ISO JTC 1 IEC
INFORMATION TECHNOLOGY STANDARDS

JTC 1 Technology Trend Report

Metaverse

Executive Summary

Standard technologies for connection and integration of the real world into virtual worlds is a key requirement for the metaverse. An important goal of the metaverse is to provide more profuse human life experiences by extending the real world to virtual worlds. The attainment of this goal is supported by having standardized information and communication technologies (ICT) for integration between real and virtual worlds, and in ICT and industry areas. ISO/IEC JTC 1 has been developing standards over many years and on an on-going basis that are currently relevant to implementing the metaverse in various industries.

This report describes JTC 1 standards and standardization that can be used in the complete and all-encompassing range of metaverse areas. This document includes discussion of:

- JTC 1 technologies for the metaverse
- Metaverse service areas
- Standards required for the metaverse
- JTC 1 standards and projects for the metaverse
- JTC 1 governance for the metaverse
- JTC 1 strategies for the metaverse
- Further JTC 1 standards development for the metaverse

This report concludes with recommendations that relevant subcommittees to the metaverse develop their standards in collaboration with other subcommittees because the metaverse includes diverse areas and scopes in ICT, and its coverage in the industry is broad.

About ISO/IEC JTC 1

ISO/IEC JTC 1, entitled "Information technology", is a joint technical committee of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). ISO/IEC JTC 1 develops Standards that support the advancement of information and communications technology (ICT) across multiple industry sectors.

About JTC 1 JETI

ISO/IEC JTC 1 Advisory Group 2 on JTC 1 Emerging Technology and Innovation (JETI) has been mandated to seek opportunities to facilitate JTC 1 Standards development for future emerging and innovative technologies as a technology watch group in JTC 1.

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Section 1

Introduction

The metaverse can be implemented based on fundamental standardized virtual worlds and avatar information processing technologies of JTC 1, along with other JTC 1 technologies such as VR/AR/MR, 3D simulation, user interface, safety and security, cloud computing and edge computing, artificial intelligence, communication platforms, etc. [1-2]. These technologies can be integrated into virtual worlds to enhance industry, business, and human life. To provide accessibility to information and to provide better and seamless communication between humans in virtual worlds, it is imperative that standardized technologies are used when implementing metaverse services.

Based on the JTC 1 technologies that are necessary for the metaverse, standards for correct terms and concepts for the metaverse are also needed and are currently being developed in JTC 1. This will provide guidance amidst a quickly expanding area where new terms often arise and sometimes lack a consensus on their meaning or conceptual application. JTC 1 standards will also address safety and security in personal and commercial environments in virtual worlds. In addition, as more and more people spend time in virtual worlds, there is a requirement for a new order and rules for ethical and moral conduct in the metaverse. JTC 1 is preparing for standards development around these issues.

This report describes JTC 1 standards and standardization for the metaverse.

Section 2

Terms and Definitions

The metaverse is based on many ICTs that are used in the development of its services and applications. As the use of the metaverse increases, its requirements will increase and more enhanced ICTs with many new terms will be needed [3]. When defining terms for the metaverse, two categories should be considered. One is about technical terms that are relevant to all technologies for metaverse implementations. The other is about defining unique terms to distinguish between real and virtual objects as these can be easily confused.

The metaverse can be defined as a universal, immersive virtual world that is principally facilitated by Virtual Reality (VR) / Augmented Reality (AR) / Mixed Reality (MR). As such, VR/AR/MR technologies combined with ICT integration are critical to the development and evolution of the metaverse. There are many other relevant standard technologies for the metaverse that should also be incorporated. These include standards for cloud computing with information communication platforms, edge computing, sensors, interaction with real and virtual worlds, 3D simulation, artificial intelligence (AI), big data processing, safety and security, knowledge and semantic information processing, and others. Technical terms for these technologies will apply and be intermingled in many diverse metaverse applications. Therefore, these terms should be uniquely defined across all applications to facilitate better understanding and communication between users when using metaverse applications.

In addition to technical terms, there can be other terms used in metaverse applications that may be duplicated or be confusing. With human life extended to virtual worlds in the metaverse, people should be able to communicate clearly in both the real world and virtual worlds with a shared understanding of terms. Terms and concepts should be consistent for communication between humans appearing as avatars in virtual worlds, as well as between real and virtual objects. For example, there is a need to clearly distinguish between two corresponding entities, the real one and the virtual one, such as a person in the real world and their avatar in the virtual world, a real object and its virtual object, and a real environment and its virtual environment.

Since the encompassing range of areas in the metaverse is large, it is imperative that terms be defined uniquely and succinctly across both the real world and virtual worlds. JTC 1 is developing standards for terms and definitions for the metaverse considering these two categories of terms.

Section 3

Concepts

3.1 General

At a fundamental level, the metaverse requires standard technologies for composing virtual worlds and incorporating the real world into virtual worlds. The goal of the metaverse is an enhancement of human life by extending it to virtual worlds. This can be obtained with ICTs for integration between real and virtual worlds in ICT and industry areas. Part of this standardization should address safety and security when immersing oneself in these environments. As more and more people spend time in virtual worlds, it becomes more and more imperative to come up with a new order for ethical and moral conduct in the metaverse. There are many and various information technologies that can be used in all these areas and so standards are necessary for the metaverse. Many JTC 1 standardization technologies apply here (Figure 1).

This report focuses on virtual worlds, connection and integration of the real world into virtual worlds, knowledge and semantic information processing, ICT integration with industry areas, and governance related topics from a JTC 1 perspective. In addition, there are many other related JTC 1 standards that will be required for the metaverse. JTC 1 will be able to provide an overall systematic structure based on JTC 1 technologies and standards that can be used for developing metaverse application services and applications.

3.2 Metaverse service areas

More and more people will use virtual worlds for social, economic, and cultural pursuits. Industry will provide metaverse services in many metaverse areas including business and social meetings and events, commerce, education and training, medicine and health, manufacturing, safety, shopping, travel, and culture, all taking place in virtual worlds (Figure 2). Almost all standard areas in JTC 1 will be needed for metaverse service applications. JTC 1 standards and standardization are the basis for metaverse service implementation.

Although metaverse service areas are diverse and include many kinds of integration depending on the application area, the necessary technologies and standards can be uniquely classified and defined according to the functional components that are needed to implement the metaverse services. This report also describes functional components and requirements that are necessary for developing metaverse application services in virtual worlds.

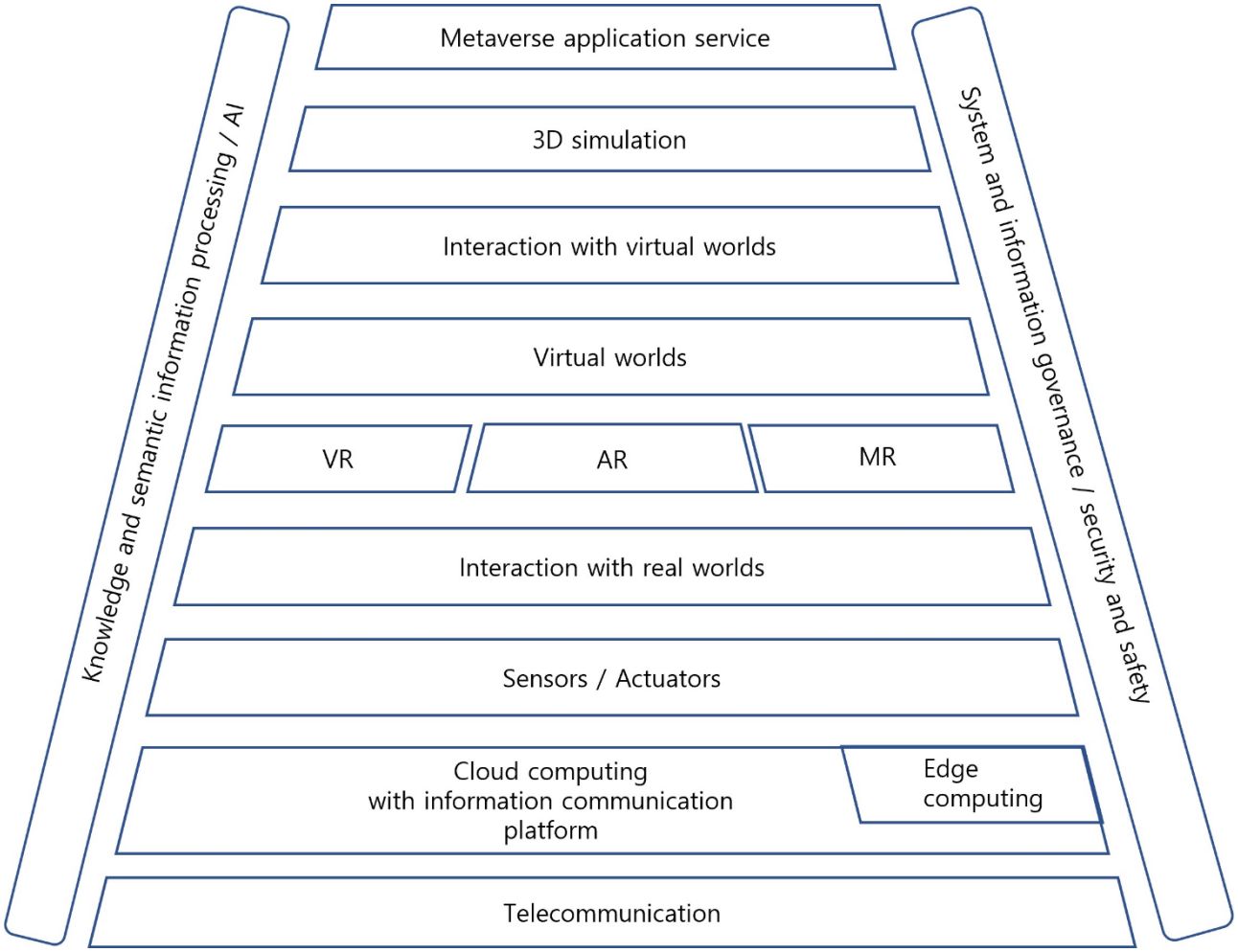

Figure 1 JTC 1 standardization technologies for the metaverse

(a) education (b) training (c) event (d) training

(e) medicine (f) health and safety [4] (g) safety [4] (h) travel

Figure 2 Example metaverse service areas

3.3 Requirements and relevant standards for metaverse services

Requirements for metaverse application services include standardized ICT integration for diverse metaverse applications, standardized software development guidelines, standardized user interface guidelines,

standardized ownership, authority, safety, and security, and standardized governance guidance for social, economic, and cultural order and ethics in the metaverse. In relation to these requirements, JTC 1 has developed many standards in ICT areas that are necessary for implementing the metaverse.

JTC 1 standard technologies for the metaverse include the following:

First, there are standards for virtual world representation, visualization, and information processing. *ISO/IEC 14772 Virtual Reality Modeling Language (VRML), ISO/IEC 19775-1 Extensible 3D (X3D), and ISO/IEC 18023 SEDRIS* are standards that can be used for creating and simulating 3D virtual worlds (Figure 3 and Figure 4). VRML and X3D standards have been developed in collaboration with the Web3D Consortium, and SEDRIS standards with the SEDRIS organization. Smart cities can be represented in the metaverse with real-world information in virtual environments using SC 24 standards. In addition to virtual environments, avatar representation can also be defined to implement human health information in smart cities. *ISO/IEC TS 5147 Guidelines for representation and visualization of smart cities* describes concepts, categories of data, guidance of representation and visualization, and use cases for smart cities (Figure 5) [5].

