

BUSINESS PLAN

ISO/TC 261

Additive manufacturing

EXECUTIVE SUMMARY

The main field and the overall size of the markets addressed by the committee

Additive Manufacturing (AM) are an inherent part of the product development process. They are used to manufacture prototypes, tools and production parts. In comparison to conventional methods where parts are molded into specified forms or cut from a massive block AM bases on the principle that liquids, powders, stands and films are layered to build 3D-structures without the use of a mold.

The size of the market in 2012 was estimated at a value of 2,204 billion US \$ (revenues generated in the primary AM market) according to Wohlers Report 2013.

The benefits already realized and/or expected through the availability of the standards

Benefits through standardization:

- systematic development, modification and use of mold-free production processes (AM) resulting in innovative products;
- assistance to users within the assessment of different additive processes resulting in using the appropriate technology for the specified product demands;
- specification of quality parameters of different processes needed for standardized test procedures;
- specification of appropriate test procedures, thereby ensuring uniform interpretation and evaluation of quality parameters;
- standardization of process chains of AM technologies securing functionality and compatibility;
- standardization of data formats, data structures and metrics for AM models;
- standardization of vocabulary required to define the product and to find a common speech.

The main objectives and the priorities in the work of the committee

The main objectives of ISO/TC 261 are to standardize the processes of Additive Manufacturing, their process chains (Hard- and Software), test procedures, quality parameters, supply agreements, fundamentals and vocabularies. It is agreed by all member bodies that those objectives always have to follow the market needs and enable flexible reaction on changes.

1 INTRODUCTION

1.1 ISO technical committees and business planning

The extension of formal business planning to ISO Technical Committees (ISO/TCs) is an important measure which forms part of a major review of business. The aim is to align the ISO work programme with expressed business environment needs and trends and to allow ISO/TCs to prioritize among different projects, to identify the benefits expected from the availability of International Standards, and to ensure adequate resources for projects throughout their development.

1.2 International standardization and the role of ISO

The foremost aim of international standardization is to facilitate the exchange of goods and services through the elimination of technical barriers to trade.

Three bodies are responsible for the planning, development and adoption of International Standards: [ISO](#) (International Organization for Standardization) is responsible for all sectors excluding Electrotechnical, which is the responsibility of [IEC](#) (International Electrotechnical Committee), and most of the Telecommunications Technologies, which are largely the responsibility of [ITU](#) (International Telecommunication Union).

ISO is a legal association, the members of which are the National Standards Bodies (NSBs) of some 140 countries (organizations representing social and economic interests at the international level), supported by a Central Secretariat based in Geneva, Switzerland.

The principal deliverable of ISO is the [International Standard](#).

An International Standard embodies the essential principles of global openness and transparency, consensus and technical coherence. These are safeguarded through its development in an ISO Technical Committee (ISO/TC), representative of all interested parties, supported by a public comment phase (the ISO Technical Enquiry). ISO and its [Technical Committees](#) are also able to offer the ISO Technical Specification (ISO/TS), the ISO Public Available Specification (ISO/PAS) and the ISO Technical Report (ISO/TR) as solutions to market needs. These ISO products represent lower levels of consensus and have therefore not the same status as an International Standard.

ISO offers also the International Workshop Agreement (IWA) as a deliverable which aims to bridge the gap between the activities of consortia and the formal process of standardization represented by ISO and its national members. An important distinction is that the IWA is developed by ISO workshops and fora, comprising only participants with direct interest, and so it is not accorded the status of an International Standard.

2 BUSINESS ENVIRONMENT OF THE ISO/TC 261

2.1 Description of the Business Environment

2.1.1 Introduction

The following political, economic, technical, regulatory, legal and social dynamics describe the business environment of the industry sector, products, materials, disciplines or practices related to the scope of this ISO/TC, and they may significantly influence how the relevant standards development processes are conducted and the content of the resulting standards.

