# AM INTERACTION DAYS

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*Additive manufacturing standardization:*
*BACKGROUND AND ONGIONG ACTIVITIES*

AMable

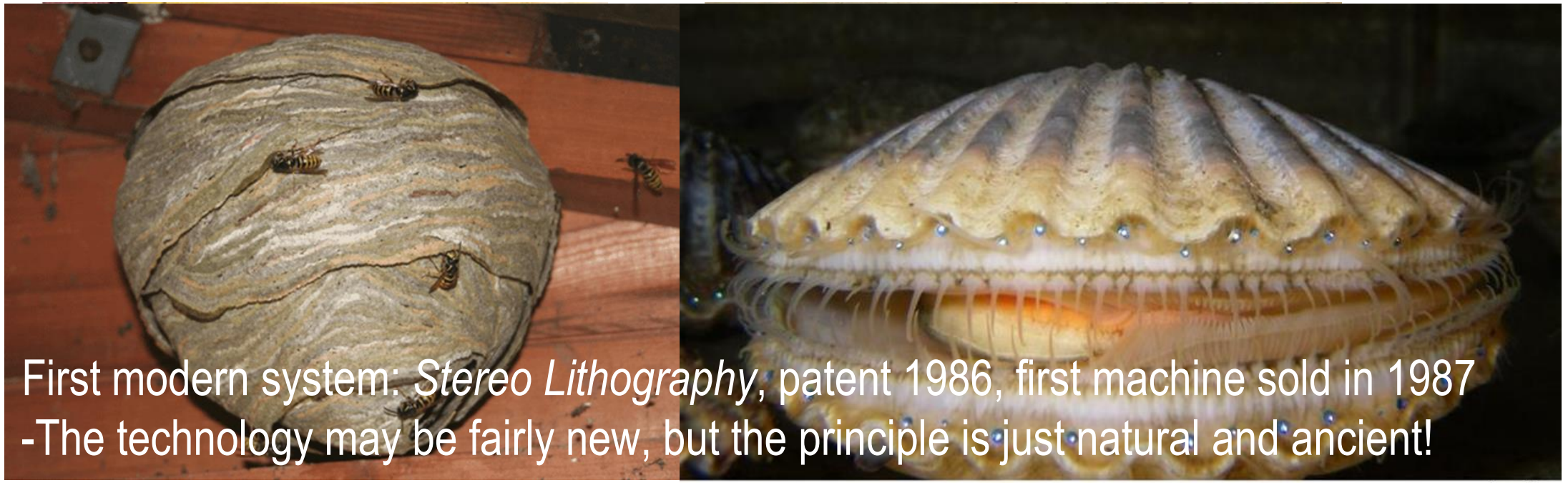
SAM
SECTOR SKILLS STRATEGY
IN ADDITIVE MANUFACTURING

EU Industry Week
#EUIndustryWeek
2021

# Introduction:
# Let's take a step back…

ARE YOU— AM —READY?

Additive Manufacturing; shaping objects by successive addition of material…
-New Technology?



First modern system: *Stereo Lithography*, patent 1986, first machine sold in 1987
-The technology may be fairly new, but the principle is just natural and ancient!

A scallop

# The origins of modern AM technology

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- 1970-s and 80-s: Developments in 3D CAD
- 1980-s; challenges, among others, in the US automotive industry identified the need for augmented prototyping processes
- Several "Rapid Prototyping" (RP) processes developed during the 1980-s and early 90-s, for example:
  - Stereolithography (SLA, Hull, 1986)
  - Selective sintering (SLS, Deckard, 1989)
  - "Apparatus and Method for Creating Three-Dimensional Objects" -Fused deposition modelling (FDM, Crump, 1992)
  - Techniques for Three Dimensional printing (3DP, Emanuel M. Sachs et al. 1993)
  - Laminated Object Manufacturing (LOM, Feygin, Sung 1996)
  - Fabrication of components by layered deposition (Vannon D. Pratt et al. 1991)
  - ….