Second, humanoid animation standards can be used for 3D avatar representation, visualization, and information processing. *ISO/IEC 19774-1 Humanoid Animation (HAnim) architecture* defines a humanoid data structure for representing human models in 3D virtual worlds. The HAnim data models are defined with several levels of articulation (LOA) structure (Figure 6). *ISO/IEC 19774-2 HAnim motion data animation* can be used to generate and exchange humanoid animation produced by human motion captured data or by motion algorithms. These standards define data models and animations for 3D avatars in virtual worlds (Figure 7). The HAnim standards have been developed in collaboration with the Web3D Consortium.

Third, VR/AR/MR based information processing standards are used to simulate virtual worlds with real world information. *ISO/IEC 18038 Sensor representation in mixed and augmented reality* can be used to define sensor related data in a virtual environment for sensor information processing (Figure 8). Real world information such as data from various types of sensor devices can be represented and simulated in virtual worlds. *ISO/IEC 18039 Mixed and Augmented Reality (MAR) reference model* provides metaverse systems with the basic components that are necessary to define and implement such systems. *ISO/IEC 18040 Live actor and entity representation in mixed and augmented reality* can be used to define live actor and entity representation in virtual worlds using MAR technologies. *ISO/IEC 18520 Benchmarking of vision-based spatial registration and tracking methods for mixed and augmented reality (MAR) provides the reference framework for the benchmarking of vision-based spatial registration and tracking (vSRT) methods for mixed and augmented reality (MAR)* can be used for benchmarking vision-based spatial registration and tracking methods for MAR [6]. JTC 1 also provides for multimedia storage, communication and coordination, and the handling of 3D visual and audio content. The encoding technologies for audio, picture, multimedia, and hypermedia information can be used for the metaverse [7]. In relation to encoding, there are standards such as *ISO/IEC 14496-16 Animation Framework eXtension (AFX), ISO/IEC 14496-25 3D graphics compression model, ISO/IEC 23008-3 3D audio, ISO/IEC 23090-2 Omnidirectional media format (OMAF), ISO/IEC 23090-5 Visual volumetric video-based (V3C) and video-based point cloud compression (VPCC)*, and others (Figure 9) [8-9].

Fourth, there are standards related to knowledge and semantic information processing in 3D virtual worlds. Virtual worlds should have semantic information so that avatars or users can recognize and access real environment information in the corresponding virtual environment. *ISO/IEC 18023 SEDRIS* specifies semantic information related to the real world represented in virtual worlds. *ISO/IEC 19775 Extensible 3D (X3D)* can include real world information for each 3D object in a virtual environment using meta statements. Knowledge transfer between the real world and a virtual world can be obtained through annotation interfaces. *ISO/IEC 19788 Metadata for Learning Resources* can be used to specify metadata elements and their attributes for semantic definition in virtual worlds. *ISO/IEC 4932 "Information technology for learning education and training - Access for all (AfA) metadata for individualized accessibility - AfA Core Terms"*

can be used to describe and specify personal needs and preferences which can be matched by resource components that are accessible to the user [10]. *ISO/IEC TR 20748 Learning analytics interoperability* provides efficient communication and operation between systems and services. *ISO/IEC 22602 Competency models expressed in MLR (Metadata for Learning Resource)* specifies the exchange and integration of heterogeneous descriptions of competency for metadata learning resources. *ISO/IEC 23126 Ubiquitous learning resource organization and description framework* provides features for dynamic aggregation of resources.

Fifth, standards for cyber safety, security, identity, and authority should be provided for virtual worlds since metaverse platforms will be used everywhere for business, education, social uses, etc. and this means the collection of a great deal of personal and organizational information. *ISO/IEC 5927 Guidance on safe immersion, set up and usage* provides guidelines for safe usage related to human factors in VR/AR/MR. JTC 1 also provides standards in the areas of information security, cybersecurity, and privacy protection. *ISO/IEC 27001 Information security, cybersecurity, and privacy protection - information security management systems requirements* can be used for information security management in the metaverse.

Sixth, standards for ICT integration technologies within diverse industry sectors and for diverse applications should be provided for the metaverse. It is expected that there will be business opportunities in the metaverse for almost every type of industry. For metaverse applications in these diverse industries, many ICT integration standards will be necessary. For example, medicine and health should be integrated with virtual worlds, as should education and training. In this way, almost all industries will be integrated with virtual worlds. From this consideration, JTC 1/SC 24 and SC 36 established JWG 12 for metaverse application services in ICT integration areas.

Finally, because it is expected that the JTC 1 technologies mentioned here will be used for the metaverse, governance guidelines for management of the metaverse must be prepared. Our society is moving rapidly towards ubiquitous virtual world services. With more and more people meeting in virtual worlds, social problems are likely to arise inside these virtual worlds. JTC 1 governance related to order, morals, and ethics in the metaverse should be provided. Because the metaverse is based on ICTs, problems may arise due to the inappropriate use of ICT information. Therefore, JTC 1 should provide guidelines for proper usage of ICT information in the metaverse.

Figure 3 ISO/IEC 19775-1 Extensible 3D (X3D)

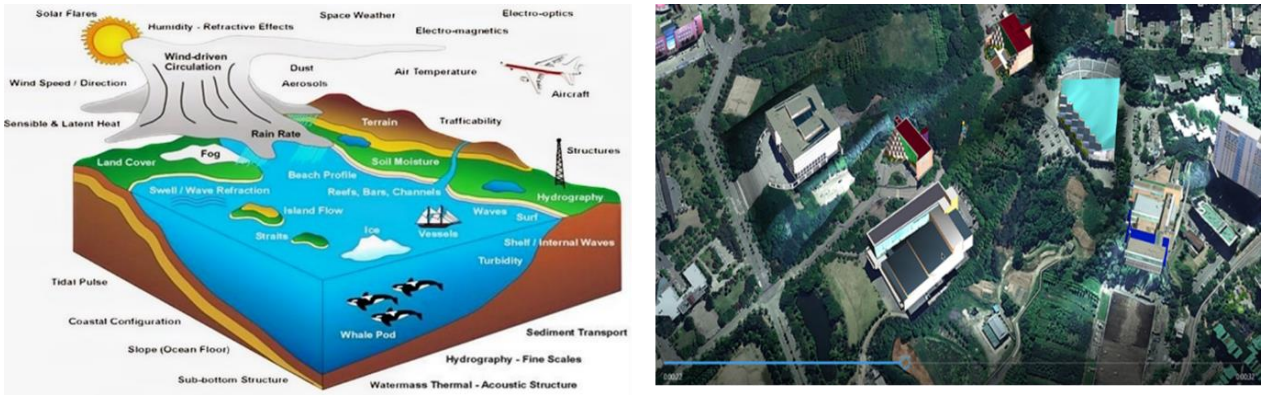

Figure 4 ISO/IEC 18023 SEDRIS and ISO/IEC 18038 Sensor Representation in Mixed and Augmented Reality (MAR)

Figure 5 ISO/IEC TS 5147 Guidelines for representation and visualization of smart cities

Figure 6 ISO/IEC 19774 Humanoid Animation (HAnim) architecture examples and LOA 3 structure

Figure 7 ISO/IEC 19774 Humanoid Animation (HAnim) examples with motion capture data

Figure 8 ISO/IEC 18038 sensor representation, 18039 MAR reference model, and 18040 Live actor and entity representation

Figure 9 ISO/IEC 23090-5 Visual volumetric video-based (V3C) and video-based point cloud compression (V-PCC)

Section 4

JTC 1 Technologies for the Metaverse

4.1 General

Virtual worlds and avatar-related technologies in JTC 1 are basic technologies for the metaverse. All types of metaverse application services are based on JTC 1 technologies such as VR/AR/MR, 3D simulation, UI, security, cloud computing, edge computing, AI, etc. In addition to these basic technologies, standard technologies related to virtual environments, avatar information processing, real-world simulation in virtual environments, and ICT integration with industry areas are necessary. JTC 1 has developed many of these relevant standards. This clause describes JTC 1 standard technologies that are necessary for developing metaverse applications.

4.2 Virtual world

For metaverse applications, virtual environments are created to represent a virtual world for human life both personal and business. Many different virtual environments should be able to be generated and connected to each other. Functions fundamental to virtual environments should be those for creation, representation, interchange, interaction, connection, and integration. JTC 1/SC 24 has many relevant standard technologies that apply to these functions for virtual environments. If virtual environments include multimedia with audio and video, many JTC 1/SC 29 standards can be used to represent these multimedia metaverse applications. Standard creation and representation of virtual environments are basic requirements to share metaverse resources. Interchange functions are needed to share, reuse, and store all the processes and resources for the metaverse. Interaction functions are needed to manage and operate virtual environments and objects in order to communicate between the real and virtual worlds. Connection functions are needed to extend the real world to virtual worlds so that users can live and work in virtual worlds. Integration functions are needed to combine and represent real world information into virtual worlds.

4.3 Humanoid avatar

Users / humans are represented as avatars in a virtual world. An avatar exists in place of an individual person who enters, lives, and conducts business and social activities in the virtual world. Humans should be able to be represented and be interacted and communicated with in virtual environments. Human representation includes many standard technologies for human information processing. JTC 1/SC 24 has developed human data model and animation standards, and there are many other resources for humanoid animation that can be used in metaverse applications. Interaction should be able to be done with the virtual environment itself as well as with other people in the environment. Interactions between avatars and virtual environments, and between avatars should be represented and processed. 3D and VR/AR/MR can resolve interactions like action and response. All 3D objects in virtual environments can be reacted and responded to by avatars and virtual environments. JTC 1/SC 24 standards provide interaction functionalities with scene graphs for virtual environments.

4.4 VR/AR/MR based information processing

VR/AR/MR are key technologies in implementing metaverse environments that use real and virtual information. VR/AR/MR based information processing refers to an integrated technology that creates,

manipulates, represents, and incorporates real world information into a virtual world using VR/AR/MR technologies. In addition, generated information should be able to be stored and interchanged or shared between virtual worlds.

VR, AR, or MR can be used to implement information processing for environments or objects in virtual worlds that integrate with real world information. VR, AR, or MR can be selected depending on the virtual environment application type. VR concepts have been around for over 30 years now since 3D graphics technology was first used to generate many VR applications. Therefore, VR is a very fundamental historical concept for metaverse environments. Since then, for around 10 years now, the term VR has also been used for 360 video images. VR should be used for the metaverse to define and represent 3D graphics virtual environments, and to process information related to 3D virtual worlds. AR should be used to process information related to the integration of virtual and real-world information. The real world is represented as a video image and is then augmented with virtual objects such as 3D synthetic images or real world sensors. MR should be used to process information in combination with VR and AR. Differently from AR, MR is based on 3D virtual environments that incorporate real world information such as video images or sensor information.