2.1.2 State of the art of Additive Manufacturing

Additive Manufacturing is now being viewed as a serious method of manufacturing. It is having a significant impact on the way companies manufacture products. Tens of thousands of parts have been manufactured and installed on several different types of aircraft (Source: Wohlers Associates, Inc.) the Boeing 787 e.g. already carries about 30 laser sintered components (Source: Scott Martin, Boeing, IAG member). GE Aviation has started to use metal AM to manufacture more than 30.000 fuel nozzles annually for its new LEAP engine (Source: Wohler Report 2015). More than 100.000 acetabular hip cups manufactured by AM have been manufactured, about half of them implanted into patients already (Source: Wohlers Report 2015, Inc.). Meanwhile, according to EOS, more than five million metal copings (used to produce crowns and bridges) are being produced on EOS AM equipment every year.

s companies qualify and certify Additive Manufacturing processes and materials, many more types of parts will be produced in the future. The development of industry standards is a prerequisite to adopt AM for the production.

Still, AM is considered to be expensive and lacking reliability, whereas part properties coming from several technologies fulfill expectations already now. Standards will help to support new users when deciding whether AM is suitable and where it has advantages over conventional manufacturing.

2.1.3 Marketing trends

AM will grow appreciably over the next ten years. The advantages are: developers can produce functional hollow structures in small batches, and the structures can be precisely modified to changing stress requirements. The components can be customized with specific porosities or surfaces, and ultra-lightweight components are also duable. Here, the aviation industry is one of the pioneers.

2.1.4 Relevant stakeholder

In the short history of Additive Manufacturing, certain stakeholders have recognized the advantages and always pushed the development of new technology, processes and materials. Also in the future, these stakeholders will lead and influence the growth of AM.

Users:

- supplier of medical devices and implants
- OEMs in Aerospace and Automotive
- OEMs in High-Tech equipment
- Universities and R&D organisations
- AM equipment and material supplier

Experts from those groups are essential to be included in the work of ISO/TC 261. Although the main committee already comprises representatives from the relevant groups, it will be a continuous effort to include more experts here and in the national mirror committees.

2.1.5 Environmental issues

Resources and energy efficiency combined with economical production are the central challenges in the future. Additive Manufacturing technologies are one of the key factors to tackle those challenges. Additive Manufacturing technologies will become in addition a key player in placing advanced industrial production on a cost- and resource-efficient footing.

The generation of parts layer-by-layer allows for a geometric design that is not possible using other methods. Moreover, it enables a design driven manufacturing. Branches like e.g. automotive and aerospace are forced to reduce fuel consumption in the coming years as resources are decreasing as well in many areas. Additive Manufacturing can support these industries to achieve their goals, e.g. by enabling lightweight structures that help to reduce fuel consumption yet making sure that the part properties remain the same or are even better.

In AM usually only those raw materials are consumed that represent the part. There is a minimal amount of waste compared to conventional technology such as milling or turning.

AM uses 3D CAD data representing the geometry to control the manufacturing process. Such data can easily be transferred electronically and do not require sending drawings around the world. It also allows for distributed manufacturing, i.e. no need for central production facilities but on-site manufacturing units which has a positive effect on transportation costs and carbon emission.

AM in the spare part business enables an on-demand and on-site production, avoiding transportation and the use of storage facilities, which both have an effect on efficiency and emission.

2.1.6 Relevant international, regional, national standards and voluntary initiatives

Several initiatives have been established already years ago, mainly on a national base. Among those are the German VDI working group, French and Spanish standardization activities and the ASTM F42 committee on Additive Manufacturing, to name only a few.

As of April 2014, several industry standards have been published by ASTM, focused on terminology, testing, Ti6Al4V alloy and AMF file format, and with many others in development.

Due to the PSDO agreement between ISO and ASTM the joint development of common standards has started with ASTM F 42. Also the national initiatives shall be considered in ISO/TC 261 and therefore avoid the development of multiple competing standards.

Experts of ISO/TC 261 are also the key players in initiatives of the European Commission on the standardization of AM (CEN/TC 438 "Additive Manufacturing" and SASAM, thereby trying to direct this work such to avoid the development of multiple competing standards as well.

Also in ISO, some other committees have started NWIPs in the field of Additive Manufacturing. ISO/TC 261 will decide in each case how to proceed (liaisons, collaboration, change of jurisdiction).

Additionally, several national and international organizations and federations are becoming aware of the rising importance of AM and are therefore starting standardization initiatives themselves, which creates challenges for the implementation of the work programme of this business plan (see also clause 6).