# The origins of AM: early applications:

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- "Rapid Prototyping": several systems launched through the late 1980s and the early 1990s
- "Rapid Tooling" (1990's to early 2000's) ; producing tools based on "RP" technology ex. Keltool, Wibatool, early DMLS…
- "Rapid Manufacturing" (late 1990's to mid 2000's): producing end-use parts based on "RP"- technology, -found some applications but did not really take off on an industrial scale

# From "Rapid Prototyping“ to industrial manufacturing

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## Need for a different perspective:

- This is NOT a single process (-or technology for that matter…)
  - Multiple different "RP" processes (i.e. 'products') with unique trademarked names…
- Prototyping processes vs. Industrial manufacturing processes
  - A prototyping process includes everything from concept idea to the delivery of the physical prototype. Requirements are ad-hoc and settled by agreement between service provider and customer.
  - An industrial manufacturing process consists of a series of sub-processes, with defined interfaces and specified requirements. Consistency, predictability, traceability and quality control… Predetermined product requirements!
- Producers and customers: purchasing process, roles and responsibilities, communication… -Need for standardization!

# The role of standards:

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Informally:

***"A standard is a specification of best practice as agreed by consensus among experts"***

Standards are used for (among others):

- Specifying requirements
- Communicating guidance
  - "What do you mean by RP, RT, RM, FFF, LF, SFF, ALM, ALF, AF, DDF, DDM, 3DP, (-and others)?"
- Documenting best practices, qualification of processes and products
- Defining test methods and protocols
- Certifying bodies typically reference publicly available standards in their procedures
- Documenting technical data
- Accelerating the adoption of new technologies

# Standardization initiatives

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International market requires international standards:

**ASTM International, Committee F42**

- Established 2009, -coined & defined "Additive Manufacturing"
- **Scope:** "The promotion of knowledge, stimulation of research and implementation of technology through the development of standards for additive manufacturing technologies."
- Membership is based on representation of different stakeholders: companies, universities, research organisations etc.
  - 1 vote/organisation

# ASTM F42 at a glance

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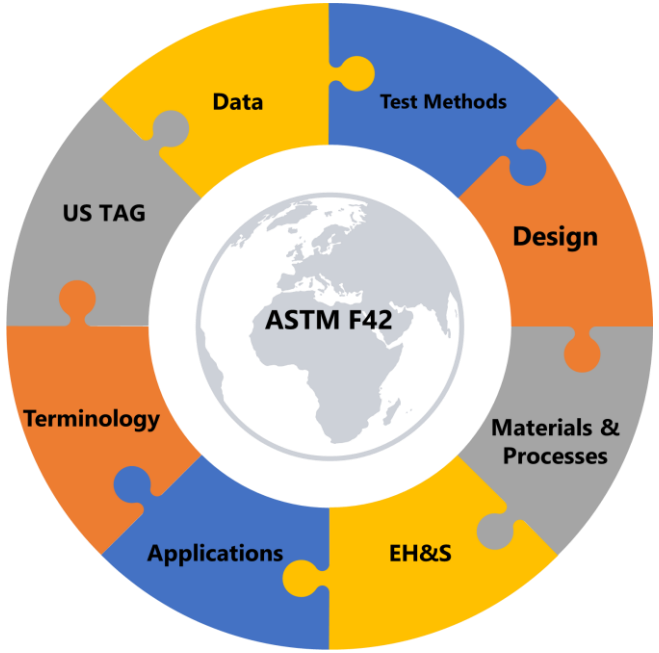
## Quick facts

Formed: 2009
Current Membership: 1000+ members (300+ outside US)
Standards: 30+ approved, 45+ in development

## Subcommittees




**Global Representation: 35+ Countries**

| | |
|---|---|
| Argentina | Netherlands |
| Australia | Nigeria |
| Austria | Norway |
| Belgium | Puerto Rico |
| Brazil | Russian |
| Canada | Federation |
| China | Saudi Arabia |
| Czech Republic | Singapore |
| France | South Africa |
| Germany | Spain |
| Greece | Sweden |
| India | Switzerland |
| Italy | Taiwan |
| Japan | Turkey |
| Korea | United |
| Malaysia | Kingdom |
| Mexico | United States |

# -Even more international…

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**ISO Technical Committee 261 (ISO/TC261)**

- Established 2011, after an initiative from DIN, based on VDI Guidelines on "Rapid Technologies"

**Scope: "**Standardization in the field of Additive Manufacturing (AM) concerning their processes, terms and definitions, process chains (Hard- and Software), test procedures, quality parameters, supply agreements and all kind of fundamentals."