4.5 Knowledge and semantic information processing

For metaverse applications, knowledge and semantic information should be included in virtual environments. This includes all information necessary to conduct personal and business activities within metaverse environments. All information should be able to seamlessly integrate within the metaverse environment depending on the application's purpose. Some examples of knowledge and semantic information processing in the metaverse are as follows:

- Metaverse education: Information and objects related education can be included in a virtual environment. Education-based semantic information for the environment can be managed in the metaverse environment. Education-based processes between educators and learners should be able to be communicated interactively in the metaverse environment.
- Metaverse medicine: Medical information for medical education or medical treatment can be included in the virtual environment. For example, medical information related to human internal organs should be able to be managed in relation to the metaverse environment or objects contained therein.
- Metaverse healthcare: Personal health can be managed directly in a metaverse environment if semantic information related to a person's health can be maintained there. For example, health sensor information can be obtained and managed through the metaverse.
- Metaverse manufacturing: Smart manufacturing related to automatic machine production can be achieved in the metaverse. Knowledge and semantic information relevant to a procedure for machine production should be included in the process of smart manufacturing. For example, a given machine may have specific physical properties and functions, and produce particular outputs. Not only visual information but also physical properties and functions should be represented. Connection should also be provided to obtain outputs outside of the metaverse.

4.6 Cyber security, identity, and authorization for the metaverse

Significant numbers of people will use metaverse service applications individually or as part of business, and this will lead to significant changes in social, cultural, and economical life. Issues of security and authorization may be exponentially more important in the metaverse, and consequently identity must be accurately represented and safeguarded. Several levels of security can be considered: at the individual, organization, nation, system, distribution, and data level. Personal and business information should be protected while considering privacy, economy, and society. National information should be protected while considering national defense, public safety, economy, and society. System information should be protected considering unexpected system failure, viruses, and

hacking. Distribution should be secured considering network issues, accessibility, and national protection. Data should be secured considering economy, information safety, society, viruses, and hacking.

4.7 AI information processing for the metaverse

Because the metaverse consists of huge amounts of big data accessible through various networks, information processing via AI is inevitable as a means to access and process that information efficiently and in a timely fashion for metaverse applications. Although there are various metaverse application areas that can benefit from AI technology, 3D virtual environments, objects, and avatars especially need generative AI technology when these virtual environments are created to correspond to those in the real world.

When generating 3D virtual environments and objects for the metaverse, a general 3D graphics tool is typically used to obtain geometrical data and attributes. Standard data models and formats can then be obtained and manipulated. The greater the need for a realistic appearance, more time-consuming the design. AI technology can reduce the time required by using standard data models when generating virtual environments and objects.

Avatars for representing humans and animals have special data structures because their motion at hierarchical joints and segments should be represented. Such articulated avatars require more time-consuming and complex design to obtain a realistic appearance. These difficulties can also be reduced with AI technology although more efficient algorithms are still needed. Apparel and accessories for avatars are other big data areas that need AI information processing. Their geometry and appearance data should be able to be generated and managed for the specific purpose of each metaverse application.

Various sensors for avatars should be able to be represented and processed in the metaverse. Wherever and whenever avatars are moving around a metaverse environment, sensor data should be able to be collected and traced along with the avatars. There are many types of sensors used in the real world and these can also be managed in virtual environments. Avatar-related sensors and information obtained from the real world should be able to be represented in the metaverse in relation to avatar motion.

4.8 ICT integration technologies with industry areas

There are many industry areas for which the metaverse can provide a visual virtual world for each real-world service. As in the real world, many types of related activities can be done within the metaverse. There are many opportunities to provide services related to education and training, medicine and health, manufacturing, shopping, sports, etc. ICT integration technologies for virtual environments are required when implementing metaverse applications. The following technologies are necessary for the metaverse:

- Real world representation: ICT integration data model is needed to represent the real world in virtual environments. Visual and functional information for the real world should be modeled to define this data as digital information. Sensor information from the real world should be able to be integrated into and represented in virtual environments.
- Visualization and simulation: Information data models obtained by ICT integration should be able to be visualized and simulated in virtual environments.
- AI and big data processing: Because the metaverse represents real world information in virtual environments, efficient big data processing is inevitable to manage the volume of necessary information. AI technology is necessary to process big data including large amounts of multimedia with streaming sensor data.
- Information exchange and interaction with virtual worlds: Information exchange between virtual worlds is needed in order to communicate and share resources. In addition, tools for interaction with virtual worlds should be provided so that users or avatars can navigate and acquire information from virtual worlds.
- Information exchange and interaction with real worlds: Real world information that can be obtained from humans or device sensors should be able to be integrated into virtual worlds. This means that

human and sensor information should be able to be represented and processed in relation to virtual environments.

- Application content creation and manipulation: Knowledge information for application content services should be able to be created and manipulated in relation to virtual environments. Semantic information for virtual environments, objects, and avatars should be able to be processed based on application content.
- Application information modelling: Information data for the metaverse should be modelled as data structures to be processed by applications. The information data should be able to be accessed independent of the specific applications.

Section 5

JTC 1 Standards and Standardization for the Metaverse

5.1 General

Many JTC 1/SCs are relevant to the metaverse because they have developed many ICT standards that are related to metaverse platforms, systems, applications, interfaces, and tools. Because metaverse implementations are based on ICT, and the coverage of the metaverse standard technologies is broad, there are many standards in JTC 1 that apply. This section describes which areas and standards of JTC 1 are related to the metaverse.

Annex A include a list of JTC 1/SC standards for the metaverse.

Note that some SCs have provided detailed information on their standards, while others have not. This report only includes information from SCs that provided a list of their standards, and so it should be considered that some standards may be missing.

5.2 JTC 1/SC 6 Telecommunications and information exchange between systems

JTC 1/SC 6 is working on standardization in the field of telecommunications dealing with the exchange of information between open systems, including system functions, procedures, and parameters as well as the conditions for their use. Because metaverse application services are conducted over networks and need telecommunication standards between platforms, SC 6 standards can be used to implement them.

5.3 JTC 1/SC 7 Software and systems engineering

JTC 1/SC 7 is developing standards for processes and, supporting tools and technologies for the engineering of software products and systems. Because metaverse application services can be obtained by developing software products and systems with interoperability, SC 7 standards for software development technologies are necessary.

5.4 JTC 1/SC 24 Computer graphics, image processing and environmental data representation

JTC 1/SC 24 is working on the development of standards within the following scope: Standardization relating to computer graphics, image processing, virtual reality, augmented reality, mixed reality, environmental data representation, and visualization of, and interaction with, information. SC 24 can provide standards about virtual worlds, 3D human and avatars, VR/AR/MR, real world simulation, smart city visualization, ICT integration, 3D product data, and digital twin for the metaverse.

SC 24 standards about 3D virtual world representation, visualization, and information processing are as follows:

- ISO/IEC 14772-1:1997 The Virtual Reality Modeling Language – Part 1: Functional specification and UTF-8 encoding
- ISO/IEC 14772-2:2004 The Virtual Reality Modeling Language – Part 2: External Authoring Interface (EAI)
- ISO/IEC 19775-1:2023 Extensible 3D(X3D) – Part 1: Architecture and base components
- ISO/IEC 19775-2:2015 Extensible 3D (X3D) – Part 2: Scene Access Interface
- ISO/IEC 19776-1:2015 Extensible 3D (X3D) encodings – Part 1: Extensible Markup Language (XML) encoding
- ISO/IEC 19776-2:2015 Extensible 3D (X3D) encodings – Part 2: Classic VRML encoding
- ISO/IEC 19776-3:2015 Extensible 3D (X3D) encodings – Part 3: Compressed binary encoding
- ISO/IEC 19777-1:2006 Extensible 3D (X3D) language bindings – Part 1: ECMAScript

- ISO/IEC 19777-2:2006 Extensible 3D (X3D) language bindings – Part 2: Java
- ISO/IEC 18023-1:2006 SEDRIS – Part 1: Functional specification
- ISO/IEC 18023-2:2006 SEDRIS – Part 2: Abstract transmittal format
- ISO/IEC 18023-3:2006 SEDRIS – Part 3: Transmittal format binary encoding
- ISO/IEC 18024-4:2006 SEDRIS language bindings – Part 3: C
- ISO/IEC 18025:2014 Environmental Data Coding Specification (EDCS)
- ISO/IEC 18026:2009 Spatial Reference Model (SRM)
- ISO/IEC TS 5147: 2023 Guidelines for representation and visualization of smart cities

SC 24 standards about 3D avatar representation and information processing are as follows:

- ISO/IEC 19774-1:2019 Humanoid Animation (HAnim) – Part 1: Architecture
- ISO/IEC 19774-2:2019 Humanoid Animation (HAnim) – Part 2: Motion data animation

SC 24 standards about VR/AR/MR based information processing with virtual worlds and avatars are as follows:

- ISO/IEC 18038:2020 Sensor representation in mixed and augmented reality
- ISO/IEC 18039:2019 Mixed and augmented reality (MAR) reference model
- ISO/IEC 18040:2019 Live actor and entity representation in mixed and augmented reality
- ISO/IEC 18520:2019 Benchmarking of vision-based registration and tracking methods for mixed and augmented reality
- ISO/IEC TS 23884:2021 Material property and parameter representation for model-based haptic simulation of objects in virtual, mixed, and augmented reality (VR/MAR)
- ISO/IEC 23488:2022 Object/environmental representation for image-based rendering in virtual/mixed and augmented reality (VR/MAR)
- ISO/IEC 3721: 2023 Information model for MAR (Mixed and Augmented Reality) contents
- ISO/IEC 5927: 2024 Augmented and Virtual Reality safety – Guidance on safe immersion, setup and usage

There are ongoing SC 24 projects that can be used for the metaverse, as follows:

- ISO/IEC AWI 20538 Human information data model for 3D virtual smart cities
- ISO/IEC CD 9234 Information modeling for VR/AR/MR based education and training systems
- ISO/IEC CD 24931-1 Metaverse – Part 1: Concepts, definitions and terminology
- ISO/IEC AWI 23620-1 VR/AR/MR based information systems for learning, education and training – Part 1: Terminology and concepts

5.5 JTC 1/SC 27 Information security, cybersecurity and privacy protection

JTC 1/SC 27 is developing standards for information security, cyber security and privacy protection to protect information. These standards include generic methods, techniques and guidelines to address both security and privacy aspects such as: information security management; cryptographic and other security mechanisms; identity management, biometrics and privacy; conformance assessment; accreditation and auditing requirements; and security evaluation criteria and methodology. SC 27 standards can be used to secure virtual environments. Further development of SC 27 standards should continue to enhance functionalities of information security.

SC 27 standards and projects relevant to the metaverse are as follows:

- ISO/IEC 27001:2022 Information security, cybersecurity and privacy protection – Information security management systems requirements
- ISO/IEC 15408:2022 Information security, cybersecurity and privacy protection – Evaluation criteria for IT security
- ISO/IEC WD 27091 Cybersecurity and privacy – Artificial intelligence – Privacy protection

5.6 JTC 1/SC 29 Coding of audio, picture, multimedia and hypermedia information

JTC 1/SC 29 is developing standards on efficient coding of digital representations of images, audio and moving pictures which includes conventional and other sensory data, and static and dynamic graphics objects. It is also developing standards on efficient coding of other digital information which includes multimedia, environment and user-related metadata, sensor and actuator information

related to audiovisual information, and other digital data such as genomics. In addition, it is developing standards related to synchronization, presentation, storage, and transport of single or combinations of media, media security and privacy management, quality of experience evaluation and system performance metrics.

Metaverse application services are typically required to process large amounts of multimedia data and communications, and so efficient coding and transmission standards are necessary. SC 29 has developed the following standards for providing efficient coding and transmission throughout various heterogeneous networks.