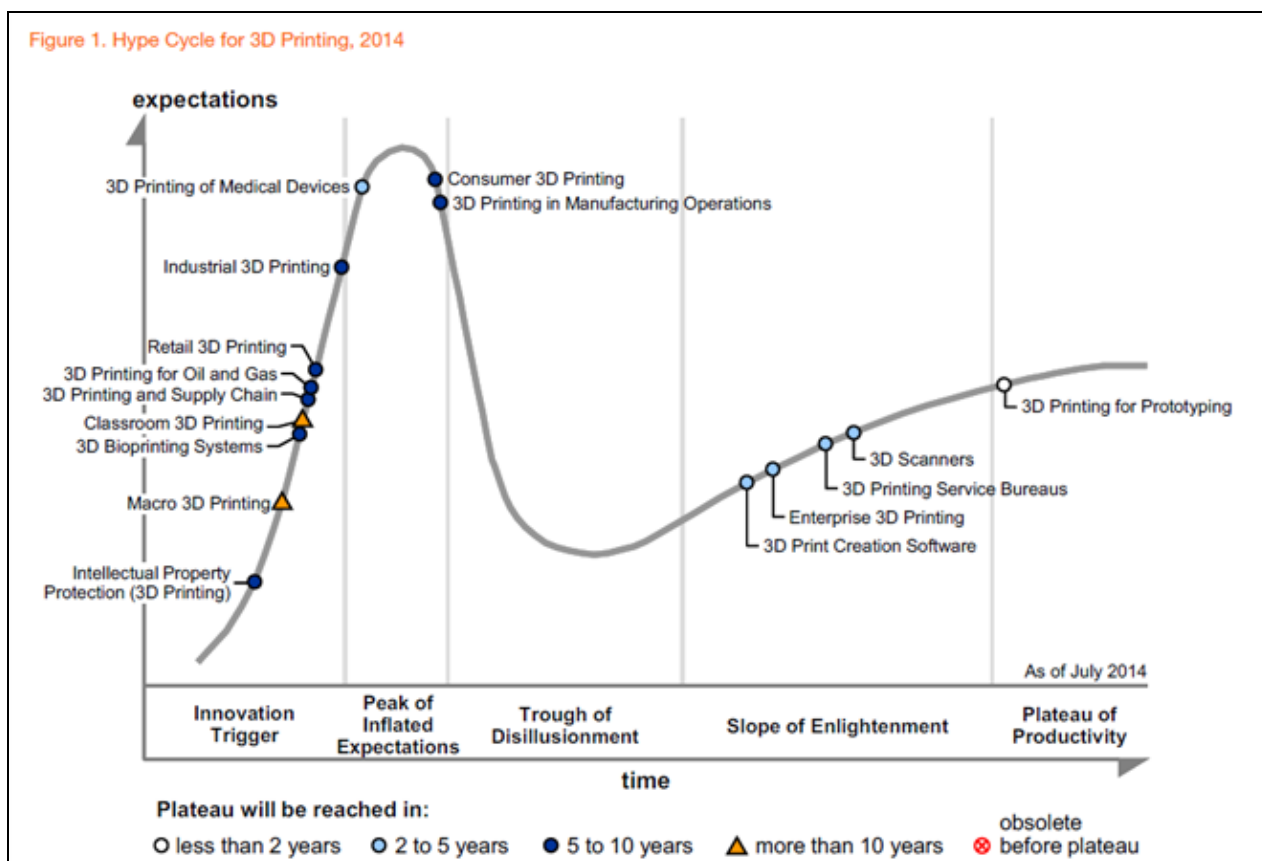
2.1.7 Technical barriers and other regulatory issues

Not known so far.

2.2 Quantitative Indicators of the Business Environment

3D Printing (3DP) is a synonym often used for Additive Manufacturing (AM) and summarizes various technologies and ways of using them. The following chart provides the expectations for these in the very popular Gartner Hype cycle.

As can be seen, the enterprise 3DP, which mainly comprises AM equipment at OEMs or 1st tier, is seen as close to being productive. The examples mentioned earlier proof that it is, in certain cases, possible already today.



Source: Gartner 2014

In 2014, the additive manufacturing industry, consisting of all AM products and services worldwide, grew 35,2 % (CAGR) to \$ 4,103 billion (Source: Wohlers Report 2015).