- Membership is based on representation of different national standardization organization. Each member organization may nominate experts for different workgroups.
  - 1 vote/organization
- Presently:  25 participating countries +8 observers

# ISO/TC 261: International participation

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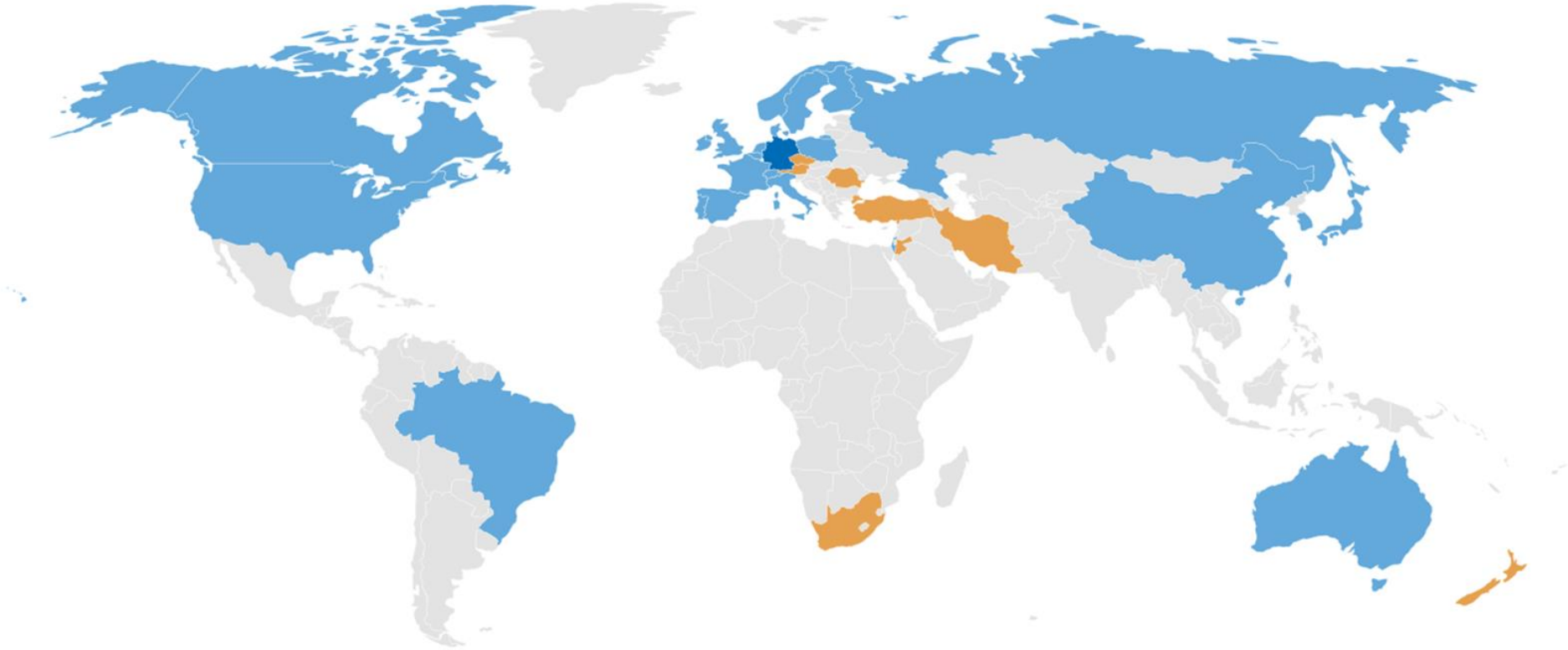

This map is designed to visually demonstrate the geographic distribution of our Members. The boundaries shown do not imply an official endorsement or acceptance by ISO.