- ISO/IEC 14496-16:2011 Information technology - Coding of audio-visual objects - Part 16: Animation Framework eXtension (AFX)
- ISO/IEC 14496-25:2011 Information technology - Coding of audio-visual objects - Part 25: 3D Graphics Compression Model
- ISO/IEC 23008-3:2022 Information Technology - High efficiency coding and Media Delivery in Heterogeneous Environments - Part 3: 3D Audio
- ISO/IEC 23090-2:2023 Information technology - Coded representation of immersive media - Part 2: Omnidirectional media format (OMAF)
- ISO/IEC 23090-5:2021 Information technology - Coded representation of immersive media - Part 5: Visual volumetric video-based coding (V3C) and video-based point cloud compression (V-PCC)
- ISO/IEC 23090-6:2021 Information technology - Coded representation of immersive media - Part 6: Immersive media metrics
- ISO/IEC 23090-7:2022 Information technology - Coded representation of immersive media - Part 7: Immersive media metadata
- ISO/IEC 23090-8:2020 Information technology - Coded representation of immersive media - Part 8: Network based media processing
- ISO/IEC 23090-9:2023 Information technology - Coded representation of immersive media - Part 9: Geometry-based point cloud compression
- ISO/IEC 23090-10:2022 Information technology - Coded representation of immersive media - Part 10: Carriage of visual volumetric video-based coding data
- ISO/IEC 23090-14:2023 Information technology - Coded representation of immersive media - Part 14: Scene description

The following SC 29 standards can be used for communication between the real and virtual worlds in the metaverse:

- ISO/IEC 23005-2:2018 Information technology — Media context and control — Part 2: Control information
- ISO/IEC 23005-3:2019 Information technology — Media context and control — Part 3: Sensory information
- ISO/IEC 23005-4:2018 Information technology — Media context and control — Part 4: Virtual world object characteristics
- ISO/IEC 23005-5:2019 Information technology — Media context and control — Part 5: Data formats for interaction devices
- ISO/IEC 23005-6:2019 Information technology — Media context and control — Part 6: Common types and tools
- ISO/IEC 23005-7:2019 Information technology — Media context and control — Part 7: Conformance and reference software

Realistic 3D humans using video can be generated and used for the metaverse. The following SC 29 standard can be used to generate coding for 3D video and graphics.

- ISO/IEC 23090-5: 2023 Information technology – Coded representation of immersive media – Part 5: Visual volumetric video-based (V3C) and video-based point cloud compression (V-PCC)

Recent SC 29 work items relevant to the metaverse are as follows:

- ISO/IEC WD 23090-4 Information technology — Coded representation of immersive media — Part 4: Immersive audio
- ISO/IEC FDIS 23090-12 Information technology — Coded representation of immersive media — Part 12: MPEG immersive video (MIV)
- ISO/IEC FDIS 23090-13 Information technology — Coded representation of immersive media — Part 13: Video decoding interface for immersive media
- ISO/IEC FDIS 23090-18 Information technology — Coded representation of immersive media — Part 18: Carriage of geometry-based point cloud compression data

5.7 JTC 1/SC 32 Data management and interchange

JTC 1/SC 32 is developing standards for data management and interchange. SC 32 standards are related to data management for local and distributed information systems environments. SC 32 standards

include reference models and frameworks; definition of data domains, data types, data structures, and their associated semantics; languages, services, and protocols for persistent storage, concurrent access, concurrent update, and interchange of data, metadata and other information resources associated with sharing and interoperability, including electronic commerce. The metaverse will use vast amounts of data from the real world and SC 32 standards can be used to provide management of that data in the metaverse.

5.8 JTC 1/SC 35 User interfaces

JTC 1/SC 35 is developing standards in the field of user-system interfaces in information and communication environments. It also develops standards on user interface accessibility; cultural and linguistic adaptability; user interface objects, actions and attributes; methods and technologies for controlling and navigating within systems, devices and applications; symbols, functionality and interactions of user interfaces, visual, auditory, tactile and other sensory input and output devices and methods in ICT environments; and user interfaces for mobile devices. All these standards are necessary to implement metaverse application services. SC 35 standards should continue to enhance these functionalities.

5.9 JTC 1/SC 36 Information technology for learning, education and training

JTC 1/SC 36 is developing standards in the scope of information technologies for learning, education, and training in order to support individuals, groups, or organizations, and to enable interoperability and reusability of resources and tools. Learning, education and training (LET) is one of the main areas for metaverse applications. Topics for SC 36 standards include access for all, metadata, VR/AR/MR, collaboration, learner management, learning analytics, artificial intelligence, and course descriptions.

SC 36 standards are applicable to conducting education and learning in the metaverse. Educational resources used in various industries should be further developed and enhanced for use in the metaverse. For example, existing educational materials should be enhanced to provide interoperability and reusability for metaverse education. SC 36 standards will contribute to these functionalities.

Semantic information with metadata is another important functionality in the metaverse. Metadata should be able to be embedded in education resource or be linked external to the resources. In addition, learners should be able to have a resource adapt to their individual needs without discrimination. SC 36 standards that can provide these functionalities for the metaverse are as follows:

- ISO/IEC 19788-1:2022 Information technology - Learning, education and training - Metadata for Learning Resources – Part 1: Framework
- ISO/IEC 24751:2023 Individualized adaptability and accessibility in e-learning, education and training Part 4: "Access for all" framework for individualized accessibility and registry server application programming interface (API)

5.10 JTC 1/SC 37 Biometrics

JTC 1/SC 37 is developing standards on generic biometric technologies pertaining to humans in order to support interoperability and data interchange between applications and systems. Generic human biometric standards include common file frameworks, biometric application programming interfaces, biometric data interchange formats, related biometric profiles, application of evaluation criteria to biometric technologies, methodologies for performance testing and reporting, and cross jurisdictional and societal aspects. These standards can be used to define human information and implement biometric related properties for human security functionalities in the metaverse.

5.11 JTC 1/SC 38 Cloud computing and distributed platforms

JTC 1/SC 38 is developing standards in the areas of cloud computing and distributed platforms including foundational concepts and technologies, operational issues, and interactions between cloud computing systems and with other distributed systems. Cloud computing provides a paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources, and the resulting distributed platform serves as a driving force toward the realization of the

metaverse infrastructure through self-service provisioning and on-demand management.

SC 38 standards relevant to the metaverse are as follows:

- ISO/IEC 22123-1:2023 Information technology – Cloud computing – Part 1: Vocabulary
- ISO/IEC 22123-2:2023 Information technology _ Cloud computing – Part 2: Concepts
- ISO/IEC 22123-3:2023 Information technology – Cloud computing – Part 3: Reference architecture
- ISO/IEC 19086:2016 Information technology – Cloud computing – Service level agreement (SLA) framework
- ISO/IEC 19941:2017 Information technology – Cloud computing – Interoperability and portability
- ISO/IEC 19944-1:2020 Could computing and distributed platforms – Data flow, data categories and data use – Part 1: Fundamentals
- ISO/IEC 19944-2:2022 Cloud computing and distributed platforms – Data flow, data categories and data use – Part 2: Guidance on application and extensibility
- ISO/IEC 23751:2022 Information technology – Cloud computing and distributed platforms – Data sharing agreement (DSA) framework
- ISO/IEC TS 5928:2023 Information technology – Cloud computing and distributed platforms – Taxonomy for digital platforms

Ongoing SC 38 projects related to the metaverse are as follows:

- ISO/IEC 5140:2024 Information technology – Cloud computing – Concepts for multi-cloud and the use of multiple cloud services
- ISO/IEC AWI 20151 Information technology – Cloud computing and distributed platforms – Database concepts and characteristics
- ISO/IEC AWI 11034 Information technology – Cloud computing – Trustworthiness in cloud computing
- ISO/IEC AWI 20996 Information technology – Cloud computing – Cloud service customer business continuity and resilience
- ISO/IEC AWI 19274 Information technology – Cloud computing and distributed platforms – Networking in cloud computing and edge computing

ISO/IEC TS AWI 10866 Information technology – Cloud computing and distributed platforms – Framework and concepts for organizational autonomy and digital sovereignty

5.12 JTC 1/SC 39 Sustainability, IT and data centres

JTC 1/SC 39 is developing standards on assessment methods, design practices, operation, and management aspects to support resource efficiency, resilience, and environmental sustainability for and by information technology, data centres and other facilities and infrastructure necessary for service provisioning. Because a great deal of information is collected from different resources, data centers, or facilities through networks in the metaverse, design, operation, and evaluation for metaverse platforms should be considered along with safety issues.

5.13 JTC 1/SC 40 IT service management and IT governance

JTC 1/SC 40 is developing standards on governance of IT, governance of data, IT service management, and IT enabled services such as business process outsourcing. Because the metaverse is an extension of the real world to virtual worlds, new cultural, economic, and social orders for life and work in virtual worlds. Information management and governance for virtual worlds should be considered similarly to the way they are the real world.

5.14 JTC 1/SC 41 Internet of things and digital twin

JTC 1/SC 41 is developing standards in the area of Internet of Things (IoT), digital twin, and related technologies. Many standards related to sensor networks, IoT vocabulary, interoperability, use cases, etc. have been developed. The metaverse will be organized with technologies about sensors and digital twin in virtual worlds, so SC 41 standards can be used to design and implement these for the metaverse.

5.15 JTC 1/SC 42 Artificial intelligence

JTC 1/SC 42 is developing standards in the area of artificial intelligence. AI should be used for big data processing that occurs in many metaverse applications because the metaverse consists of a vast amount of multimedia and real-world data from many sensors. The

more the metaverse grows, the greater the quantity and complexity of virtual world and real-world data, and so efficient data management using AI is required. SC 42 standards will fulfill this requirement.

5.16 JTC 1/WG 11 Smart cities

JTC 1/WG 11 is developing standards in the areas of ICT in Smart Cities that can be used for a virtual representation of any and all aspects of a city in the metaverse. This spans municipal government, and its assets, services and operations. It also includes the city's many stakeholders including residents, corporations, NGOs, etc. it can represent the past and be used to explore possible futures based on alternative policies and decisions.

Standardized city data models serve as a foundation for integration and interaction among diverse city components, enabling a precise digital replica of cities with semantic interoperability. Meanwhile, effective data governance and data use policies ensure data security, privacy, quality, and validation, facilitating responsible data exchange and management within virtual environments.

WG 11 standards and projects relevant to the metaverse are as follows:

- ISO/IEC 5087-1:2023 Information technology – City data model – Part 1: Foundation level concepts
- ISO/IEC 5087-2:2024 Information technology – City data model – Part 2: City level concepts
- ISO/IEC AWI TS 5087-3 Information technology – City data model – Part 3: Service level concepts – Transportation planning

Section 6

Relevant Standardization Activities of Other Groups

6.1 ISO/IEC JSEG 15

ISO/IEC JSEG 15 is tasked with exploring the need for standardization and for opportunities in the area of the metaverse and related technologies [11]. This includes developing a common understanding and definition of the metaverse, and investigating the need for standardization, taking into account current research, technology and standardization activities. In addition, JSEG 15 is working on an initial roadmap for metaverse standardization activities which it may propose to ISO and IEC. JSEG 15 provides a description of an ontology based metaverse system that defines components, factors, engineering areas, and consensus. For system components, there are governance systems, cooperative systems, economic systems, content systems, and technical system. Key factors include collaboration, identity, asset, and activities. Engineering areas include space, application, service, system, and network. Consensus is needed in governance and regulation, application and service, content and asset, data and protocol, and technology and platform.

