agile & market responsive need to be tackled with end-users through dedicated interoperability test-bed frameworks, and OntoCommons should have as an objective to find the right channels that can allow that.
- Even more attention should be dedicated in the future to the connection between National and International Standards Bodies.

6.Ongoing collaborations

Given the CSA-nature of OntoCommons.eu, the project aims to build a community of relevant stakeholders to share the results of the project and strengthen the efforts towards ontology-driven standardisation activities across materials and manufacturing domains.

Since the launch of the project, OntoCommons started a continuous engagement with relevant initiatives in the standardisation ecosystem. An inventory of initiatives has been continuously updated and now includes more than **30 potential contacts.** From these contacts, Ontocommons.eu has begun a specific collaboration with a number of these that is elaborated in the sections below. The following paragraphs show practical details of some of the initiatives OntoCommons is collaborating with in the standardisation area, contributing to the definition of user requirements that standards need for the materials and modelling community to be able to exploit them. A complete list of all the initiatives can be found in the Deliverable D1.2 "Cooperation Monitor v2", submitted in M10.

6.1 Collaborations with relevant related projects and initiatives

6.1.1 *Industry Ontology Foundry (IOF)*
About

The IOF is a working group that aims to co-create a set of open reference ontologies to support the manufacturing and engineering industry needs and advance data interoperability. The group aims to work with Government, Industry, Academic and Standards organizations to advance data interoperability in their respective fields.

Type of collaboration

Members of the OntoCommons EAB are members of the Governance Board of the Industry Ontology Foundry - IOF (Barry Smith, Boonserm Kulvatunyou) and the same Dimitris Kiritsis, WP1 leader, is also member of the IOF Governance Board and one of the Technical Oversight Board co-chairs. Thanks to these connections, OntoCommons.eu has become one of the members of this group, contributing to the development of the creation of a standardised set of open industrial ontologies that spans the entire domain of traditional manufacturing, in collaboration also with OAGi (Open Application Group). Common terms used for the IOF core ontology are Failure event, Maintenance notification, Maintenance notification trigger, Maintenance schedule list, Maintenance task, Product, Process, Infrastructure, Resource and Software.

Furthermore, the IOF Working Group is developing the ZDM (Zero Defects Manufacturing) ontology, related to quality improvement and that could be implemented by some of the OntoCommons demonstrators.

Standards

The standards shown below represent the ones developed by the Industry Ontology Foundry, that the OntoCommons project can benefit from over the course of the project:

- ISO/IEC 21838-1:2021 Information technology — Top-level ontologies (TLO)
- ISO/IEC 21838-2 Information technology — Top-level ontologies (TLO)
- BFO - Basic Formal Ontology

Moreover, the IOF-Core ontology is a middle-level ontology developed by the Industrial Ontologies Foundry (IOF) and IOF has joined OAGi (https://oagi.org/) as a formal legal entity. OAGi will establish an IOF membership category, accept ownership of ontology artifacts developed by the IOF, and release them under MIT and CC BY 4.0 (or similar) licenses. The IOF adopted BFO as the TLO to support the development of the IOF-Core ontology.

Impact

Currently the IOF-Core ontology is still under development and being updated frequently. The demonstrator IRIS-Industrial co-design Support used the latest public version of the IOF-Core to support the development of the corresponding application ontology. The demonstrator will keep updating the application ontology according to the new versions of IOF-Core in the future.

The Industrial Ontology Foundry and OAGi will produce open Industrial Ontologies that spans the entire domain of digital manufacturing. The OntoCommons members involved in the IOF will contribute to this work. The first open IOF ontology, called IOF-Core, is expected to be published in December 2021.

Next steps:
Currently, there are eight Working Groups under IOF covering a variety of industrial topics of interest such as Maintenance, Production Planning and Scheduling, Supply Chains, Product Service Systems, Manufacturing Equipment Connectivity (MTConnect), Systems Engineering and Zero-Defect Manufacturing, which are expected to publish their respective ontology modules as soon as they are ready after the publication of IOF-Core ontology.

6.1.2 EMMC ASBL and EMCC

About

The European Materials Modelling Council (EMMC) is an initiative started informally in 2014, supported by a H2020 CSA project 2016-2019 and founded as a not-for-profit association EMMC ASBL in Brussels in 2019. The main remit of EMMC is to support, coordinate and

represent the field of materials modelling and digitalisation for industrial application and impact. From the start, EMMC has been working on establishing a common language that helps to bring together the various domains and sub-disciplines and achieve a standardised documentation (referred to as MODA). This work culminated in a CEN Workshop Agreement CWA 17284 (more information is provided in the following sections) which formed the basis for the development of an ontology that can support materials science and applied sciences in general. The result is the EMMO, formerly European Materials Modelling Ontology, now called Elementary Multiperspective Material Ontology, which provides a general ontological framework consisting of Top and Middle Level Ontologies. EMMC is the governing body for EMMC TLO and MLO developments.

In addition, the European Materials Characterisation Council (EMCC) is an informal association supporting similar aims in the materials characterisation field. Following the example of the EMMC work on standardised documentation of materials modelling, the EMCC community recently agreed on a documentation terminology and template (CHADA) for characterisation.