Forecasts, according to Wohlers, in 2016 are \$ 7,300 billion, increasing to \$ 12,700 in 2018 and \$ 21,200 in 2020. CAGR therefore is expected to more than quadruple within 6 years. The forecasts from Gartner contain similar numbers.

3 BENEFITS EXPECTED FROM THE WORK OF THE ISO/TC

Standardization is essential for the use of AM in critical applications like in energy saving applications in air craft engines or for medical applications healing injured people with medical implants manufactured by AM.

Standards will support the possibilities for certification and approval for medical applications (e.g. FDA) and aviation applications (e.g. AIA). Without standards such certifications and approvals are very complicated if not impossible. The business case for all stakeholders is evident as standardization will boost the application of this technology in critical sectors. The time consuming standardization process is limiting energy saving applications and improved quality of life for injured and disabled people.

Generally speaking, the aims of standardization are:

- a) to promote the quality of products, processes and services by defining those features and characteristics that govern their ability to satisfy given needs i.e. their fitness for purpose;
- b) to promote improvements in the quality of life, safety, health and protection of the environment;
- c) to promote the economic use of materials, energy, and human resources in the production and exchange of goods;

d) to promote clear and unambiguous communication between all interested parties, in a form suitable for reference or quotation in legally binding documents;

e) to promote international trade by the removal of barriers caused by differences in national practices;

f) to promote industrial efficiency through variety control.

(Source: SASAM)

Benefits through standardization:

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- assistance to users within the assessment of different additive processes resulting in using the appropriate technology for the specified product demands;
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4 REPRESENTATION AND PARTICIPATION IN THE ISO/TC

4.1 Countries/ISO member bodies that are P and O members of the ISO committee

4.2 Analysis of the participation

In the ISO/TC 261 committee there are currently 20 P-members and 5 O-members.

Among the P-members, 100 % come from developed countries and zero % from developing countries or countries with economies in transition. The reason for this imbalance is that the industry on Additive Manufacturing is located within the developed countries. The participants are mainly from Europe and the USA as well as Japan and Korea.

Internal liaisons have been initiated with ISO/TC 61, ISO/TC 61/SC 9, ISO/TC 106, ISO/TC 106/SC 9, ISO/TC 119, ISO/TC 184, ISO/TC 213 and IEC/TC 76. The intensity of these liaisons has nevertheless to be improved.

5 OBJECTIVES OF THE ISO/TC AND STRATEGIES FOR THEIR ACHIEVEMENT

5.1 Defined objectives of the ISO/TC

The main objectives of ISO/TC 261 are to standardize the processes of Additive Manufacturing, their process chains (Hard- and Software), test procedures, quality parameters, supply agreements, fundamentals and vocabularies.

5.2 Identified strategies to achieve the ISO/TC's defined objectives

The following key strategies have been identified to achieve the defined objectives in 5.1:

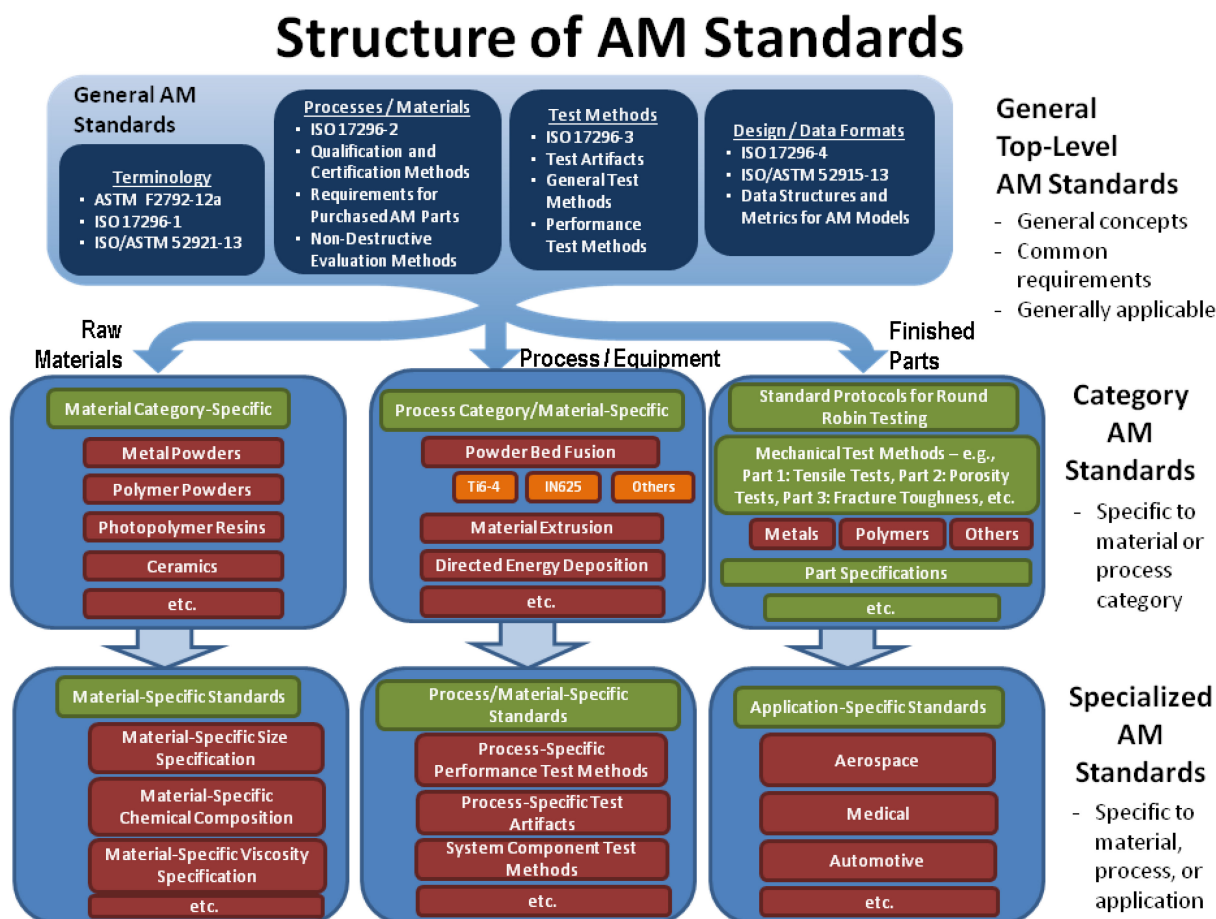
- Use of national, regional or other standards as source documents on which to base International Standards
- Frequent physical- and webmeetings, use of correspondence and ISO's balloting portal in order to shorten the time of developing International Standards

A main part of the strategy is the close cooperation with ASTM F 42 according to the PSDO agreement with joint development resulting in of one set of AM standards In order to develop the

common roadmap and organizational structure for AM standards, ISO/TC 261 and ASTM F42 agreed upon a common structure which defines multiple levels and a hierarchy of AM standards, with the following three levels:

- General standards: standards that specify general concepts, common requirements, or are generally applicable to most types of AM materials, processes, and applications
- Category standards: standards that specify requirements that are specific to a material category or process category
- Specialized standards: standards that specify requirements that are specific to a material, process, or application

The figure below illustrates the agreed-upon common structure of AM standards.



Several specific procedures are determined for how ISO/TC 261 and ASTM F42 will cooperate and work together in a practical sense, in accordance with the agreement between ISO and ASTM.

Joint Groups: A joint group (JG) of committed experts will be formed from both ISO/TC 261 and ASTM F42 for each joint standards development. The committed experts will be removed from the joint group if not contributing. For each joint standards development, there is an open option for both ISO/TC 261 and ASTM F42 to contribute. The target size of the joint group is 3-5 members from each organization, but this number is not mandatory. The expected maximum size of the joint group is 10 participants. The joint group will ensure the visibility of its work to the corresponding internal working group (WG) structure of ISO/TC 261 and the corresponding internal subcommittee (SC) structure of ASTM F42. The experts that form the joint groups will be identified and confirmed by the respective ISO and ASTM organizations. The convener of the joint group will be jointly agreed upon by ISO/TC 261 and ASTM F42. A key contact from the organization other than the convener will be nominated to improve communications among the joint group and between the organizations.