6.2 IEC/TC 100

TC 100 is doing work related to the metaverse in the areas of terminals for VR/AR/MR in TA 1/WG 1, multimedia systems and equipment liaison with ITU-T/FG-MV in WG 12, and multimedia home systems and applications for end-user networks in TA 18 [12-13]. TA 1/WG 1 is developing standards on AR technology, test methods about durability for AR devices, and a reference model for consumer VR/AR/MR devices. WG 12 is developing standards on multimedia systems and equipment for the metaverse. WG 12 developed a TR of a conceptual model on multimedia cyber technology. In addition, there are several ongoing projects about the concept of the metaverse for multimedia equipment, and definitions and classifications of the metaverse.

TA 18 developed a TR of a conceptual model of standardization for haptic multimedia systems, and there are ongoing projects related to haptic conceptual models.

6.3 EC (European Commission)

The EC has proposed tools on developing open human-centric virtual worlds such as the metaverse [14]. These would provide a myriad of possibilities for industry and service sectors, the creative arts and citizens, as well as opportunities to address broader social challenges such as health and smart cities. The EU wants to shape the metaverses according to European values, principles, rules and strategic interests, from the outset which includes being trustworthy and secure and respecting EU norms and legislation.

The vision of the EC is one of a trustworthy, secure, and interoperable metaverse, based on widely accepted standards and ensuring that European data is used for the good of EU citizens and businesses. It is based on being centered on people and European values and rules, mastering the technologies that shape the metaverse, and providing a resilient connectivity infrastructure.

6.4 IEEE

IEEE has established the IEEE metaverse congress series and the IEEE metaverse community [15]. IEEE has standardization and pre-standardization activities relating to

the metaverse, including:

IEEE P2048 Standard for metaverse: terminology, definitions, and taxonomy; P7016 Standard for ethically aligned design and operation of metaverse systems; P7030 Recommended practice for ethical assessment of Extended Reality (XR) technologies; P3322 Guide for comfort requirements for Extended Reality (XR) devices, and IEEE *P3812.2 Standard for data access management for identity relationships*. Pre-standards activities include the IEEE global initiative on ethics of Extended Reality.

6.5 ITU-T Focus Group on Metaverse (FG-MV)

FG-MV provides a collaboration platform for dialogue, for identifying stakeholders with whom ITU-T could collaborate, and for enabling the inclusion of non-members to contribute to technical pre-standardization work. FG-MV work will be enriched with the identification of relevant use cases [16].

FG-MV will consider the following aspects for pre-standardization work on the metaverse: working definitions and terminology, concepts, vision, use cases and ecosystem, technical requirements, technical framework and characteristics, security and personally identifiable information (PII) protection related aspects, networking infrastructure and connectivity, interoperability, application interfaces, accessibility including for people with disabilities, gap analysis of standardization activities in other standardization bodies, economic aspects and regulatory implications, and environmental sustainability.

6.6 ISO/TC 307

Blockchain and distributed ledger technologies enhance the transparency, reliability, and security of digital assets and transactions within the metaverse. Metaverse platforms combine these technologies to foster economic activities and interactions within virtual spaces [17].

TC 307 is developing standards for block chain and distributed ledger technologies. These include reference architecture, taxonomy and ontology, auditing guidelines, overview of and interactions between smart contracts in blockchain and distributed ledger technology systems, interoperability framework, security management of digital asset custodians, guidelines for governance, physical assets using Non-Fungible Token (NFT), etc.

6.7 Joint Development Foundation's Alliance for OpenUSD

The Alliance for OpenUSD (AOUSD) is part of the Joint Development Foundation, which is a JTC 1 PAS submitter. AOUSD is an open, non-profit organization dedicated to promoting the interoperability of 3D content through OpenUSD (Open Universal Scene Description). OpenUSD is a high-performance extensible framework and ecosystem for describing, composing, simulating, and collaboratively navigating and constructing 3D scenes. Standardizing the 3D ecosystem will enable developers and content creators to describe, compose, and simulate large-scale 3D projects and build an ever-widening range of 3D-enabled products and services.

AOUSD is currently developing a Core USD Specification, that will specify core behavior and functionality necessary for interoperable 3D authoring and transmission, including composition, file format, and data model, based on the OpenUSD Repository and what is widely implemented across the industry. AOUSD also recently launched a Materials Working Group that will standardize the description of materials in OpenUSD, and a Geometry Working Group that will define and evolve the strategy for the description of 3D geometry in OpenUSD.

6.8 SEDRIS Organization

The SEDRIS Organization has developed SEDRIS standards on environmental data in collaboration with SC 24. The standards allow for representation and simulation of the real world precisely in the metaverse. Environmental data includes geospatial, terrain, and natural phenomena including smoke, rain, and haze.

SEDRIS offers a data representation model, augmented with its environmental data coding specification and spatial reference model. In addition, SEDRIS can be used to interchange environmental data described using the data representation model. The SEDRIS API, its format and all the associated tools and utilities play a primary role, while being semantically coupled to the data representation model. SEDRIS provides the enabling foundation for the metaverse to express, understand, share, and reuse environmental

data.

6.9 The Khronos Group

The Khronos Group is a JTC 1 PAS submitter and an open, member-driven consortium that provides a space for the creation of the interoperability standards that enable developers to harness the full power of 3D graphics, XR (VR/AR), parallel computing, machine learning, vision processing and the metaverse. The standards of the Khronos Group include 3D Commerce, ANARI, glTF, Kamaros, KTX, NNEF, OpenCL, OpenGL, OpenGL ES, OpenVG, OpenVX, OpenXR, SPIR, SYCL, Vulkan, WebGL and a number of Safety Critical derivatives, including Vulkan SC, SYCL SC, OpenGL SC and the OpenVX safety critical profile. These standards provide interactive 3D on desktop and mobile, widespread use of 3D on web, desktop, and mobile, virtual and augmented reality, parallel computing on HPC and desktop, vision inferencing and compute for embedded and mobile, computer vision and embedded cameras, and 3D compute and vision for safety critical applications.

6.10 The World Wide Web Consortium (W3C)

The World Wide Web Consortium (W3C) is a JTC 1 PAS submitter that develops standards and guidelines to help everyone build a Web based on the principles of accessibility, internationalization, privacy and security. W3C's Immersive Web Working Group brings high-performance Virtual Reality (VR) and Augmented Reality (AR) to the open Web via APIs to interact with XR devices and sensors in browsers. Specifically, it develops standardized APIs to provide access to input and output capabilities commonly associated with XR hardware such as tethered headsets and sensors, as well as mobile handheld devices and standalone headsets. It is currently developing a number of specifications, including the WebXR Device API, and WebXR modules for Gamepads, Augmented Reality, Hit Test, DOM Overlays, Light Estimation, Hand Input, Anchors, Layers, Raw Camera Access, and Real World Geometry. It is also developing a Depth/Occlusion API, Navigation, Model Element, XR Capture Module, Marker Detection, and Geo-alignment specifications. The W3C's Immersive Web Community Group seeds many of the Working Group's specifications and/or features, and other W3C Working Groups developed specifications related to or building on the Immersive Working Group. The GPU for the Web Working Group develops the WebGPU and WebGPU Shading Language Specifications that could apply to features provided by the WebXR Device API and modules.

6.11 Web3D Consortium

Extensible 3D (X3D) and Humanoid Animation (HAnim) standards were developed by the Web3D Consortium in collaboration with JTC 1/SC 24. These standards have continually been revised for about two decades now along with the advancement of 3D technologies. X3D provides a system for the storage, retrieval and playback of real time graphics content embedded in metaverse applications to support a wide array of domains and user scenarios. HAnim provides humanoid data structures depending on the level of articulation and human motion for avatars in the metaverse.

The Web3D Consortium standards strategy carefully improves and evolves standards while maintaining long-term archival stability. These standards have been continuously developed, tested, maintained, and updated by Web3D Consortium members. Following public comment and subsequent approval by the Web3D Consortium, all changes are submitted to the International Standards Organization (ISO) as part of a series of annual reviews by national bodies around the world.

Section 7

The Direction of Standards Development for the Metaverse

7.1 Overview

Standards and standardization for the metaverse that should be progressed in JTC 1 are summarized as follows:

- Provide standards for metaverse information definition and information processing related to virtual worlds and humans/avatars based on VR/AR/MR and 3D simulation and interaction.
- Provide standards for software design and development, and their guidelines for metaverse service applications.
- Provide standards for VR/AR/MR-based user interfaces for metaverse service applications.
- Provide VR/AR/MR-based ICT integration standards necessary for metaverse service development.
- Provide standards for AI applied big data processing for metaverse applications.
- Provide standards for safe and secure metaverse applications.
- Provide standards for cloud computing and edge computing for efficient management of big data of metaverse applications.
- Provide standards for communications network that transfer metaverse application data.
- Provide governance standards on safety and security for social and cultural order and ethics in the metaverse.

7.2 Metaverse governance in JTC 1

Standards and standardization for the metaverse that should be progressed in JTC 1 are summarized as follows:

When considering governance in the metaverse, there are two applicable concepts. One is governance related to technical aspects such as safety and security that must be considered when generating and using metaverse service systems. The other is social and cultural aspects around ethics, morality, and order. The consideration of social and cultural aspects would follow once governance related to technical aspects has been addressed and obtained. JTC 1 should focus on the first concept, which will then lead into the second concept of governance.

Based on these considerations, there is a requirement to develop JTC 1 standards to provide guidance for metaverse governance focusing on safety and security for systems, users, and data. For systems, governance should include safety and security related to platforms and virtual worlds in which humans will participate when using metaverse services. For users, safety and security related to human health, both mental and physical, impacted by issues like the use of many sensor devices and computer systems, abnormal content, or insufficient performance of systems should be addressed. For data, governance should be conducted so that it is secure, sharable and interoperable between systems and so that it can be used by humans without discrimination.

To pursue these goals, collaboration between various subcommittees is required because governance should encompass the complete range of JTC 1 technologies

Section 8

Concluding Remarks

As the metaverse evolves and services increase, JTC 1 technologies will more than likely be required for developing related standards. The scope of the metaverse will only get broader, as will its use of ICT, and therefore significantly more advanced ICT implementation and performance will be required. It is expected that many JTC 1/SCs will be and should be involved in developing standards relevant to the metaverse because the metaverse needs more enhanced computing and information processing related to network platforms, big data, artificial intelligence, safety and security, user interfaces, device interfaces, and system integration. This will need more collaboration between JTC 1/SCs as well as with other SDOs.