Type of collaboration

EMMC have two focus areas linked to Interoperability and Digitalisation that are relevant for OntoCommons given the similarity with the work performed by the two initiatives.

In particular, the Interoperability Focus Area aims to increase awareness and impact of interoperability, taxonomy and ontology standards and to make materials models and related data more accessible and usable to industry.

The Digitalisation Focus Area, instead, aims to promote the establishment of a sustainable digitalisation eco-system for the benefit of industry and research, and increase interoperability based on ontology between models, data repositories, and communities to enhance and facilitate integration and digitalisation.

EMCC has a Working Group on Characterisation Data and Information Management including MODA & CHADA work and collaboration with EMMC.

There are overlaps of OntoCommons partners active in EMMC and/or EMCC (TU Wien, UNIBO, GCL, SINTEF, UKRI) which enables a close interaction.

Standards

The standards shown below represent the ones developed by EMMC and EMCC with support from related H2020 projects (MODENA and EMMC-CSA for CWA 17284 and OYSTER for CWA 17815), that the OntoCommons project can benefit from over the course of the project:

- CWA 17284: Materials modelling - Terminology, classification and metadata
- CWA 17815: Materials characterisation - Terminology, classification and metadata[6]

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[6]   https://www.cencenelec.eu/get-involved/research-and-innovation/cen-and-cenelec-activities/cwa-download-area/

Both these standards and the semiotic approach taken by EMMO to the declaration of properties are well aligned with the information model of ISO 10303-235 (AP235) which basically states that any property definition requires the processes by which a property value is determined.

Impact

The CWA standards have been and are being used as a basis for EMMO ontology implementations that underpin materials modelling marketplaces and open innovation environments in characterisation.

OCES recommendations are very much sought and starting to be applied in these projects (such as NanoMECommons) for example regarding ontology engineering (competency questions etc) and ontology maintenance, as well as regarding integration of and alignment with other existing ontologies.

Further impact will be achieved by OntoCommons bringing together the materials communities represented in EMMC/EMCC with the product and related standards efforts in ISO/TC 184/SC 4 and future updates to ISO 10303 (see ISO section).

Next Steps:
The collaboration between OntoCommons and EMMC ASBL and EMMC will revolve around three main points:
- Support in updating the CWA 17284 scheduled in 2022
- Working with EMMO regarding compliance with ISO standards for TLO
- Liaising between EMMC/EMCC/EMMO communities and ISO/TC 184/SC 4

6.1.3 IAOA

About

The International Association for Ontology and its Applications (IAOA) is a non-profit organization promoting interdisciplinary research and international collaboration at the intersection of philosophical ontology, linguistics, logic, cognitive science, and computer science, as well as in the applications of ontological analysis to conceptual modelling, knowledge engineering, knowledge management, information-systems development, library and information science, scientific research, and semantic technologies in general. The Association was formally established in Trento (Italy) in 2009 and relocated in Bern (Switzerland) in 2013. The association concentrates on spreading the knowledge, adoption and use of ontology, ontological principles and methodologies in all areas and domains and has been pivotal in introducing modern modelling views. This is done primarily via public events including the Formal Ontology in Information System conference series and the Formal Ontology in Industry workshop series, as well as by supporting students, young researchers and other personnel via scholarships to attend ontology-related conferences and meetings. IAOA also

establishes liaisons with other organisations with similar goals to create synergies and foster the scientific use of ontology.

Type of collaboration

OntoCommons has established collaborations with IAOA in several ways including:
- participation of IAOA members as partners in OntoCommons
- participation of IAOA representatives in OntoCommons workshops across 2021
- invitation of a keynote speech of the IAOA President Laure Vieu at the OntoCommons Global Workshop in November 2021
- co-organization of the FOMI 2021 workshop in September 2021
- discussion with co-chairs of the IAOA Industry and Standards Technical Committee for the organization of events in the coming years.

The active IAOA members involved in OntoCommons.eu are Nicola Guarino, Stefano Borgo, Claudio Masolo, Roberta Ferrario and Emilio Sanfilippo, who are involved in the Top Reference Ontology, Industrial Domain Ontologies, Ontology Commons Ecosystem Toolkit and Demonstrators WPs in OntoCommons.eu.

In particular, Stefano Borgo and Nicola Guarino are members of the Advisory Board of the International Association on Ontology and its Applications, where in the past they served in the Executive Council. Nicola Guarino was president of the association in the period 2009 - 2013 and is currently a fellow of the IAOA. Emilio Sanfilippo, instead, is currently a member of the IAOA Executive Council.

