



ASTM INTERNATIONAL  
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# The Global Leader in Additive Manufacturing Standards

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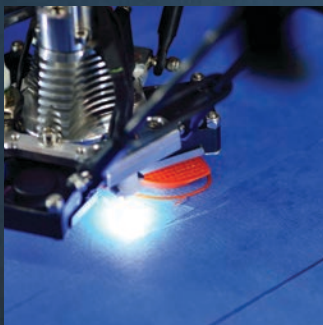
# Additive Manufacturing Standards Drive Innovation

Additive manufacturing (AM), also known as 3D printing, uses computer-aided design to build objects layer by layer. This contrasts with traditional manufacturing, which cuts, drills, and grinds away unwanted excess from a solid piece of material, often metal.

New equipment, technologies, and materials in AM are driving down the costs of building parts, devices, and products in industries such as aerospace, medicine, automotive, consumer products, and more.

3D printers are proving to be useful in hard-to-reach locations, such as military bases, the International Space Station, and more. AM also helps with medical applications such as patient-specific orthopaedic implants. In addition, consumer products such as athletic shoes or custom lighting are being made through AM.

Several ASTM technical committees write standards related to this growing field.



Additive Manufacturing Technologies

F42



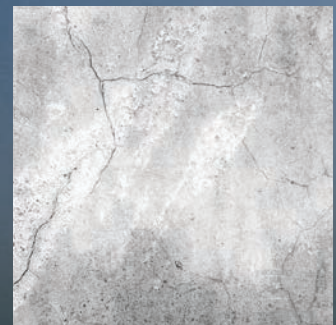
Aerospace and Aircraft

F07



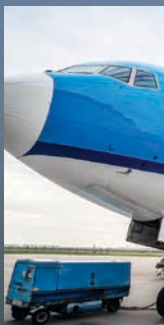
Aircraft Systems

F39



Fatigue and Fracture

E07



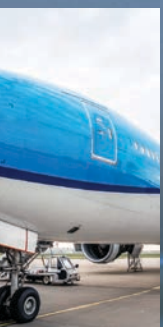
General Aviation Aircraft

F44

The value of a shortened development cycle and a more efficient process means that products can be created more quickly than ever before, and design changes can be incorporated more easily. Moreover, additive manufacturing also holds the promise of creating new designs that simply can't be made through traditional manufacturing.

In sum, the vast potential for AM to change our lives is coming into full view.

Powder bed fusion, directed energy deposition, binder deposition, vat photopolymerization, material jetting, and material extrusion are AM technologies that rely on new technical standards. Hundreds of experts on ASTM International's committee on additive manufacturing technologies (F42) are leading the way with standards that serve as a crucial foundation for innovation and growth. Moreover, ASTM International has attracted partnerships in AM from other standards groups as well as innovation hubs, industry associations, and more.



Medical and Surgical Materials and Devices

F04

Metal Powders and Metal Powder Products

B09

Plastics

D20

Unmanned Aircraft Systems

F38



## The Committee on Additive Manufacturing Technologies (F42)

Formed 2009

500+  
Members

14  
Standards

25  
Nations Represented

ASTM International President Katharine Morgan sees 3D printers and 3D printed parts during a tour led by Richard Martukanitz, Ph.D., of Pennsylvania State University's CIMP-3D lab.

# Leading the Way with Innovation through Standards

Startups, established businesses, trade associations, academia, and government are all represented in the committee on additive manufacturing technologies (F42). The group has been meeting since 2009 when the vast potential for AM was coming to light.