# Collaboration:

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## Standards are needed, but we don't necessarily need several competing standards…

ISO & ASTM have signed a Partnership Standards Development Organization (PSDO) agreement

- Fast tracking the adoption process of an ASTM International standard as an ISO FDIS (Final Draft International Standard
- Formal adoption of a published ISO standard by ASTM International
- Maintenance of published standards
- Publication, copyright and commercial arrangements

James Thomas, ASTM President, and Rob Steele, ISO Secretary-General

## Guiding principles:

- One set of AM standards – to be used all over the world
- Common roadmap and organizational structure for AM standards
- Use and build upon existing standards, modified for AM when necessary
- Emphasis on joint standards development

# Standardization: Getting structured…

- What are we actually working on?
  - Name? The least common denominator…
  - Definition: what is the actual *AM-process*, and what is a the AM enabled *production chain*?
  - Single-step and multi-step processes
- Many different processes, with trademarked names: categorization..!
- Identification of process categories:
  - Identification of common denominators based on process architecture
  - Naming of process categories

# -The least common denominator

ARE YOU— AM —READY?

## Understanding AM - Definition by ISO/ASTM 52900:

**3.1.2**
**additive manufacturing**, noun
**AM**
process of joining materials to make *parts* (3.9.1) from 3D model data, usually *layer* (3.3.7) upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies

Note 1 to entry: Historical terms include: additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, solid freeform fabrication and freeform fabrication.

- *AM is enabled by the creation and communication of a 3D model data file*
  - *The 3D model is, in practice, a specification for the parts made by an AM process*
- *An AM process is characterized by how the material is added:*
  - *Mechanism for delivering the feedstock material*
  - *Mechanism for joining the feedstock – Subject to the laws of physics and chemistry!*

# The AM-process, beginning and end

By definition: "process of joining materials to make parts from 3D model data…"

- The beginning, defined by: "….from 3D model data…."
- The end, defined by: "….to make parts…"

The AM process starts by the 3D model file and ends when all the material needed to fulfil the specification of this model has been joined to a part

# What about the "part"?

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## Definition by ISO/ASTM 52900:

**3.9.1**

**part**, noun

joined material forming a functional element that can constitute all or a section of an intended product

Note 1 to entry: The functional requirements for a part are typically determined by the intended application.

- The part is formed by joining material such that the bonding of the intended product material has been formed:
  - Metallic material: metallic bonding
  - Ceramic material: ceramic bonding (ionic, covalent, etc…)
  - Polymer material: covalent bonds with entangled and/or cross-linked polymer chains…
- In essence: the AM process builds the part material to the shape of a product!

# Categorization!

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- In the beginning: Many different processes, with common traits, but different trademarked names
- Categorization based on common process architecture
- 7 Process categories identified (so far):
  - Binder jetting (BJT)
  - Directed energy deposition (DED)
  - Material extrusion (MEX)
  - Material jetting (MJT)
  - Powder bed fusion (PBF)
  - Sheet lamination (SHL)
  - Vat photopolymerization (VPP)

# HOW STANDARDS ARE DEVELOPED

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Very basic:

- All standards development is based on contribution from members
  - Members are stakeholders and base their contribution on an interest in developing the standards
  - No funding or compensation provided from the SDOs
  - SDO's have all the IPR
- Consensus based!
- ASTM: experts nominated directly by stakeholder (Company, University, Professional organization, etc.)
  - Type of membership depend on the nature of the stakeholder's interest
- ISO & CEN experts nominated national SDO committees, -which is based on stakeholder memberships

# HOW STANDARDS ARE DEVELOPED:
# New work item proposal

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**ASTM:**

**Submitted to Sub-committee**

- Request for participation
- Sufficient commitment from members – work to develop standards documents begins
- A minimum of 60% committee participation in ballots is required for continuation of project

**ISO:**

**Submitted to Secretariat**

- Proposal circulated and submitted for ballot
- Call for experts from National mirror committees
- Work group secretariat normally appointed to the same SDO as submitted the proposal
- Draft circulated and submitted to repeated ballot processes

*Joint ISO/ASTM: Each SDO may propose an item & invite the partner to join*

*A selected number of experts from each SDO participate in the JG*

# JOINT STANDARDS DEVELOPMENT AGREEMENT:


- Draft for review by both organizations
- Parallel ASTM and ISO ballots
  - ISO/TC 261: "Draft International Standard" (DIS) ballot; 3-month balloting cycle
    - Approval requires more than 66.67% Affirmative, and no more than 25% Negative
  - An FDIS ballot may be needed…
    - Yes/No vote: 66.67% Affirmative, and no more than 25% Negative required for approval
  - ASTM F42: Final balloting; 30-days balloting cycle
    - Approval requires more than 60% returned ballots, No Negatives, Affirmative/Abstain only
- Editorial changes are allowed, comments resulting from the ASTM balloting can be submitted into the ISO balloting process