Standards

The IAOA Industry and Standards Technical Committee (ISTC) is devoted to fostering the use of applied ontology in standardization initiatives, and to facilitate the interactions across people in industry and in applied ontology research. Activities include the dissemination of information about initiatives with the aim to gather experts interested in the development of ontologically sound standards, and the organization of virtual and physical meetings and events where to discuss how to understand and apply ontological approaches and methodologies. Members of the ISTC have been active in several standardisation initiatives like:
- ISO 18629-1:2004 Industrial automation systems and integration — Process specification language
- ISO/IEC 21838-1:2021 Information technology — Top-level ontologies (TLO)
- Distributed Ontology, Model, and Specification Language (OGM)
- IEEE 1872.2-2021 - IEEE Approved Draft Standard for Autonomous Robotics (AuR) Ontology

Next Steps: OntoCommons.eu. partners are already involved and suggesting we support IAOA in their technical committee group on standards and industry. As a parallel activity the OntoCommons.eu team would invite IAOA members to be part of the Technical Working Group on Ontologies within the remit of the StandICT.eu TWGs.

6.1.4 StandICT.eu

About

StandICT.eu 2023, Supporting European Experts Presence in International Standardisation Activities in ICT, GA No. 951972, is an EU-funded, Coordination and Support Action StandICT.eu 2023 addressing the specific challenges of the topic ICT-45-2020, "Reinforcing European presence in international ICT standardisation, running from September 2020 to August 2023.

Building on the success of the StandICT.eu 2018-2020 precursor Project, StandICT.eu 2023 has a dual objective. The first, **to support the participation of European ICT experts in international SDO Working Groups, through a series of 10 Open Calls, which will provide a total of 3 million Euro of funding** over the duration of the Project through the StandICT.eu 2023 Fellowship Programme, The second, to deliver the **"EUOS – The European Observatory for ICT Standardisation", an interactive platform that will monitor the global ICT Standardisation landscape**, with the ultimate goal of providing the community of ICT experts with accurate coverage of relevant and timely ICT Standards into which the results of the fellowships feed and contribute.

Within the EUOS, StandICT.eu has also launched a **series of rotating Technical Working Groups (TWG) to harness expert advice and stimulate discussion among SDOs, public bodies, academic institutions and acclaimed specialists** to provide and expert overview of documents and activities relevant to standardisation in identified key fields such as Artificial Intelligence, Big Data Spaces, Blockchain, Cybersecurity, Data Interoperability, Smart Cities and Trusted Information with a **further dedicated TWG on Ontologies launched** in March 2022. Chaired by the OntoCommon.eu project, the output of this group will provide an overview of the diverse array of global standardisation work underway in Ontologies and the various organisations behind it. This information will be updated and evolve via the above mentioned EUOS database and ultimately result in the release of a dedicated Gaps Analysis Report.

The benefits of the collaboration forged between Ontocommons.eu and StandICT.eu 2023 is therefore not only easily discernible but symbiotic with obvious advantages to be gained by both on multiple facets, as outlined below:

- **OntoCommons.eu** with its objective to **drive standardisation of data documentation** is perfectly positioned to provide **key insights on appropriate and pertinent gaps, recommendations and priorities in ICT Standardisation around ontologies** for StandICT.eu's future Open Calls and **StandICT.eu can tap into this insight in discussions for the topics of the forthcoming calls.**

- As a natural consequence of the above, **OntoCommons.eu may publicise the opportunities offered to its stakeholders by the StandICT.eu Open Calls** and encourage applications from individuals to apply for funding be included in the Working Groups (WG) or Technical Committees (TC) of the SDOs working on standardisation around ontologies and **concrete examples of where this type of cooperation has yielded results** over the first 12 months of the project in terms of funded experts working on ICT and industrial standardisation activities in ontologies are provided below.
- **OntoCommons.eu may also take part in webinars and events organised by StandICT.eu 2023 and vice versa**, or contribute to the Standards Assembly foreseen upon conclusion of StandICT.eu. Likewise, **each may bring its use cases to be showcased at events as practical results of the projects** and in the StandICT.eu 2023 EUOS.
- As part of future activities, **StandICT.eu** is about to launch a **new TWG on Ontologies** which will include experts from OntoCommons.eu and ultimately yield a **Gaps Analysis Report for ICT and industrial standardisation activities in the Ontology domain** and generate timely and pertinent content to feed directly into the StandICT.eu EUOS,

Funded Applicants in Ontologies from the StandICT.eu Open Calls

A list of the successful applications received in response to StandICT.eu Open Call #3 and #4 to fund activities on ontologies applied to standards (and vice versa), at the time of writing is provided in the table below.

Title	EU Priority	SDO
IoT Semantic Interoperability - Specialization to Energy and relationship to AI	Key Enablers and Security	●ISO SC41 IoT and Digital Twins ●ISO SC42 AI
Participation in SA WG4 and Contributions to Augmented Reality in 3GPP Mobile AR Report TR26.998	Key Enablers and Security	●IEEE RAS Standards Working Group - Ontologies for Robotics and Automation
Ontologies' Standardization and Harmonization for Industry Commons (SHICO)	Sustainable Growth	●OAGi (Open Applications Group)
Development of content delivery standard for smart content, iiRDS	Sustainable Growth	●iiRDS
iiRDS, Working Group participation and Maintenance Domain extension	Sustainable Growth	●iiRDS