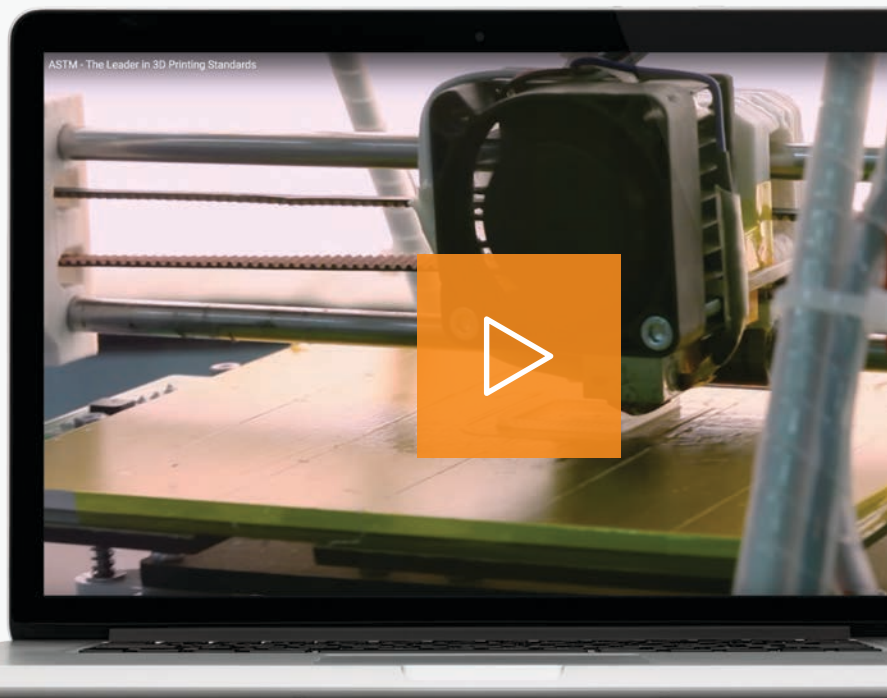
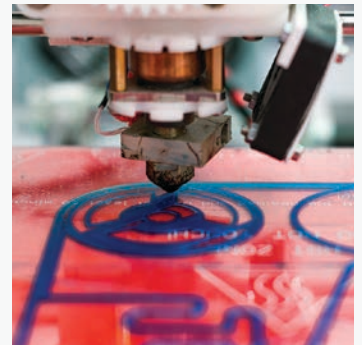
The committee's founders recognized the need for robust international standards in this fast-growing field. They have developed standards that support the application and adoption of AM for diverse materials and processes. These standards are providing a common language, broadly accepted specifications for AM materials, guides for these new technologies, and more.

ASTM International's AM standards (see list of key standards) and proposed standards are becoming more robust, detailed, and application-specific. As a result, businesses around the globe are creating parts and products with ever-increasing levels of quality and functionality.

ASTM International provides the space and resources for all standards stakeholders to collaborate through in-person meetings as well as with 24/7 online tools, collaboration areas, and balloting. The committee also provides an important forum for exchanging ideas, networking, and creating partnerships. This robust and inclusive process is open to anyone from anywhere in the world, giving a voice to every participant.

## Key Standards

- Practice for Reporting Data for Test Specimens Prepared by AM (F2971)
- Guide for Evaluating Mechanical Properties of Metal Materials Made via AM Processes (F3122)
- Specification for AM File Format (AMF) Version 1.2 (EN ISO/ASTM 52915)
- Guidelines for Design for AM (ISO/ASTM 52910)
- Guide for AM – General Principles – Requirements for Purchased AM Parts (ISO/ASTM 52901)
- Terminology for AM – General Principles – Terminology (EN ISO/ASTM 52900)
- Terminology for Additive Manufacturing – Coordinate Systems and Test Methodologies (EN ISO/ASTM 52921)
- Guide for Characterizing Properties of Metal Powders Used for AM Processes (F3049)
- Specification for Powder Bed Fusion of Plastic Materials (F3091/F3091M)
- Guide for Directed Energy Deposition of Metals (F3187)



Watch a video about AM standards:  
[www.astm.org/video/F42](http://www.astm.org/video/F42).

# The ASTM International/ISO Partner Agreement

“This structure will help experts worldwide interact in a more streamlined and meaningful way, leading to the integration and application of new technologies at an accelerated rate. In the future, we could see even more benefits, such as uniform workforce training and a stronger ability to focus on constant quality improvement rather than potential confusion surrounding specifications.”

**Carl Dekker**

president of MET-L-FLO Inc. and chair of ASTM International’s committee on additive manufacturing technologies (F42)

A Partner Standards Developing Organization (PSDO) agreement between ASTM International and the International Organization for Standardization (ISO), signed in 2011, paved the way to create joint AM standards.

**Through the agreement, joint standards can be created where none have existed. Also part of the partnership are:**

- Fast-tracking the adoption process of an ASTM International standard as an ISO final draft standard;
- Formal adoption of a published ISO standard by ASTM International; and
- Maintenance of published standards.

The agreement aims to make the best use of experts and resources to drive AM standards development while reducing duplication of effort. (See infographic.) Specifically, the PSDO allows for synergy between ASTM International’s committee on additive manufacturing technologies (F42) and the ISO committee on additive manufacturing (TC 261).

The agreement’s goal was to respond to this burgeoning industry’s need for a set of AM standards that would be recognized worldwide. To do this, they began to develop a common roadmap and organizational structure for AM standards, which was announced in 2016.

**These standards have been approved under the agreement:**

- Guide for AM – General Principles – Requirements for Purchased AM Parts (ISO/ASTM 52901);
- Guidelines for Design for AM (ISO/ASTM 52910);
- Specification for AM File Format (AMF) Version 1.2 (originally published as F2915-11) (EN ISO/ASTM 52915);
- Terminology for AM – General Principles – Terminology (EN ISO/ASTM 52900); and
- Terminology for Additive Manufacturing – Coordinate Systems and Test Methodologies (originally published as F2921-11) (EN ISO/ASTM 52921).