Meetings of Joint Groups: The guiding principle is that joint groups will have limited face-to-face meetings and will have increased and substantial use of web-based and/or tele-conference meetings and online collaboration tools to complete their work. The first (kick-off) meeting of a joint group is recommended to be held as a face-to-face meeting to introduce the participants. All joint groups have the opportunity to meet (optionally and as needed) during the annual fixed plenary meetings of ISO/TC 261 (once per year) and ASTM F42 (twice per year).

Online Collaboration Tools: The ISO Livelink and ASTM Collaboration Area online collaboration tools are available for use by the joint groups. Joint groups are strongly encouraged to use these online collaboration tools, at the discretion of the convener of the joint group. Access to the collaboration area for each joint group will be limited to the committed experts of the joint group and others as necessary from the internal working groups of ISO/TC 261 or subcommittees of ASTM F42.

Standards Development: The leadership of ISO/TC 261 and ASTM F42 will review the progress of each joint group periodically. During the development period, the joint group experts are encouraged to interact with their respective organizations to communicate the status of the development and to ensure that requirements are incorporated.

Standards Review and Balloting: Following the release of a document by a joint group, the draft standard will be distributed for review by both organizations. A three-month review period for feedback and comment is required, with all comments provided back to the joint group for resolution. The revised standard will then be balloted concurrently (in parallel) by ISO and ASTM. ISO/TC 261 will conduct a Draft International Standard (DIS) ballot with a three-month balloting cycle. ASTM F42 will conduct a final balloting with a 30-days balloting cycle. During this balloting period, true editorial changes are allowed and any comments resulting from the ASTM balloting can be submitted into the ISO balloting process. Key contacts from each organization, likely technical experts from the joint group, must be identified to address any issues resulting from the balloting.

Formatting of Documents: The formatting of the joint standards documents should be the same and should adhere to the requirements specified in the formal agreement already established between ISO/TC 261 and ASTM F42. Both ISO/TC 261 and ASTM F42 agree to distribute their existing language usage and style guidance. For example, the word “shall” means required and the word “should” means optional, based on existing agreements.

Standards Projects: Both ISO/TC 261 and ASTM F42 shall have the option to continue and to finish their current standards activities that are already in process as of the start of this joint Additive Manufacturing Standards Development Plan. As such, both organizations will share their lists of existing standards activities. All new ideas or new standards projects by either ISO/TC 261 or ASTM F42 shall be communicated to the other organization, with an invitation to participate through the joint development process. The invitation to participate shall include the title, abstract, and any other available information for the new standards project in a common new item proposal format. Any revision of a published standard shall be done by the joint development process.

Joint Steering Group: A Joint Steering Group will be established to monitor the progress of the joint groups, report on the status of the joint groups, resolve any problems, present proposals for joint activities to the respective plenary groups, and maintain a three-year plan for joint standards development. At a minimum, the Joint Steering Group will be composed of the ISO/TC 261 Chair, ISO Secretariat, and Working Group representatives, along with the ASTM F42 Chair, ASTM Secretariat, and Subcommittee Chairs. If a Joint Steering Group member cannot attend a meeting, a replacement may be nominated. The maximum target size of the Joint Steering Group is approximately 12 participants. The joint collaboration will begin with the four pilot standards developments indicated above, with other priorities as identified forming the initial three-year plan. The Joint Steering Group will conduct virtual meetings twice per year (in spring and autumn) to be

scheduled between the fixed ISO/TC 261 and ASTM F42 plenary meetings. The group may also take the opportunity to meet face-to-face at meetings of ISO/TC 261 or ASTM F42.

6 FACTORS AFFECTING COMPLETION AND IMPLEMENTATION OF THE ISO/TC WORK PROGRAMME

As already mentioned in clause 2.1.6, more and more national and international organizations and federations are becoming aware of the rising importance of AM and are trying to start standardization initiatives themselves. Such competing initiatives would endanger the benefits of the standardization efforts described above. In order to avoid these competing initiatives their representatives are being contacted as soon as they have made themselves aware in the hope to channel these initiatives into the combined work of ISO and ASTM).