QuaFair: Data quality assessment through Contextual Intelligence using the FAIR data methodology	Key Enablers and Security	●IEEE ComSoc Internet of Things Emerging Technical Subcommittee
Open Ethics Transparency Protocol RFC	Innovation for the societal challenges	●ANEC
Building Information Modeling, WG4 – Support Data Dictionary	Key Enablers and Security	●CEN
Improving the adoption of BIM according to ISO 19650 in the construction sector in the Netherlands	Sustainable Growth	●ISO
Semantics and concepts to enable interoperable conversions between calendar systems	Sustainable Growth	●ISO
Danish participation in the ISO/IEC JTC 1/SC 32 WG 3 Database languages (SQL and new GQL), 3rd term	Key Enablers and Security	●ISO/IEC

Table 3 - StandICT.eu Funded Applications in Ontologies

Among these applications some of them are strictly related to the OntoCommons.eu project and have already reached a state of maturity to gather the first results and impacts:

- Hedi Karray, professor at ENIT and OntoCommons technical coordinator, has submitted the application called "Ontologies' Standardization and Harmonization for Industry Commons (SHICO)": this project is highly aligned with the aims and objectives of the 2021-2022 work program of Horizon Europe related to the digitalization of the European industry, in which data sharing and interoperability in a heterogeneous environment are major challenges. Ontologies are presented as a valuable solution for interoperability and semantic data sharing. However, for various reasons, ontologies are often not themselves interoperable and thus fail to be widely accepted. Establishing a shared semantic basis, open and standardized ontologies contributions, and the co-innovation abilities as well as via fostering translation, SHICO will provide a boost to Open Digital Innovation.

  The work led by Hedi Karray contributes to the work of three standardisation groups: **OAGi-IOF**, **INCITS 573-3-202xAd Hoc Mid-Level Ontology (MLO)** and **Core Terminology for Industrial Data group of ISO/TC 184/SC 4**.

Within the OAGi-IOF group, Hedi Karray will participate in the group IOF-core to contribute to the elaboration and the review of IOF core Ontology through the following activities:

- New Term Introduction & Term Evolution (Development & Test)
- Formalisation of the IOF-Core Relationship (for the extensive use of Common Core Ontology terms within IOF Core term definitions)
- Representation of N-ary relations in OWL
- Modularisation of IOF Core
- Mid-level terms (classes & relations): mid-level modules
- Relations: industrial relations module.

Within the INCITS 573-3-202xAd Hoc Mid-Level Ontology (MLO), Hedi Karray will participate in the elaboration and the review of Information technology – Mid-Level Ontology (MLO). His involvement will include the participation in the following activities:

- Contribution to the definition of the scope of middle-level Ontology
- Contribution to generalise and "de-militarise" the Common Core ontologies by working on definite classes, the annotation of classes by adding general examples, and by working on the relations ontology.

Within the activities of the Core Terminology for Industrial Data group of ISO/TC 184/SC 4, he will contribute to the elaboration, the review, and the ontological alignment of the Core Terminology for Industrial Data. His involvement will include the participation in the following activities:

- Contribution to the identification and definition of terms
- Contribution to align terms with Basic Formal Ontology (BFO).

Webinars and events organised by OntoCommons.eu with participation of StandICT.eu

The OntoCommons.eu team has organised two webinars in which Silvana Muscella, OntoCommons.eu standardisation task leader and StandICT.eu project coordinator, has joined and presented the potential collaborations between the two projects. During the first webinar "OntoCommons.eu: An industrial ontology journey exploring the benefits of Standardisation, FAIR Data & Innovation", organised on 23 February 2021, the attendees had the opportunity to learn more about how OntoCommons.eu can liaise with StandICT.eu to create a Technical Working Group for experts collaboration and consultation on ontologies and standards. The second event, organised on 30 September 2021, "What can ontologies do for standardisation? OntoCommons.eu project in the standardisation ecosystem" added additional content on the open calls funded by StandICT.eu 2023 that supports work to align existing ontologies and ultimately contribute to filling the gap in ontology-based Standards to support European Policy objectives.

Figure 1 - Banner of the second OntoCommons webinar on standardisation and ontologies

Figure 2 - Banner of the first OntoCommons webinar

Next Steps: At the time of writing this deliverable, exchanges have gone on with the chairs of the ICT rolling Plan of Standardisation and the Ontocommons.eu partners have been given the opportunity to add content to the new dedicated chapter entitled "Data Economy" ready for the ICT Rolling Pan 2022 edition. Moreover, the definition of the Technical Working Group on Ontologies is being finalised with a number of key players from OntoCommons.eu consortium to drive this forward.

6.1.5 RDA

About

With over 12,000 members from 146 countries, the Research Data Alliance (RDA) builds the social and technical bridges to enable the open sharing and re-use of data by addressing challenges related to data sharing, data management plans, certification of data repositories and interdisciplinary interoperability.

It was launched as a community-driven initiative in 2013 by the European Commission, the United States Government's National Science Foundation, the National Institute of Standards and Technology and the Australian Government's Department of Innovation to allow researchers and innovators to share and re-use data across technologies, disciplines, and countries to address the grand challenges of society through its 49 recommendations (specific tools, code, best practices and standards produced by its 36 working groups), which include 8 ICT technical specification.