# Additive Manufacturing Standards Structure

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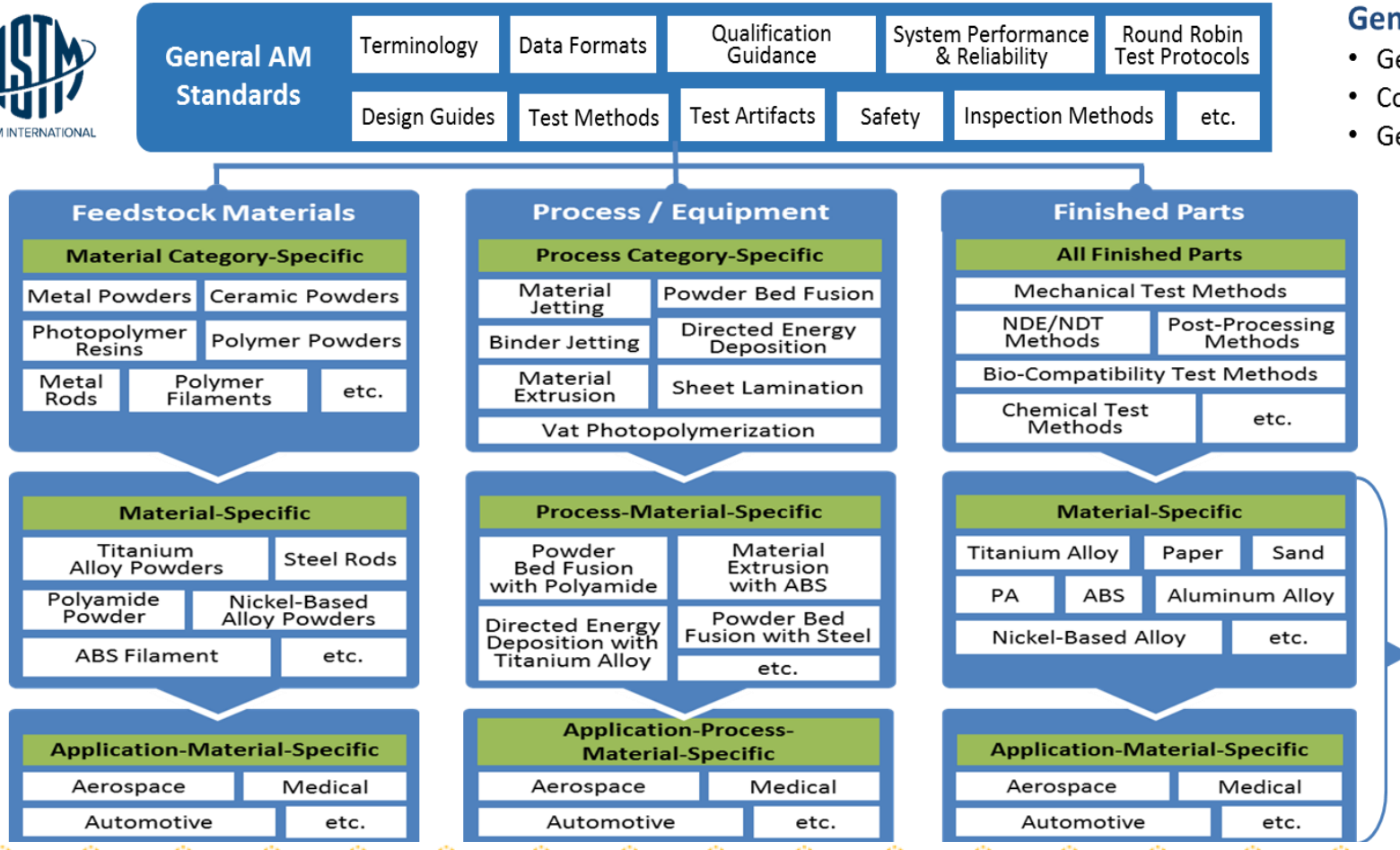
ISO