Additional standards are underway under the ISO/ASTM umbrella, including documents that will specify metal powders, characterize flow properties, and guide property measurements, among others.

The ISO/ASTM standards are also being published as European Standards (EN). These EN ISO/ASTM standards include the AM file format and terminology documents plus several more standards in process. The work is happening through the European Committee for Standardization (CEN) to help ensure consistent, harmonized international standards. CEN also plans for ongoing close cooperation between its Technical Committee 438 on Additive Manufacturing with the ISO and ASTM work on AM standards. As part of CEN’s approach, CEN will propose new ideas for European standards to the ISO/ASTM group according to a recently approved Additive Manufacturing Standards Development Structure.

ISO and ASTM International published the jointly crafted Additive Manufacturing Standards Development Structure, a framework to help meet the needs for new technical standards in this fast-growing field. The structure was approved by the organizations’ additive groups in July 2016.

**The structure will help:**

- Guide the work of global experts and standards development organizations involved in AM standardization;
- Identify standards-related gaps and needs in the AM industry;
- Prevent overlap and duplicative efforts in AM standards development;
- Ensure cohesion among AM standards;
- Prioritize AM standards areas; and
- Improve usability and acceptance among the AM community, including manufacturers, entrepreneurs, consumers, and others.

“This coordinated approach to standards development in AM is crucial to building out robust standards at all levels. Standards developers can see how this new structure allows them to come together, leading to further innovation in fields like aerospace, medical, and automotive, and also other benefits such as a platform for certification activities.”

**Jörg Lenz**  
collaborative projects coordinator at Electro Optical Systems and chair of ISO Technical Committee 261 on additive manufacturing



# Additional Partnerships in Additive Manufacturing

## Society of Manufacturing Engineers

The Society of Manufacturing Engineers signed a memorandum of understanding with ASTM International in early 2009 that established F42 as the home for the new standards development work. The MOU supports participation from SME's Rapid Technologies and Additive Manufacturing (RTAM) community in the ASTM standards process. RTAM is one of the world's largest communities of technical experts focused on these advanced technologies.

## America Makes

America Makes — a U.S.-based innovation institute under Manufacturing USA and the national accelerator for additive manufacturing and 3D printing — and ASTM International signed a memorandum of understanding in October 2013. The partnership further solidified in 2017 when ASTM joined America Makes as a Silver Member. The work is building more and stronger connections between researchers and the standards community, with the goal of developing standards in tandem with the introduction of new AM technologies and innovations. Key to this is the role of ASTM as it fills gaps identified by the Standardization Roadmap for Additive Manufacturing, developed by the Additive Manufacturing Standards Collaborative, where ASTM has a leadership role.

## 3MF Consortium

The 3MF Consortium — an industry association driving a new full-fidelity 3D-printing file format - signed a liaison agreement with ASTM International in June 2016 to collaborate and align standards and roadmaps that advance AM innovation and deliver state-of-the-art 3D printing technologies to market. "As adoption of the 3MF file format continues to ramp, it becomes increasingly important to develop a long-term 3MF technology roadmap that businesses support and trust," said Adrian Lannin, executive director, 3MF Consortium. "This agreement creates a cooperative

relationship for knowledge sharing and the pursuit of developing an established set of standards that will allow businesses to adopt 3MF with confidence."

## Aerospace - NADCAP

15 proposed ASTM International AM standards will help companies comply with an accreditation checklist from the National Aerospace and Defense Contractors Accreditation Program (NADCAP). Broad participation is sought to develop these standards:

- Guide for Creating Feedstock Specifications for Metal Powder Bed Fusion
- Guide for Storage of Build Cycle Technical Data
- Specification for Post Thermal Processing of Metal Powder Bed Fusion Parts
- Guide for Specifying Gases and Nitrogen Generators Used with Metal Powder Bed Fusion Machines
- Guide for Receiving and Storing of Metal Powders Used in Powder Bed Fusion
- Practice for Metal Powder Reuse in the Powder Bed Fusion Process
- Guide for Cleaning Metal Powder Bed Fusion Machines
- Guide for Disposal of Metal Powders Used for Powder Bed Fusion
- Guide for IQ, OQ, and PQ of Metal PBF Machines
- Practice for Digital Data Workflow Control for the Metal Powder Bed Fusion Process
- Guide to Establish Manufacturing Plan for Metal Powder Bed Fusion Production Parts
- Guide for Metallographic Evaluation of Metal Powder Bed Fusion Test Specimens and Parts to Determine Porosity
- Guide for Establishing a Personnel Training Program for Metal Powder Bed Fusion Part Production
- Guide for Creating Maintenance Schedules and Maintaining Metal Powder Bed Fusion Machines
- Guide for Calibrating Metal PBF Machines and Subsystems

"Standardization of materials and methods, where quality is essential, will be helpful for this rapidly evolving, highly process-sensitive industry. We are pleased to see F42 stepping up to write the necessary standards to make NADCAP accreditation as straightforward as possible."