RDA Members come together through self-formed, volunteer and focused Working Groups, exploratory Interest Groups and communities of practices to exchange knowledge, share discoveries, discuss barriers and potential solutions, define policies and harmonise standards to enhance and facilitate global data sharing & re-use.

RDA members collaborate together across the globe to tackle numerous infrastructures & data sharing challenges related to: data sharing, data management plans, certification of data repositories and interdisciplinary interoperability.

Type of collaboration

RDA proposes to provide support to identify and get in contact with the relevant stakeholders with the RDA galaxy of Interest Groups and Working Groups and provide advice to handle and sustain multi-stakeholder collaboration as developed by Task 1.3 and 1.4 in the project. This multi-stakeholder collaboration, called the Knowledge Exchange Space (KExS), already involves Interest Groups interested in ontologies such as the RDA Chemistry IG and the Vocabulary and Semantic Service IG. RDA will also help the project to identify the relevant recommendations for the OntoCommons project and its stakeholders.

Standards

RDA provides 34 recommendations on different aspects of data sharing, management and governance. Although not standards per se, they should be used as a source of information for building standards that integrate such consensus-based recommendations and technical solutions.

Impact

RDA will provide OntoCommons with existing community recommendations to be integrated and tested within the context of the project. This will accelerate the internal development of FAIR data, FAIR semantic artefacts. RDA is also a large network of experts that could be leveraged to address some of the challenges of the industrial partners.

> **Next Steps:** Further dialog will be established with the RDA secretariat to ease the identification of the right recommendations and the right expert groups. A continuous dialog will be maintained with the relevant Interest Groups identified by T1.3. and T1.4. Through the KExS, we will invite other Interest Groups to present their work as well as Working Groups generating relevant recommendations.

6.1.6 Dome4.0

About

Digital Open Marketplace Ecosystem 4.0 (DOME 4.0) is an RIA project, funded by the European Commission under the call H2020-NMBP-TO-IND-2020-twostage that intends to offer an intelligent semantic industrial data ecosystem for knowledge creation across the entire materials to manufacturing value chains. The ecosystem provides a sustainable solution to the information silos problem related to the past efforts and puts forward a formal, ontology-based documentation for open and confidential data spaces applicable to future and current projects thereby delivering added value. Furthermore, the flexibility of the proposed semantic architecture of DOME 4.0 naturally adapts to the emerging Industry Commons developments and the scale-up of the ecosystem to large amounts of data, tools and services applicable to wider sectors of the European economy.

Type of Collaboration

DOME 4.0 is going to collaborate with OntoCommons by:

- Participating in workshops and webinars to present UCs
- Preparing an overview of ontologies to share with OntoCommons

The expected collaborations from OntoCommons with DOME 4.0 are:

- Feedback on DOME 4.0 ontologies
- Transfer of documents/ontologies/expertise
- Alignment on the landscape of ontologies in both projects

Standards

Key to DOME 4.0 success is in widely agreed standards for ontology-based data documentation to be further developed and recommended by the OntoCommons.eu project, as discussed in this document.

Impact

DOME 4.0 can be regarded as the **impact testbed** for OntoCommons, enabling a step change in data valorisation both within value chains and in complex cross sector utilisation of data.

Next Steps: Additional dialogues will be established to foster the cooperation between the two projects. As a matter of fact, discussions will be carried out to understand how the OntoCommons.eu ecosystem of ontologies and evaluation framework can be applied to DOME4.0 ontologies, in the context of Industry Commons Marketplaces.

6.2 Collaborations with SDOs

6.2.1 ETSI

About

ETSI supports the timely development, ratification and testing of globally applicable standards for ICT-enabled systems, applications and services, with 900+ member organizations drawn from over 60 countries and five continents.

Type of collaboration

The Consortium Partner Universidad Politécnica de Madrid (UPM) collaborates with ETSI for the SAREF (Smart Applications REFerence Ontology) developments and is also involved in W3C Web of Things Working Group, the Spatial Data on the Web Working Group and the Linked Building Data Community Group

Standards

The Universidad Politécnica de Madrid has taken part in the creation of SAREF and several extensions. In particular, their work has been focused on:
- Publication of SAREF v2 and v3
- Among the ETSI SmartM2M Technical Body has supported the production of standards
    - ETSI STF 513 (Maintenance & Evolution of SAREF Reference Ontology): SAREF4ENVI and SAREF4BLDG
    - ETSI STF 534 (SAREF extensions): SAREF4CITY, SAREF4INMA and SAREF4AGRI
    - ETSI STF 556 (Consolidation of SAREF and its community of industrial users, based on the experience of the EUREKA ITEA - 12004 SEAS project): SAREF consolidation and SAREF portal requirements
    - ETSI/EC STF 566 (SAREF extensions for Automotive, eHealth/Ageing-well, Wearables and Water): SAREF4WEAR and SAREF4WATR
    - ETSI STF 578
    - ETSI STF 602 (SAREF: Industry adoption facilitation and oneM2M ontology alignment): SAREF4LIFT

Impact

The collaboration between OntoCommons and ETSI will benefit the adoption, use and refinement of existing ontologies developed by ETSI as for example the SAREF ontology or its extensions for industry and manufacturing (SAREF4INMA) or for building devices (SAREF4BLDG). As a consequence, the communities will benefit from avoiding the duplication of efforts, building again similar models, and from adopting common standards (e.g., specific SAREF models or the underlying standards as OWL, RDFS or SHACL). In addition, common and best practices for building and managing ontologies will be shared by sharing experiences about the methodological framework for developing ontologies adopted by SAREF and OntoCommons, both based on the LOT methodology (https://lot.linkeddata.es/).