Annex A

Usage and Areas of ISO/IEC JTC 1 and ISO/TC 307 Standards for the Metaverse

A.1 JTC 1/SC 24 Standards

No	Standard or Project number	Title	Description	Usage for the Metaverse	Relevant Areas
1	ISO/IEC 19775-1	Extensible 3D (X3D) — Part 1: Architecture and base components	X3D is a 3-dimensional data model that defines an object in a virtual environment. The object can consist of graphics, image, and/or video data, and a virtual world is obtained by the collection of the objects. It provides interactive multimedia information and 3D virtual worlds using computer graphics and animation technologies.	ISO/IEC 19775-1 can be used to generate 3D virtual worlds that represent metaverse environments. Metaverse objects that should be represented in a virtual environment can be created using X3D.	Virtual environments, 3D information modeling, representation, and visualization
2	ISO/IEC 19775-2	Extensible 3D (X3D) — Part 2: Scene access interface (SAI)	X3D is a file format and related access services for describing interactive 3D objects and worlds. X3D is also a universal interchange format for integrated 3D graphics and multimedia. X3D may be used in a variety of application areas such as engineering and scientific visualization, multimedia presentations, entertainment and educational titles, web pages, and shared virtual worlds. This part of ISO/IEC 19775 defines a scene access interface that can be used to interact with X3D worlds both from within the worlds themselves or from external programs.	An API (Application Program Interface) is provided to implement applications when generating metaverse environments and objects.	Metaverse applications for which virtual environments and objects should be generated
3	ISO/IEC 19774-1	Humanoid animation — Part 1: Architecture	ISO/IEC 19774-1 specifies a data structure for a humanoid with its skeleton and skin data models. A basic humanoid data model is defined by segments and joints using four levels of articulation depending on the complexity of the humanoid structure. In addition, HAnim site and displacer nodes can define clothing and accessories for human bodies.	ISO/IEC 19774-1 can be used to generate 3D avatars to conduct businesses, engage in social activities, and/or communicate in a virtual world on behalf of a person. An avatar appears as a person in order to communicate or interact with other people or virtual objects in the virtual world.	Human and avatar representation, information modeling, and exchange
4	ISO/IEC 19774-2	Humanoid animation — Part 2: Motion data animation	ISO/IEC 19774-2 HAnim motion data animation can be used to generate and exchange humanoid animation using motion data. Based on 19774-1 humanoid structure, animation sequences of a humanoid avatar are generated using keyframe parameters,	ISO/IEC 19774-2 can be used to generate the motion of a 3D avatar when communicating between avatars or with people in the real	Human and avatar motion generation and information exchange

			algorithms, or motion capture data depending on the levels of articulation.	world and simulating people's activities in a 3D virtual world using motion parameters and/or motion capture data.	
5	ISO/IEC 12087-5	Basic Image Interchange Format BIIF	This part of ISO/IEC 12087 establishes the specification of the Basic Image Interchange Format (BIIF) part of the standard. BIIF is a standard developed to provide a foundation for interoperability in the interchange of imagery and imagery-related data among applications. This part of ISO/IEC 12087 provides a detailed description of the overall structure of the format, as well as specification of valid data type and format for all fields defined with BIIF	Image data can be used in metaverse applications. Using this standard, image can be exchanged between different platforms and applications.	Image generation and exchange for metaverse applications
6	ISO/IEC 18023-1	SEDRIS – Part 1: Functional specification	ISO/IEC 18023-1 defines the syntax, semantics, and structure for the representation and interchange of environmental data, along with the means to produce and access that data.	Synthetic environments for metaverse applications can be generated and exchanged using this standard. Semantic virtual environments can be obtained.	Semantic virtual environments
7	ISO/IEC 18023-2	SEDRIS – Part 2: Abstract transmittal format	ISO/IEC 18023-2 specifies the semantics and abstract syntax of SEDRIS transmittals.	The SEDRIS abstract transmittal format provides a platform independent interchange mechanism for the metaverse.	Transmission of semantic virtual environments
8	ISO/IEC 18023-3	SEDRIS – Part 3: Transmittal format binary encoding	ISO/IEC 18023-3 defines a binary encoding technique that allows encoding DRM objects specified in ISO/IEC 18023-1 according to the abstract syntax specified in ISO/IEC 18023-2.	The binary encoding named SEDRIS Transmittal Format (STF) can be used for transferring metaverse data.	Transmission of semantic virtual environments
9	ISO/IEC 18025	Environmental Data Coding Specification (EDCS)	This International Standard provides mechanisms to unambiguously specify objects used to model environmental concepts. To accomplish this, a collection of nine EDCS dictionaries of environmental concepts are specified: classifications, attributes, attribute value characteristics, attribute enumerants, units, unit scales, etc.	Standard environment data coding specification can be used to define metaverse environments with semantic information such as environmental attributes.	Generation and exchange of semantic virtual environments
10	ISO/IEC 18026	Spatial Reference Model (SRM)	ISO/IEC 18026 defines relevant aspects of spatial positioning and related information processing. It allows precise and unambiguous specification of geometric properties such as position (location), direction, distance, and time associated with spatial information.	Precise geometric properties for virtual environments can be defined.	Generation and exchange of geometrically and geographically correct environments
11	ISO/IEC 18024-4	SEDRIS language bindings – Part 4: C	SEDRIS is a system for representing and interchanging environmental data including terrain, oceanographic, atmospheric, and near space environmental data. SEDRIS includes an application program interface (API) that allows a variety of proprietary systems to consistently interchange and interoperate with the environmental data.	Environmental data for the metaverse can be defined using the SEDRIS API through the C programming language.	Environmental information creation using the C programming language

			Access to the information stored in a SEDRIS transmittal is through the API. This document defines a standard binding for the C programming language.		
12	ISO/IEC 18041-4	EDCS language bindings – Part 4: C	EDCS (Environmental Data Coding Specification) provides mechanisms to unambiguously specify objects used to model environmental concepts. To accomplish this, a collection of nine EDCS dictionaries of environmental concepts are specified: classifications, attributes, attribute value characteristics, attribute enumerants, units, unit scales, etc.	Environmental attributes for the metaverse can be defined using the EDCS interface through the C programming language.	Environment attributes information creation using the C programming language
13	ISO/IEC 18042-4	SRM language bindings – Part 4: C	The Spatial Reference Model (SRM) precisely and unambiguously specifies the context in which positions, directions, and distances are defined. It also provides the concepts needed to convert locations, directions and distances accurately among multiple spatial reference frames. Access to the data types and concepts defined by this specification is through an application program interface (API). This document defines a standard binding for the C programming language.	SRM can be used to precisely represent metaverse environment data precisely using positions, directions, and distances using C programming language.	Spatial information creation for virtual environments using C programming language
14	ISO/IEC 18038	Sensor representation in MAR (Mixed and Augmented Reality)	This International Standard defines a framework and information reference model for representing sensor- based 3D mixed reality worlds. It defines concepts, an information model, architecture, system functions, and how to integrate 3D virtual worlds and physical sensors in order to provide mixed reality applications with physical sensor interfaces. It defines an exchange format necessary for transferring and storing data between physical sensor-based mixed reality applications.	This standard supports metaverse applications using sensors by defining how to represent sensors and to define sensor information in relation to a virtual environment.	Environments and facilities management areas that include sensors
15	ISO/IEC 18039	MAR reference model	This International Standard defines the scope and key concepts of mixed and augmented reality (MAR), the relevant terms and their definitions, and a generalized system architecture that together serve as a reference model for MAR applications, components, systems, services, and specifications. This architectural reference model establishes the set of required sub-modules and their minimum functions, the associated information content, and the information models that shall be provided and/or supported by a compliant MAR system.	This standard can be used as a reference model when developing metaverse applications.	Metaverse platforms, systems, functions, and services
16	ISO/IEC 18040	Live actor and entity representation in MAR	This International Standard, Live Actor and Entity (LAE) Representation in Mixed and Augmented Reality, defines a reference model and base components for representing and controlling a single LAE or multiple LAEs in a MAR scene. It defines concepts, a reference model, system framework, functions, and how to integrate a 2D/3D virtual world and LAEs, and their interfaces, in order to provide MAR applications with interfaces of LAEs. It also defines an exchange format necessary for transferring	Video-represented human characters can be represented in metaverse environments in a seamless way.	Metaverse application areas using human videos and 3D virtual environments

			and storing LAE-related data between LAE-based MAR applications.		
17	ISO/IEC 3721	Information Model for Mixed and Augmented Reality (MAR) Contents	This standard describes an information model for representing mixed and augmented reality scene/contents description: extending the existing and conventional constructs for representing the virtual reality scene graph and structure; representing physical objects in the mixed and augmented reality scene targeted for augmentation; providing ways to spatially associate the aforementioned physical objects, etc.	A metaverse scene graph and required information can be defined.	Information creation for metaverse environments
18	ISO/IEC 18520	Benchmarking of vision-based spatial registration and tracking methods for mixed and augmented reality (MAR)	This standard identifies a reference framework for the benchmarking of vision-based spatial registration and tracking (vSRT) methods for mixed and augmented reality (MAR). It provides typical benchmarking processes, benchmark indicators, and trial set elements that are necessary to successfully identify, define, design, select, and apply benchmarking of vSRT methods for MAR.	The qualities of a metaverse environment using video can be evaluated.	Metaverse applications using MAR environments
19	ISO/IEC 21145	Style representation for mixed and augmented reality	This standard describes a set of information constructs for stylizing MAR content and its objects. ISO/IEC 3721 specifies a MAR scene with core objects and their attributes. This standard further refines ISO/IEC 3721 similarly to how CSS (Cascading Style Sheets) augments HTML-5 for web document stylization. Virtual objects that augment real world objects may be subject to further stylization. Stylization refers to the act of making certain information follow a particular form for various purposes.	Metaverse styles can be defined, augmented, and managed separately in relation to metaverse objects.	Automation and user interaction for metaverse environment generation
20	ISO/IEC 23488	Object/environmental representation for image-based rendering in virtual/mixed and augmented reality (VR/MAR)	The purpose of this standard is to provide image-based representation concepts and to specify required elements. This document specifies an image-based representation model that represents target objects/ environments using a set of images, and an optionally underlying 3D model for accurate and efficient objects/environments representation at an arbitrary viewpoint. It is applicable to a wide range of graphic, virtual reality and mixed reality applications that require a method of representing a scene with various objects and environments.	Materials for 3D metaverse environments and objects can be represented by using a set of images.	Image-based 3D modeling for metaverse environments and objects
21	ISO/IEC TS 23884	Material property and parameter representation for model-based haptic simulation of objects in virtual, mixed and augmented reality (VR/MAR)	The objective of this specification is to propose an extension to the existing standard virtual and mixed reality scene/contents description and information models: (1) physical and material parameters of virtual/real objects are expressed to support comprehensive haptic rendering methods, such as stiffness, friction, and micro-textures, and (2) a flexible specification of a rendering algorithm. The specification also provides definitions for terms as related to various material properties, physical simulation, and haptic rendering and algorithm.	Haptic information for metaverse environments and objects can be defined and represented.	Metaverse applications where haptic devices are used or where physical material properties are necessary to be represented
22	ISO/IEC TS 5147	Guidelines for Representation and	Representation and visualization of smart cities will enable prototyping, demonstration, and analysis of smart city concepts for further	Representation and visualization technologies can be	Smart city visualization for metaverse applications

		Visualization of Smart Cities	development. Both physical/geometric and semantic data will need to be represented and visualized. Representation and visualization of smart cities is a prime application for an integrated approach to leverage standardization since no single standard will address all requirements. This document provides guidelines as to what needs to be represented for smart cities and how this can be achieved.	used for smart city metaverse applications	