ASTM INTERNATIONAL




## General Top-Level AM Standards

- General concepts
- Common requirements
- Generally applicable

## Category AM Standards

Specific to material category or process category

## Specialized AM Standards

Specific to material, process, or application

# ASTM F42 and ISO/TC261:

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## Sub-Committees

- F42.01 Test Methods
- F42.04 Design
- F42.05 Materials and Processes
  - F42.05.01 Metals
  - F42.05.02 Polymers
  - F42.05.05 Ceramics
- F42.06 Environment, Health, and Safety
- F42.07 Applications*
- F42.08 Data
- F42.91 Terminology

## Workgroups

- ISO/TC 261/WG 01 "Terminology"
- ISO/TC 261/WG 02 "Processes, systems and materials"
- ISO/TC 261/WG 03 "Test methods and quality specifications"
- ISO/TC 261/WG 04 "Data and Design"
- ISO/TC 261/WG 06 "Environment, health and safety"
- JWG 10 "Joint ISO/TC 261 - ISO/TC 44/SC 14 WG; Additive manufacturing in aerospace applications
- JWG 11 "Joint ISO/TC 261 - ISO/TC 61/SC 9 WG; Additive manufacturing for plastics"
- ISO/TC 150/JWG 1: Joint ISO/TC 150 - ISO/TC 261 WG: Additive manufacturing in surgical implant applications

# New subcommittee:
# F42.07 Applications

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"Bridging the gap between AM standards and existing product specifications"

- F42.07.01: Aviation
- F42.07.02:Spaceflight
- F42.07.03: Medical/Biological
- F42.07.04: Transportation/Heavy machinery
- F42.07.05: Maritime
- F42.07.06: Electronics
- F42.07.07: Construction
- F42.07.08: Oil & Gas
- F42.07.09: Consumer

# ISO/TC261 – ASTM F42 Joint Groups

- Currently 27 active ISO/ASTM JGs
- Working on 28 different standards
- 15 joint ISO/ASTM standards on AM published
- 4 ISO/TC261 standards on AM published
- 16 ASTM F42 standards on AM published

For more information, please see:

- https://www.iso.org/committee/629086.html
- https://www.astm.org/COMMIT/SUBCOMMIT/F42.htm

# CEN/TC438
# European AM standards

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## Mandatory as national standards in all member countries!

- **EN ISO 17296-2:2016** Additive manufacturing - General principles - Part 2: Overview of process categories and feedstock
- **EN ISO 17296-3:2016** Additive manufacturing - General principles - Part 3: Main characteristics and corresponding test methods
- **EN ISO 17296-4:2016** Additive manufacturing - General principles - Part 4: Overview of data processing
- **EN ISO/ASTM 52900:2017** Additive manufacturing - General principles – Terminology
- **EN ISO/ASTM 52901:2018** Additive manufacturing - General principles - Requirements for purchased AM parts
- **EN ISO/ASTM 52902:2019** Additive manufacturing - Test artifacts - Geometric capability assessment of additive manufacturing systems
- **EN ISO/ASTM 52903-2:2020** Additive manufacturing - Material extrusion based additive manufacturing of plastic materials - Part 2: Process equipment
- **EN ISO/ASTM 52904:2020** Additive manufacturing - Process characteristics and performance - Practice for metal powder bed fusion process to meet critical applications

# EN ISO/ASTM 52901-17

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Additive manufacturing — General principles — Requirements for purchased AM parts

- Intended to enable efficient and unambiguous communication between part providers and customers of parts made by additive manufacturing to ensure that the resulting part meets the customer's requirements. Specification includes:
  - **Part ordering information**
  - **Definition of the part to be manufactured:** part geometry, tolerances, surface texture, build orientation of the part, feedstock for the part to be manufactured, repair methods, Acceptable imperfection(s) or non-conformance, process control information
  - **Part characteristics:** test methods & inspection criteria, post processing (specification requirements…), etc.
  - **Procedure for acceptance**: qualification parts, first production part, final or reference part
  - **Documentation of acceptance**