Next Steps: One of the future expectations for the collaboration between OntoCommons and ETSI would involve the analysis and alignment of SAREF extensions with other standard or existing models, for example for the building domain.

6.2.2 CEN CENELEC

About

CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 34 European countries. CEN is one of three European Standardization Organizations (together with CENELEC and ETSI) that have been officially recognised by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level. CEN provides a platform for the development of European Standards and other technical documents in relation to various kinds of products, materials, services and processes.

Type of collaboration

OntoCommons.eu members from Universitetet i Oslo take part in the CEN-CENELEC Workshop Agreement (CWA) on Zero Defects Manufacturing (ZDM) in digital manufacturing terminology. The CWA defines and collates terms for zero defects manufacturing in digital manufacturing with correlation to Industry 4.0 and quality management. Indeed, the main objectives of the ZDM standardisation activity are to establish the terminology and definition of concepts associated with digital manufacturing in the context of Industry 4.0, and to explain how these concepts relate to quality management initiatives.

Industry 4.0 technologies such as smart sensors, cyber-physical systems and machine learning offer cost efficient solutions for continuous monitoring and computation that can be applied for the

prediction and avoidance of manufacturing defects, leveraging the ZDM solutions blossom as a specific movement part of quality management initiative where mathematical models, IoT and robotics cooperate to prevent defects and provide a competitive edge to manufacturing companies.

The ZDM cooperates also with IOF (as shown in the section 6.2 of this deliverable) and the connection between these two Technical Working Groups can enhance and improve the ZDM ontology development.

Standards

BFO and IOF core ontologies will be used for the development of the ZDM ontology. Common terms that can be used in this process are:

- Failure event
- Maintenance notification
- Maintenance notification trigger
- Maintenance schedule list
- Maintenance task
- Product
- Process
- Infrastructure
- Resource
- Software

Next Steps: the ZDM ontology could be used for further developing the standardisation work on selected OntoCommons demonstrators, which will be identified over the next months.

6.2.3 International Organisation for Standardisation (ISO)

About

ISO is a non-governmental, independent, global organisation composed of a network of the world's leading standardisers. Through their members (the national standards bodies in 165 different countries) they bring together experts from all over the world to develop International Standards. ISO ensures that the developed standards follow quality, safety, and efficiency of products, services, and systems.

Type of collaboration

Hedi Karray, OntoCommons Technical Coordinator, is collaborating within the ISO/TC 184/SC4.

This subcommittee 4 'Industrial Data' develops technology and standards for the digital representation of all engineering product data, where 'product' in fact includes materials, hence there is a very close alignment with the domains of interest of OntoCommons. The history and current work of the committee has recently been reviewed[7] with a particular focus on materials and related information models, in particular the ISO 10303 standard and its Application Protocols are of key importance, The review highlights the opportunity for further updates to the standard that integrates materials and products into a common scheme across the life cycle. Furthermore, implementations of the related information model exist currently mostly in EXPRESS language and there is an opportunity to update to owl/rdf.

The OntoCommons.eu team is also involved in the development of other ISO standards, namely: The ISO/IEC 21838 standard is about domain-neutral top-level ontologies (TLO). The Part 1 and Part 2 of this standard are already in the publication phase. The Part 1 (ISO/IEC 21838-1, www.iso.org/standard/71954.html) specifies required characteristics of a top-level ontology that can be used in tandem with domain ontologies at lower levels to support data exchange, retrieval, discovery, integration and analysis. The Part 2 (ISO/IEC 21838-2, www.iso.org/standard/74572.html) specifies Basic Formal Ontology (BFO) as a TLO conforming to the requirements defined in Part 1. The Parts 3 and 4 in future will specify DOLCE and TUPPER as TLOs in a similar manner.

Impact

> **Next Steps:** The team is going to attend dedicated meetings to continue contributing on the work about ISO/TC/184/SC4, and ISO/IEC 21838 standard (BFO), IOF-Core (OAGi) currently being adopted in the demonstrator IRIS-Industrial co-design Support.

6.2.4 iiRDS

About

iiRDS aims to establish standards that cover the request and the delivery of intelligent information between companies, organisations and individuals. The standards open new methods of advanced technical communication and iiRDS enables the delivery of precise information in the area of smart manufacturing. iiRDS has developed a Consortium that aims to advance the development of the standards.