A.2 JTC 1/SC 27 Standards

No	Standard or Project number	Title	Description	Usage for the Metaverse	Relevant Areas
1	ISO/IEC 27001	Information security, cybersecurity, and privacy protection-Information security management systems-Requirements	This document is the world's best-known standard for information security management systems (ISMS). It defines requirements an ISMS must meet. The ISO/IEC 27001 standard provides companies of any size and from all sectors with guidance for establishing, implementing, maintaining and continually improving an information security management system. Conformity with ISO/IEC 27001 means that an organization or business has put in place a system to manage risks related to the security of data owned or handled by the company, and that this system respects all the best practices and principles enshrined in this International Standard.	With cyber-crime on the rise and new threats constantly emerging, it can seem difficult or even impossible to manage cyber-risks in the Metaverse. ISO/IEC 27001 may help in the development of information security management in the Metaverse.	Information security management in the Metaverse
2	ISO/IEC 15408 series	Information security, cybersecurity and privacy protection-Evaluation criteria for IT security	These documents include the general concepts and principles of IT security evaluation and the general model of evaluation provided by various parts of the standard; a catalogue of functional components that meets the common security functionality requirements of many IT products; the individual assurance components and other packages, and the criteria for evaluation of Protection Profiles (PPs), PP-Configurations, PP-Modules, and Security Targets (STs); a standardized framework for specifying objective, repeatable and reproducible evaluation methods and evaluation activities; packages of security assurance and security functional requirements.	ISO/IEC 15408 series may help define security requirements for IT products using in the Metaverse and for those IT products be evaluated.	Security requirements and evaluation for IT products in the Metaverse
3	ISO/IEC WD 27091	Cybersecurity and Privacy — Artificial Intelligence — Privacy protection	This document provides guidance for organizations to address privacy risks in artificial intelligence (AI) systems and machine learning (ML) models.	The guidance in this document helps organizations identify privacy risks throughout the AI system lifecycle and establishes mechanisms to evaluate the consequences of these risks and to remediate them. This document is applicable to all types and sizes of organizations, including public and	Privacy in AI systems

				private companies, government entities, and not-for-profit organizations that develop or use AI systems.	

A.3 JTC 1/SC 29 Standards

No	Standard or Project number	Title	Description	Usage for the Metaverse	Relevant Areas
1	ISO/IEC 14496-16:2011	Coding of audio-visual objects - Part 16: Animation Framework eXtension (AFX)	This document specifies MPEG-4 Animation Framework eXtension (AFX) model for representing and encoding 3D graphics assets to be used standalone or integrated in interactive multimedia presentations (the latter when combined with other parts of MPEG-4). Within this model, MPEG-4 is extended with higher-level synthetic objects for geometry, texture, and animation as well as dedicated compressed representations.	Can be used to encode 3D virtual world for the efficiency of streaming and storage.	Coded representation of virtual environments/assets
2	ISO/IEC 14496-25	Coding of audio-visual objects - Part 25: 3D Graphics Compression Model	This document describes a model for connecting 3D graphics compression tools defined in ISO/IEC 14496 to graphics primitives defined in any other standard, specification, or recommendation. The goal of this document is to specify an architectural model able to accommodate third-party XML based descriptions of scene graph and graphics primitives with (potential) binarization tools and with MPEG-4 3D graphics compression tools specified in ISO/IEC 14496-2, ISO/IEC 14496-11 and ISO/IEC 14496-16.		
3	ISO/IEC 23008-3	High efficiency coding and Media Delivery in Heterogeneous Environments - Part 3: 3D Audio	This document specifies technology that supports the efficient transmission of immersive audio signals and flexible rendering for the playback of immersive audio in a wide variety of listening scenarios. These include home theatre setups with 3D loudspeaker configurations, 22.2 loudspeaker systems, automotive entertainment systems and playback over headphones connected to a tablet or smartphone.	Can be used to encode 3D audio for metaverse environment by supporting efficient transmission and flexible rendering.	
4	ISO/IEC 23090-2	Coded representation of immersive media - Part 2: Omnidirectional media format (OMAF)	This document specifies the omnidirectional media format for coding, storage, delivery and rendering of omnidirectional media, including video, images, audio and timed text. Omnidirectional image or video can contain graphics elements generated by computer graphics but encoded as image or video. Multiple viewpoints, each corresponding to an omnidirectional camera, are supported. The document also specifies storage and delivery of overlay images or video intended to be rendered over the omnidirectional background image or video.	Can be used to provide coding, storage, delivery, and rendering for an omnidirectional metaverse environment including video, image, audio and timed text.	
5	ISO/IEC 23090-5	Coded representation of immersive media - Part 5: Visual volumetric video-based coding (V3C) and video-based point cloud compression (V-	This document specifies the syntax, semantics and decoding for visual volumetric media using video-based coding methods. This document also specifies processes that can be needed for reconstruction of visual volumetric media, which can also include additional processes such as post-decoding, pre-reconstruction, post-reconstruction, and adaptation.	Provides coding of visual volumetric media for a metaverse based on video coding technology.	

		PCC)			
6	ISO/IEC 23090-6	Coded representation of immersive media - Part 6: Immersive media metrics	This document specifies immersive media metrics and the measurement framework. The immersive media metrics can be collected by service providers and used to enhance the immersive media quality and experiences. This document also includes a client reference model with observation and measurement points for collection of the metrics.	Provides a framework for measuring quality and experiences for a metaverse service.	
7	ISO/IEC 23090-7	Coded representation of immersive media - Part 7: Immersive media metadata	This document specifies common immersive media metadata focusing on immersive videos (including 360° videos) and images.	Can be used to provide metadata for 360 video-based metaverse.	
8	ISO/IEC 23090-8	Coded representation of immersive media - Part 8: Network based media processing	The network-based media processing (NBMP) framework defines the interfaces including both data formats and application programming interfaces (APIs) among the entities connected through digital networks for media processing. Users can access and configure their operations remotely for efficient, intelligent processing. This document describes and manages workflows to be applied to the media data. This process includes uploading of media data to the network, instantiation of the media processing tasks, and configuration of the tasks. The framework enables dynamic creation of media processing pipelines, as well as access to processed media data and metadata in real-time or in a deferred way. The media and metadata formats used between the media source, workflow manager and media processing entities in a media processing pipeline are also specified.	Provides a processing framework for media processing of a metaverse using entities connected through digital networks.	
9	ISO/IEC 23090-9	Coded representation of immersive media - Part 9: Geometry-based point cloud compression	This document specifies geometry-based point cloud compression.	Provides compression of metaverse environment and 3D assets for efficient delivery and storage.	
10	ISO/IEC 23090-10	Coded representation of immersive media - Part 10: Carriage of visual volumetric video-based coding data	This document specifies carriage of coded media representations which comply with visual volumetric video-based coding and video-based point cloud compression (specified in ISO/IEC 23090-5).		Transmission and storage of coded virtual environments/assets.
11	ISO/IEC 23090-12	Coded representation of immersive media - Part 12: MPEG immersive video	This document specifies the syntax, semantics, and decoding processes for MPEG immersive video (MIV), as an extension of ISO/IEC 23090-5. It provides support for playback of a three-dimensional (3D) scene within a limited range of viewing positions and orientations, with 6 Degrees of Freedom (6DoF).		Coded represen-tation of virtual environments/assets
12	ISO/IEC 23090-14	Coded representation of immersive media -	This document specifies extensions to existing scene description formats in order to support MPEG media, in particular immersive media. MPEG media includes but is not limited to media encoded with MPEG codecs, media stored in MPEG containers, MPEG	Can be used to a construct metaverse environment based on a scene description.	

		Part 14: Scene description	media and application formats as well as media provided through MPEG delivery mechanisms.		
13	ISO/IEC 23090-18	Coded representation of immersive media - Part 18: Carriage of geometry-based point cloud compression data	This document specifies a media format that enables the storage and delivery of geometry-based point cloud compression data. The geometry-based point cloud compression data can be timed or non-timed. It supports flexible extraction of geometry-based point cloud compression data at delivery or decoding time.	Can be used to store and deliver metaverse information compressed using geometry-based point cloud compression.	
14	ISO/IEC AWI 23090-29	Coded representation of immersive media - Part 29: Video-based dynamic mesh coding (V-DMC)	This document specifies a media format for representing in a compressed form a sequence of dynamic meshes. The basic principle consists in organizing the volumetric 3D data into a base mesh accompanied by its corresponding refinement components. During the decimation phase, the mesh topology is simplified to this base mesh, which is then encoded using an established static mesh coding solution. In the subdivision phase, the base mesh undergoes subdivision via a predefined algorithm.	Provides compression of a metaverse environment and 3D assets for efficient delivery and storage.	
15	ISO/IEC AWI 23090-30	Coded representation of immersive media - Part 30: Low latency, low complexity LiDAR coding	This document specifies a media format for representing in a compressed form a sequence of dynamic point clouds aquired by LIDAR sensors.		
16	ISO/IEC 23090-31	Coded representation of immersive media - Part 31: Haptics coding	This document specifies technology that supports the efficient transmission and rendering of haptic signals for the playback of immersive experiences in a wide variety of scenarios. The document describes in detail a robust coded representation of haptic media covering the two most popular haptic perceptions leveraged by devices today: vibrotactile and kinesthetic. Support for other haptic modalities has also been integrated. The coded representation allows to encode both descriptive and quantized data in a human readable JSON format used for exchange purposes, and a compressed bitstream version, optimized for memory usage and distribution purposes.	Provides compression of haptics data for providing immersive experience in a metaverse.	Sensory effects in the metaverse/virtual world for immersive experience
17	ISO/IEC 23005-2	Media context and control - Part 2: Control information	The technologies of this document specified are description languages and vocabularies to characterize devices and users; control information to fine tune the sensed information and the actuator command for the control of virtual/real worlds, i.e., user's actuation preference information, user's sensor preference information, actuator capability description, and sensor capability description. This document specifies syntax and semantics of the tools required to provide interoperability in controlling devices (actuators and sensors) in real as well as virtual worlds.	Allows personalized and controlled experience of sensory effects so that players/users of a metaverse can experience the sensory experience for the immersive metaverse based on their preference and equipment	
18	ISO/IEC 23005-3	Media context and control - Part 3: Sensory information	The technologies specified in this document are description languages and vocabularies which describe sensorial effects. The adaptation engine is not within the scope of this	Allows standardized description of sensory effects so that players/users of a	

			document (or the ISO/IEC 23005 series). This document specifies syntax and semantics of the tools describing sensory information to enrich audio-visual contents.	metaverse can experience the sensory experience for the immersive metaverse.	
19	ISO/IEC 23005-4	Media context and control - Part 4: Virtual world object characteristics	The technologies of this document specified are description languages and vocabularies to describe virtual world objects. The adaptation engine is not within the scope of this document. This document specifies syntax and semantics of the tools used to characterize a virtual world object related metadata.	Provides a standardized way of describing virtual world objects such as 3D virtual assets or avatars in the metaverse, so that the objects or avatars can be interoperable in a heterogeneous metaverse.	Avatar and virtual object description for exchange among metaverses/virtual worlds
20	ISO/IEC 23005-5	Media context and control - Part 5: Data formats for interaction devices	This document specifies syntax and semantics of the data formats for interaction devices by providing a standardized format for interfacing actuators and sensors by defining XML schema-based language named Interaction Information Description Language (IIDL).	Allows standardized interface to sensors and devices so that the physical world and the metaverse can be synchronized in the sense of providing sensory effects as well as environments such as weather or lighting.	Sensory effects in the metaverse/virtual world for immersive experience
21	ISO/IEC 23005-6	Media context and control - Part 6: Common types and tools	This document provides definitions of data types and tools, which are used in other parts of the ISO/IEC 23005 series but are not specific to a single part. This document specifies syntax and semantics of the data types and tools common to the tools defined in the other parts of the ISO/IEC 23005 series, such as basic data types which are used as basic building blocks in more than one of the tools in the ISO/IEC 23005 series, colour-related basic types which are used in light and colour-related tools to help in specifying colour-related characteristics of the devices or commands, and time stamp types which can be used in device commands, and sensed information to specify timing related information.	Provides basic data types and tools which can be used to construct descriptions generated based on ISO/IEC 23005-2, 3, 4 and 5.	