# CEN/TC438
# European AM standards, contd.

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- **EN ISO/ASTM 52907:2019** Additive manufacturing - Feedstock materials - Methods to characterize metal powders
- **EN ISO/ASTM 52910:2019** Additive manufacturing - Design - Requirements, guidelines and recommendations
- **EN ISO/ASTM 52911-1:2019** Additive manufacturing - Design - Part 1: Laser-based powder bed fusion of metals
- **EN ISO/ASTM 52911-2:2019** Additive manufacturing - Design - Part 2: Laser-based powder bed fusion of polymers
- **EN ISO/ASTM 52915:2020** Specification for additive manufacturing file format (AMF) Version 1.2
- **EN ISO/ASTM 52921:2016** Standard terminology for additive manufacturing - Coordinate systems and test methodologies
- **EN ISO/ASTM 52941:2020** Additive manufacturing - System performance and reliability - Acceptance tests for laser metal powder-bed fusion machines for metallic materials for aerospace application
- **EN ISO/ASTM 52942:2020** Additive manufacturing - Qualification principles - Qualifying machine operators of laser metal powder bed fusion machines and equipment used in aerospace applications

# So, where's my standard?

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Search and find…!

- ASTM standards: https://www.astm.org/search/fullsite-search.html?query=compass&
  - The ASTM International Compass: Search keywords; +"additive manufacturing"
- ISO standards: https://www.iso.org/home.html ,
  - ISO search: https://www.iso.org/search.html?q=&hPP=10&idx=all_en&p=0
  - Search keywords; +"additive manufacturing"
- CEN standards: https://standards.cen.eu/dyn/www/f?p=CENWEB:105::RESET::::
  - Search title/scope, select Committee "CEN/TC 438"
- Terms and Definitions: https://www.iso.org/obp/ui/#home
  - ISO online browsing platform: Access the most up to date content in ISO standards, graphical symbols, codes or terms and definitions.
  - For AM terms and definitions: search for: "52900"

# Mind the gap!

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- On many occasions there is a gap to fill between the established practices, and presents S.O.T.A. research with respect to the requirements to fill for the needs of standardization
- ASTM AM Center of Excellence supports research to fill the gap between the needs and standards development

# Filling the knowledge gaps with targeted research

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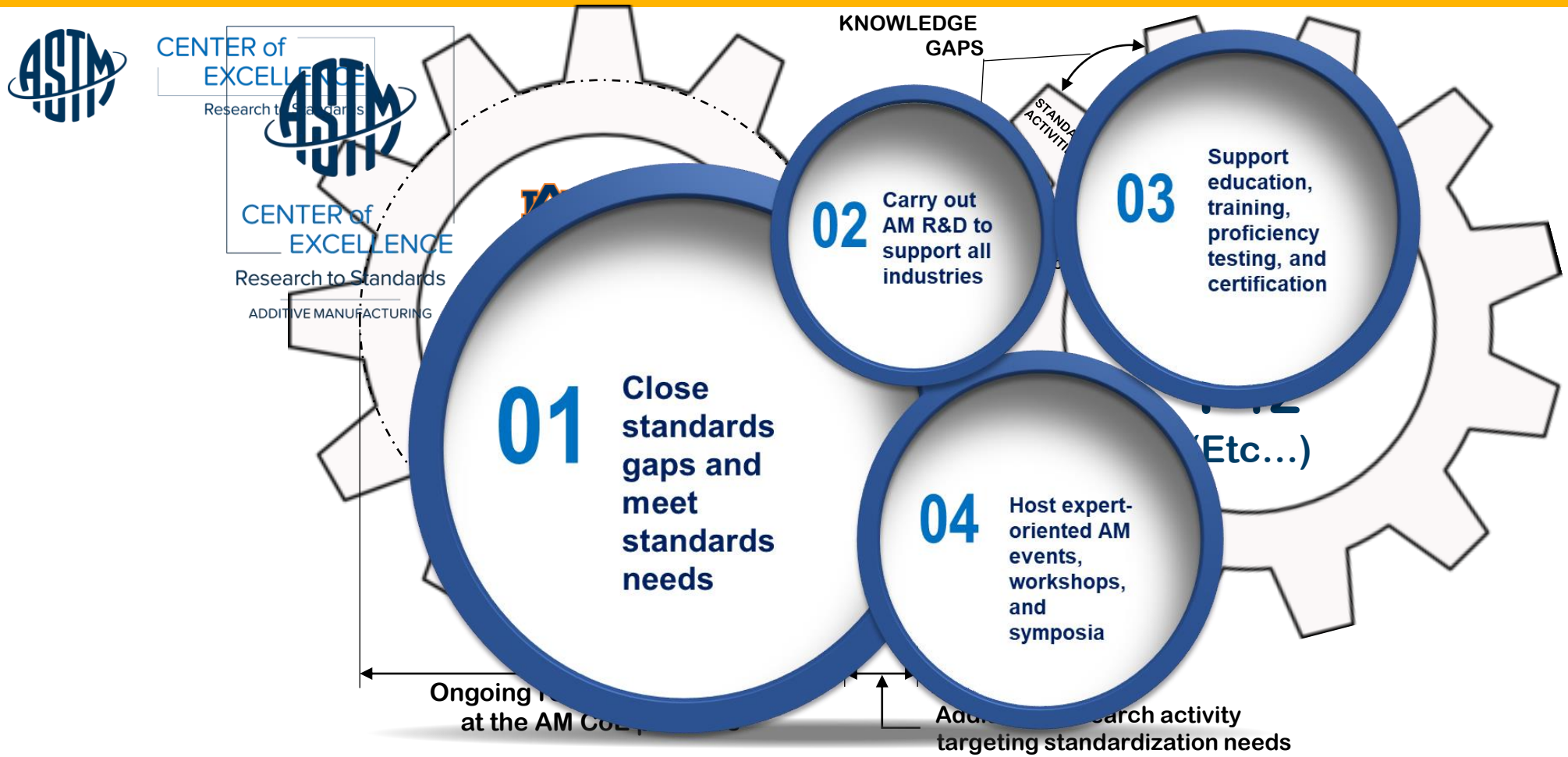