Type of collaboration

OntoCommons and iiRDS have started cooperative discussions in the following areas:

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[7] https://www.royce.ac.uk/content/uploads/2021/06/Materials-4.0-A-Role-for-Standards.pdf

- the standards and ontologies developed by iiRDS can be exploited for the development of a new OntoCommons demonstrator;
- the iiRDS ontology can be harmonised and made interoperable with the other ontologies involved in the OntoCommons project (e.g., EMMO, DOLCE, BFO).
- iiRDS will provide insights and recommendations to shape the OntoCommons Roadmap.

Moreover, the current Steering Committee Chair at iiRDS, Ulrike Parson, has joined panel discussions about the role played by standards and ontologies during the webinar "What can ontologies do for standardisation? OntoCommons.eu project in the standardisation ecosystem", and the session "Enabling intra ontology interoperability through shared terminology", as part of the first Horizontal Workshop, organised by the OntoCommons team. All the recommendations shared will be addressed for the preparation of the first version of the OntoCommons Roadmap.

Standards

iiRDS is a standard for the delivery of intelligent information, provided with the product for the purpose of assisting the users in setting up, operating, and maintaining the product. iiRDS consists of:

- A vocabulary for the metadata provided with the content (e.g., product lifecycle phases, information types)
- A package format for the exchange of packages with intelligent information between different systems

Impact

The iiRDS Consortium representatives applied to the StandICT.eu open calls and have been successful in the third open call, in order to align iiRDS with European ontology standards and frameworks, among which OntoCommons. The goals of this alignment are:

- Adapting iiRDS in a way that it can be used with other European industry ontologies. This would enable to connect smart content as defined by iiRDS with other subject areas, i.e. sensor technology, manufacturing data, or maintenance information.
- Using common and state-of-the-art implementation methods, e.g. OWL and an architecture of upper-level, domain, and application ontology.
- Avoiding duplication of data structures that are defined by other European standardization initiatives
- Creating linked data on a European scale by providing an open standard that companies and standardisation bodies can use for delivery of smart content
- Coordinating with European and global activities regarding smart digital standards, for example driven by DKE and ISO
- Feedback the experiences from the development of iiRDS to other standardization initiatives, especially in the field of ontologies

Next Steps: as iiRDS addresses metadata and exchangeability of technical information, it may also serve to drive the digitization of standards themselves and enable dynamic content delivery for standard specifications and targeted access to requirements and definitions contained in international standard documents. This work can be useful for further driving standardisation efforts to the OntoCommons demonstrators and can define the basis for developing a new demonstrator.

Moreover, the iiRDS aims to align with the OntoCommons working group linked to Domain Ontologies and to define all the needed requirements for aligning iiRDS with the OntoCommons architecture of upper-level ontology, domain ontology and application ontology.

6.2.5 IEEE

About

With an active portfolio of nearly 1,300 standards and projects under development, IEEE is a leading developer of industry standards in a broad range of technologies that drive the functionality, capabilities, and interoperability of a wide range of products and services, transforming how people live, work, and communicate.

Type of collaboration

Michela Magas, OntoCommons Innovation and Sustainability Manager, has had several rounds of discussions with IEEE stakeholders on the topic of the establishment of an Industry Commons Interest Group within IEEE:

- Early interest was shown by the IEEE Industry Engagement group and by Sri Chandrasekaran, Senior Director, Standards & Technology, IEEE India, and IEEE Senior Member, IoT & Foundational Technologies Practice Lead.
- An expression of interest has been obtained from Hermann Brand, European Standards Affairs Director of IEEE to become member of the OntoCommons External Advisory Board.
- A mutually beneficial alignment is envisaged between several IEEE standardisation efforts and Industry Commons initiatives.

Standards

An IEEE standard upper-level ontology was created in 2001 by Adam Pease and Ian Niles (https://www.cambridge.org/core/journals/knowledge-engineering-review/article/abs/ieee-standard-upper-ontology-a-progress-report/215797ACBB7DACEE2C4100D18F51A04F). In recent years IEEE has been less involved with upper ontologies but very strong on the lower layers of

communication systems, including cooperation with ETSI in oneM2M to enhance 3GPP IoT network services (https://portal.etsi.org/Services/Centre-for-Testing-Interoperability/Activities/M2M/oneM2M).

In the field of domain ontologies, IEEE prioritises ontologies in the AI and IoT domains, and focuses particularly on robotics and automation. in 2015 the IEEE standard for ontologies for robotics and automation was approved (https://ieeexplore.ieee.org/document/7084073). Recent ontology developments in the robotics and automation domain include IEEE 1872.2-2021 – the IEEE Approved Draft Standard for Autonomous Robotics (AuR) Ontology (https://standards.ieee.org/standard/1872_2-2021.html) and IEEE 7007-2021 – the IEEE Ontological Standard for Ethically Driven Robotics and Automation Systems.