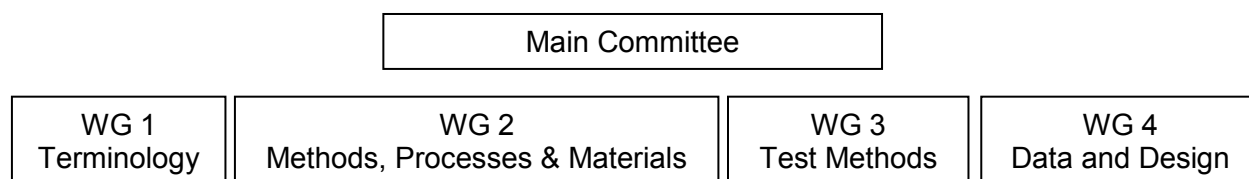
The more such initiatives insist on staying in existence, the greater are the demands on the resources to keep these initiatives in line and informed about the developments.

7 STRUCTURE, CURRENT PROJECTS AND PUBLICATIONS OF THE ISO/TC 261

This section gives an overview of the ISO/TC's structure, scopes of the ISO/TCs and any existing subcommittees and information on existing and planned standardization projects, publication of the ISO/TC and its subcommittees.

7.1 Structure of the ISO committee

The following figure shows the structure (working groups) as established.



As explained in 5.2, in the cooperation with ASTM F 42 Joint Groups will be used for the development of combined ISO/ASTM standards. The work of these Joint Groups is being monitored by a Joint Steering Group.

ISO/TC 261 has also installed a Coordination Group with the following tasks:

- a. Sufficient flow of information between ISO/TC 261 experts participating in the JG activities with ASTM F 42 on the work of the Joint Groups (JGs),
- b. Coordination of the work of the ISO/TC 261 experts in the JGs,
- c. Monitoring of progress, efficiency and effectiveness of the work of the JGs from ISO point of view,
- d. Developing proposals for further joint ISO/ASTM activities and possible JGs,
- e. Provisional nomination of ISO experts to JGs (final nomination to be performed by ISO/TC 261),
- f. ISO feedback to current questions/discussions in JGs,
- g. Continuous reporting of the JG activities – supported by allocation of each JG to a WG of ISO/TC 261, so that:
 - i. the main documents of the JGs (JG minutes, drafts etc.) will be distributed both in the respective WGs and in this Coordination Group,
 - ii. necessary technical discussion while developing a draft in the JG will take place in the respective ISO WG, not in this Coordination Group,

- iii. ISO experts in the JGs will be able to represent the opinion of the according ISO WGs,
- iv. the output of the JGs will be more familiar and acceptable to ISO/TC 261 when voting procedure starts according to PSDO agreement with ASTM.

7.2 Current projects of the ISO technical committee and its subcommittees

ISO/TC 261 and ASTM F42 identified a consensus list of high-priority candidates for potential joint AM standards development as follows:

- Qualification and certification methods
- Design guidelines
- Test methods for characteristics of raw materials
- Test methods for mechanical properties of finished AM parts
- Material recycling (re-use) guidelines
- Standard protocols for round robin testing
- Standard test artifacts
- Requirements for purchased AM parts
- Harmonization of existing ISO 17296-1 and ASTM 52912 terminology standards

Though all of these topics are high-priority, the following have been chosen by ISO/TC 261 and ASTM F42 to pursue as pilot AM standards for joint development:

1. Harmonization of existing ISO 17296-1 and ASTM 52912 terminology standards (convened by ISO)
2. Standard test artifacts (convened by ASTM)
3. Requirements for purchased AM parts (convened by ISO)
4. Design guidelines (convened by ASTM)

Due to the importance and continued development of terminology, it is expected that the first JG will be kept even after the publication of the documents, since an ongoing joint group on Terminology will be needed at all times.

Five more Joint Groups have been set up since, on

- Standard Specification for Extrusion Based Additive Manufacturing of Plastic Materials,
- Standard Practice for Metal Powder Bed Fusion to Meet Rigid Quality Requirements,
- Specific design guidelines on powder bed fusion
- Qualification, quality assurance and post processing of powder bed fusion metallic parts and
- NDT for AM parts

7.3 Publications of the ISO technical committee and its subcommittees

Article in several issues of ISO Focus

Reference information

[**Glossary of terms and abbreviations used in ISO/TC Business Plans**](#)

[**General information on the principles of ISO's technical work**](#)