# ASTM AM Center of Excellence

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## Global Approach and Direct Funding for Accelerated Standards Development

- Round 1: 5 Projects, 17 Standards gaps addressed, 20 Existing standards impacted
  - *Example:* Project 1803: AM Feedstock (MTC)
    - Existing powder test methods: Assess the relevance for, and the impact on AM processing
  - *Example*: Project 1804: Process Qualification for PBF-LB
    - Establish a consensus of minimum requirements for qualification of PBF-LB machines and processes
- Round 2: 9 Projects, 20 Standards gaps addressed, 43 Existing standards impacted
  - *Example:* Project1903: AM Powder Spreadability (MTC)
    - Correlate powder flowability testing with performance in PBF test beds, investigate spreadability parameters and test methods
  - *Example*: Project 1906: In-process Monitoring (NAMIC)
    - Conversion of In-process 2D optical and thermal metrics into a 3D file for PBF processes

# Round 3:
# AM CoE's New Funding Mechanism

- New Call for Projects (CFP) mechanism allowing non-AM CoE partners to receive support to conduct targeted R&D projects
- Objectives
  - Allow the wider AM community to participate in Research to Standardization initiative
  - Evaluate the possibility of bringing on additional partners to the AM CoE team, to further accelerate standard development in AM
- Projects:
  - "Measuring moisture contents in AM feedstock" (NRC Canada)
  - "Standards for the determination of maintenance and calibration repetition cycles based on the condition of the optical system in PBF-LB" (Fraunhofer ILT)

# Concluding remarks

ARE YOU— AM —READY?

## International standards development

- Development of AM standards is a key element in establishing AM as a part of the industrial manufacturing system and provide an intellectual infrastructure to the market.
- International collaboration between ASTM, ISO and CEN is formally established and is growing
  - One set of standards used all over the world!
  - Common roadmap and organizational structure for AM standards
    - Use and build upon existing standards, modified for AM when necessary
  - Joint working groups are in progress
- Several standards, both common and by the individual organizations, have been published and more are on the way

# Final remarks

ARE YOU— AM —READY?

*We are just in the beginning of exploring the many possibilities of AM technology*

*Knowledge is critical; This is a learning process for all of us*

*Misdirected expectations leads to disappointments*

*No one benefits from competing standards.*

*Please join and take part in the ongoing efforts,*

*through ASTM F42, ISO/TC261 and your national standardization organizations!*

*Let's work together and get this right!*

# Thank you!

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SECTOR SKILLS STRATEGY
IN ADDITIVE MANUFACTURING

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