A new standard P2957 for a Reference Architecture for Big Data Governance and Metadata Management has been proposed in September 2020 (https://standards.ieee.org/project/2957.html). The standard defines a big data governance, metadata management and machine-readable reference architecture to enable scalability, findability, accessibility, interoperability and reusability of datasets among corporate heterogenous and cross-domain repositories. The expected date of submission of draft to the IEEE SA for Initial Standards Association Ballot is November 2023 and the projected completion date for submission is June 2024. Both OntoCommons and the Industry Commons use cases can make a substantial contribution to this standard.

Impact

The collaboration between IEEE and the Industry Commons initiatives and particularly the OntoCommons project can impact on the alignment between the IEEE Reference Architecture for Big Data Governance and Metadata Management standard and the Industry Commons demonstrator use cases and ontology ecosystem building. Existing IEEE domain ontology applications in robotics and automation can provide a demonstrator use case for Industry Commons initiatives and ensure further cross-domain alignment and harmonisation.

Next Steps: An approval of Hermann Brand, European Standards Affairs Director of IEEE as Member of the OntoCommons External Advisory Board is pending by the OntoCommons Coordinator and the Executive Board at the First Year Project Review. This will be followed by a proposal for cooperation and collaborative work on the establishment of a long-term engagement and alignment with Industry Commons initiatives.

7.Conclusions: Impact, Recommendations and Future Actions

The first OntoCommons Standardisation Impact Report has shown how cooperation with relevant SDOs and other standardisation stakeholders is crucial to facilitate the development and adoption of ontologies by industrial players.

This deliverable has highlighted the critical and complementary role played by ontologies and standards in the industrial ecosystem and the aim of OntoCommons.eu to further contribute to the adoption of industrial ontologies in the standardisation field with continuous engagement with standardisation players.

In the months following the release of this deliverable, OntoCommons will maintain and increase the engagement and cooperation on standardisation, through the following planned activities:

1. Despite the considerations made on the critical relation between ontologies and standards, in the Rolling Plan for ICT Standardisation 2021, there are no sections specifically dedicated to ontologies: one of the next steps that the Consortium is focusing on, is to potentially include the most relevant recommendations coming from the work performed by the StandICT.eu TWG on ontologies and the OntoCommons Roadmap **in the next Rolling Plan for ICT Standardisation**, in a new chapter dedicated to the **Data Economy** and to ontologies and semantic interoperability.

2. **Recommendations, gaps and priorities** around the Ontology domain from a standardisation perspective will also be listed in the **OntoCommons.eu Roadmap**. A complete list of recommendations will be provided in **the second OntoCommons Standardisation Impact Repor**t, due in M24.

3. The **OntoCommons OCES** can represent an important vehicle to overcome existing bottlenecks to apply standards and ontologies in the industrial sector as it supports the collection of industry-relevant data and including them in in a single repository and ensuring that they are used in a consistent way.

4. The analysis brought forward by the **OntoCommons demonstrators** can influence standards from industry input and how they may become valid use cases as part of EOSC to include in the **EOSC Set up Task Forces**. This work will be proposed from M24, after the development and initial validation of cases have been finalised.

5. A constant monitoring of the **number of applications in the ontology domain** that are potentially supported as part of the StandICT.eu project (11 applications by M13, as shown in Table 2) and the number of active **community members** within the **Working Group of EUOS of StandICT.eu** (this cannot be provided at the moment, as the Working Group around ontologies has not been created yet), will be provided in the next iteration of this deliverable.

6. Continuous engagement with the standardisation community: 76 people, from the **active community of members** registered on the OntoCommons.eu website, participated in the events organised and specifically related to standardisation, (the Webinar: "What can ontologies do for standardisation? OntoCommons.eu project in the standardisation ecosystem" and the dedicated session of the "Global Workshop: Ontology Commons

addressing challenges of the industry 5.0 transition", called "Enabling intra-ontology Interoperability through shared terminology").

7. The release of the EU's strategy on standardisation includes the establishment of a Standardisation Booster a platform to help beneficiaries, whose Horizon 2020 and Horizon Europe research results are likely to lead to the revision or creation of a standard, to test the relevance of their results for standardisation. The HSbooster.eu project will deliver a pilot of the booster. The project started in April 2022 and will run for 24 months. HSbooster.eu will provide a tailor-made online platform and resources for standardisation experts in Europe to advise 1,000 Horizon Europe and H2020 projects on how best their research results can lead to the revision or creation of standards. Services and training modules will help projects assess the standardisation readiness of their results and match them up with experts in the field who can guide them on how these results can feed into standardisation working groups or technical committees. With the Booster an integral part of the EU Strategy on Standardisation, ONTOCommons will explore avenues to engage with the Booster. This could include:

   a. Participation by individuals within the project with experience in the standardisation landscape to apply as experts and deliver support services to projects interested in discovering how their results can contribute to standardisation.
   b. Sharing of relevant standards-related training material that could be relevant to ontology-related standards activities.

OntoCommons.eu, through these concerted efforts, of showing how Ontologies can support standardisation, we would like to be in a position, by the project end, to demonstrate some relevant results through the diverse collaborations and results from the demonstrators and where we can prove some impacts in contributing to better efficiency, automation, information traceability, representation, optimised processes thanks to the use of data and models, ultimately through the use of Standards.