A.4 JTC 1/SC 38 Standards

No	Standard or Project number	Title	Description	Usage for the Metaverse	Relevant Areas
1	ISO/IEC 22123-1	Cloud computing — Part 1: Vocabulary	This document defines terms used in the field of cloud computing including distributed platforms.	Cloud computing provides a paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources, and the resulting distributed platform serves as a driving force toward the realization of the Metaverse infrastructure through self-service provisioning and on-demand management.	Infra-structure

2	ISO/IEC 22123-2	Cloud computing — Part 2: Concepts	This document specifies concepts used in the field of cloud computing that provides a foundation for other documents that are associated with cloud computing and detailed descriptions on the application of these concepts in cloud computing.		Infra-structure
3	ISO/IEC 22123-3	Cloud computing — Part 3: Reference architecture	This document specifies the cloud computing reference architecture (CCRA)		Infra-structure
4	ISO/IEC 5140	Concepts for multi-cloud and the use of multiple cloud services	This document specifies foundational concepts for multiple cloud services including multi-cloud, hybrid cloud, inter-cloud and federated cloud.		Infra-structure
5	ISO/IEC 19086	Cloud service level agreement (SLA) framework	This document seeks to establish a set of common cloud SLA building blocks (concepts, terms, definitions, contexts) that can be used to create cloud Service Level Agreements (SLAs).		Service level agreement
6	ISO/IEC AWI 20151	Dataspace concepts and characteristics	This document provides the foundational concepts and essential characteristics of dataspaces. This document is applicable to all organizations.		Dataspace
7	ISO/IEC PWI (NP) 11034	Trustworthiness in cloud computing	This document provides an overview, frameworks, and concepts for Trustworthiness in cloud computing.		Trust-worthiness
8	ISO/IEC 19941	Interoperability and portability	This document specifies cloud computing interoperability and portability types, the relationship and interactions between these two cross-cutting aspects of cloud computing and common terminology and concepts used to discuss interoperability and portability, particularly relating to cloud services.		Inter-operability and portability
9	ISO/IEC PWI (NP) 20996	Cloud service customer business continuity and resilience	This document provides guidance to cloud service customers on business continuity and resilience when using cloud services.		Business continuity and resilience
10	ISO/IEC 19944-1	Data flow, data categories and data use — Part 1: Fundamentals	This document describes the various types of data flowing within the devices and cloud computing ecosystem, describes the impact of connected devices on the data that flow within the cloud computing ecosystem, describes flows of data between cloud services, cloud service customers and cloud service users, provides foundational concepts, including a data taxonomy, and identifies the categories of data that flow across the cloud service customer devices and cloud services. This document is applicable primarily to cloud service providers, cloud service customers and cloud service users, but also to any person or organisation involved in legal, policy, technical or other implications of data flows between devices and cloud services.		Data flow, data categories and data use
11	ISO/IEC 19944-2	Data flow, data categories and data use — Part 1: Part 2: Guidance on application and extensibility	This document provides guidance on the application of the taxonomy and use statements from ISO/IEC 19944-1 in real world scenarios, and how to develop extensions to the data taxonomy, data processing and use categories and data use statements.		Data flow, data categories and data use
12	ISO/IEC 23751	Data sharing agreement (DSA) framework	This document establishes a set of building blocks, i.e. concepts, terms, and definitions, including Data Level Objectives (DLOs) and Data Qualitative Objectives (DQOs), that can be used to create Data Sharing Agreements (DSAs). This document is		Data sharing agreement

			applicable to DSAs where the data is intended to be processed using one or more cloud services or other distributed platforms.		
13	ISO/IEC AWI 19274	Networking in cloud computing and edge computing	This document describes the foundational concepts for edge computing and its relationship to cloud computing including the terminology, models and functional elements for networking in edge computing and cloud computing systems. This document also applies to distributed platforms, multiple cloud models (including multi-cloud, hybrid cloud, inter-cloud and federated cloud) and related intelligent nodes.		Infra-structure
14	ISO/IEC TS 5928	Taxonomy for digital platforms	This document specifies a taxonomy related to digital platforms, by providing definitions and supporting information that disambiguates different uses of the term platform as it applies to digital services (such as cloud computing and other distributed computing systems).		Infra-structure
15	ISO/IEC AWI TS 10866	Framework and concepts for organizational autonomy and digital sovereignty	This document provides concepts related to the intersection of digital sovereignty, organizational autonomy, and digital platforms. It provides a framework enabling organizations to: — understand the relevant digital sovereignty and autonomy matters; — identify the relevant attributes for the organization's potential digital platform and the choices necessary to address the issues; — balance the range of available options to achieve the desired organizational autonomy. This document is applicable to all organizations and policy makers involved in organizational autonomy and digital sovereignty in cloud services and distributed platforms.		Organizational autonomy and digital sovereignty

A.5 JTC 1/WG 11 Standards

No	Standard or Project number	Title	Description	Usage for the Metaverse	Relevant Areas
1	ISO/IEC 5087-1:2023	Information technology — City data model — Part 1: Foundation level concepts	This document is part of the ISO/IEC 5087 series, which specifies a common data model for cities. This document specifies the foundation level concepts.	standardized city data models serve as a foundation for integration and interaction among diverse city components, enabling a precise digital replica of cities with semantic interoperability.	City data model
2	ISO/IEC PRF 5087-2	Information technology — City data model — Part 2: City level concepts	This document defines an ontology for city-level concepts defined using terms specified in ISO/IEC 5087-1. City- level concepts are used to represent data that is shared across multiple services and stakeholders in the city. City- level concepts are distinguished by their data being read and updated by multiple city services and stakeholders.		
3	ISO/AWI TS 5087-3	Information technology — City data model — Part 3: Service level concepts - Transportation planning	This is part 3 of the multi-part standard that specifies a common data model for cities. Part 3 is a standard for a service level data model focusing on transportation planning		
4	ISO/IEC AWI TR	Information	This document provides use cases and common		

	10267-2	technology — Data use in smart cities — Part 2: Use case analysis and common considerations	considerations for use cases analysis for data use in smart cities.		

A.6 ISO/TC 307 Standards

No	Standard or Project number	Title	Description	Usage for the Metaverse	Relevant Areas
1	ISO 22739	Blockchain and distributed ledger technologies — Vocabulary	This document defines fundamental terminology for blockchain and distributed ledger technologies.	Blockchain and distributed ledger technologies enhance the transparency, reliability, and security of digital assets and transactions within the metaverse. Metaverse platforms combine these technologies to foster economic activities and interactions within virtual spaces.	Vocabulary
2	ISO 23257	Blockchain and distributed ledger technologies — Reference architecture	This document specifies a reference architecture for Distributed Ledger Technology (DLT) systems including blockchain systems. The reference architecture addresses concepts, cross-cutting aspects, architectural considerations, and architecture views, including functional components, roles, activities, and their relationships for blockchain and DLT.		Reference architecture
3	ISO/TS 23258	Blockchain and distributed ledger technologies — Taxonomy and Ontology	This document specifies a taxonomy and an ontology for blockchain and distributed ledger technologies (DLT). The taxonomy includes a taxonomy of concepts, a taxonomy of DLT systems and a taxonomy of application domains, purposes and economy activity sections for use cases. The ontology includes classes and attributes as well as relations between concepts.		Taxonomy
4	ISO/TS 23635	Blockchain and distributed ledger technologies — Guidelines for governance	This document provides guiding principles and a framework for the governance of DLT systems, also provides guidance on the fulfilment of governance, including risk and regulatory contexts, that supports the effective, efficient, and acceptable use of DLT systems.		Governance
5	ISO/AWI TS 18126	Smart contract taxonomy and classification	This document categorizes the various types of smart contracts and discusses the characteristics of each. It also identifies classification principles, criteria and taxonomies of smart contracts that help the users, industry, policy makers, other interested parties and stakeholders to further understand the smart contracts and their essential feature		Taxonomy
6	ISO/AWI 20435	Representing Physical Assets using Non-Fungible Token	This document establishes a DLT agnostic architecture for physical assets using NFTs.		Non-Fungible Token
7	ISO/AWI TS 23353	Blockchain and distributed ledger technologies — Auditing guidelines	This document offers guidance on auditing blockchain and distributed ledger technology (BC/DLT) systems, covering the principles of auditing, risks of BC/DLT systems, auditing framework, and managing and conducting BC/DLT audit programs.		Audit
8	ISO/WD TS 23516	Blockchain and Distributed Ledger Technology — Interoperability Framework	This document specifies a framework, recommendations and requirements for interoperability between DLT systems, between DLT and entities outside the DLT system, the relationship and interactions between these and cross-cutting aspects.		Interoperability

Bibliography

[1] JTC 1 Standards and Standardization for the Metaverse, Myeong Won Lee, https://jtc1info.org/jtc-1-standards-and-standardization-for-the-metaverse/, 2023-08-21

[2] Tony Holland, "Who's building the Metaverse?: How Standardization is essential in its creation", http://tinyurl.com/MetaverseArticle, December 2023

[3] JTC 1/SC 24 standards and projects for the metaverse, Myeong Won Lee, 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[4] ISO/IEC DIS 9234 Information technology – Information modelling for VR/AR/MR based learning, education and training systems (A.4 AIST, Japan, and A.5 Curtin U., Australia)

[5] Metaverse fundamentals: concepts, definitions, and terminology, Peter Ryan, 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[6] JTC 1/SC 24 standards and projects of SC 24/WG 9 on Metaverse and Interverse, Takeshi Kurata, 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[7] JTC 1/SC 29 Coding of audio, picture, multimedia and hypermedia information, Gary J Sullivan, 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[8] JTC 1/SC 29/WG 4 MPEG video coding standards and projects for the metaverse, Lu Yu, 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[9] JTC 1/SC 29/WG 7 MPEG 3D graphics and haptics coding, Marius Preda, 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[10] Metaverse, SC 36 Information Technology for Learning, Education, and Training (ITLET), Jon Mason and Erlend Øverby, 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[11] Thought of Metaverse standardization, Ming Li, 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[12] Introduction of IEC/TC 100, Masatake Sakuma, 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[13] Metaverse of the IEC/TC 100, Ockwoo Nam et. al., 2023 ISO/IEC workshop on standards for the metaverse, 2023-06-26

[14] European Commission Rolling Plan 2023

[15] Metaverse and its governance, The IEEE global initiative on ethics of Extended Reality (XR) report, IEEE SA, 2022

[16] Base document of FGMV-D9.1-gap_analysis Technical Report on a gap analysis on metaverse standardization, Stella Kipsaita, Ziqin Sang, and Jungha Hong, ITU-T FG-MV-O-078-R1, 2023

[17] ISO TC 307's Contribution to TTR on Metaverse, ISO/IEC JTC 1/AG 2 N 741, 2024

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