## Brian Kosinski

vice president of mission assurance at SSL, a major satellite company based in Silicon Valley, California (USA)

**RESEARCH**  
*Technology*



**Basic  
Manufacturing  
Research**

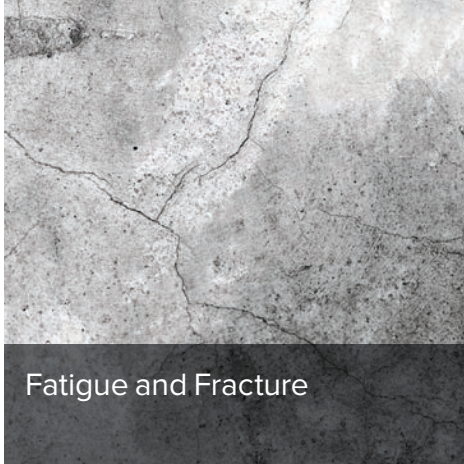




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Building the Bridge  
from Innovation to Market

## Collaboration across Committees

Beyond the committee on additive manufacturing technologies (F42), more than 2,000 ASTM International technical-expert members contribute to the overall advancement of AM. Hundreds of standards from many committees are advancing AM technology in some way. These committees include:



Fatigue and Fracture

The committee on fatigue and fracture (E08) leads fatigue-related work on AM to further validate use and adoption. Programs are being held to share research in areas such as strength, strain life, crack growth, and other parameters. The group of more than 400 members from 25 countries oversees about 40 standards.



Medical and Surgical Materials and Devices

AM opens up design possibilities for many medical applications such as cutting guides, bone augments, artificial joints, hearing aids, and dental crowns. ASTM International's committee on medical and surgical materials and devices (F04) is exploring a standard to assess cleanliness of medical devices made by AM techniques and another standard to guide the design of AM devices for cleanability. More than 800 F04 members from 30 countries oversee more than 300 standards.



Metal Powders and Metal Powder Products

The committee on metal powders and metal powder products (B09), works on powder metallurgy standards that apply to materials frequently used for AM. The standards cover methods and practices related to a variety of base metal powders as well as specifications and tests for various powder metallurgy parts used in mechanical applications. The group has about 60 standards, with 100 members from about 10 countries participating.

## ASTM International: Solutions and Services

A robust, enterprise-level family of services that strengthen organizations – in addition to standards – are available from ASTM International. Specific available offerings that may be customized for additive manufacturing are highlighted here.

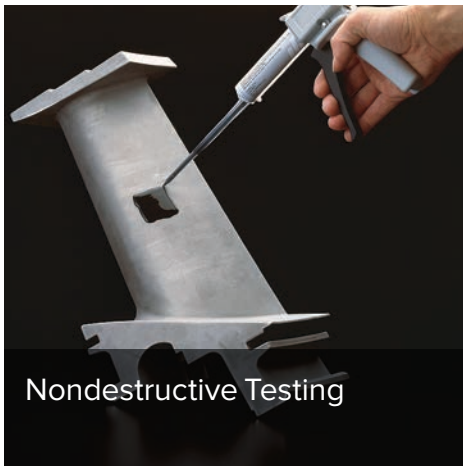
### *Proficiency Testing Programs*

Statistical quality assurance programs available through ASTM International help laboratories assess their performance in conducting test methods in their own laboratories by comparing data against that of other participants. Nearly 5,000 labs, more than half of which are non-U.S., use these programs. Programs in plastics, metals, and petroleum products are among the options. Programs are accredited in accordance with the recognized International Standard ISO/IEC 17043:

2010, Conformity Assessment - General Requirements for Proficiency Testing, by the American Association for Laboratory Accreditation.

### *Training and E-Learning*

ASTM International's practical, hands-on training programs – accredited by the International Association for Continuing Education and Training – bring together industry-respected standards and instructors who helped develop those standards. These include self-paced e-learning courses, webinars, and in-person courses in industries such as construction, coal, petroleum,



AM is increasingly used for turbine blades, engine parts, pumps, and other products in the aviation and aerospace industry. Experts from the committee on nondestructive testing (E07) are looking at developing standards and test methods that could help understand how AM relates to part defects, damage tolerance, and more. With 600 members from about 35 countries, the committee oversees about 225 standards.



An important material used for AM, plastics are the focus of another committee (D20). This group works on standards related to raw materials, components, and compounding ingredients as well as finished products made from plastics. The committee is exploring ways to apply existing ASTM International test methods for plastics to AM. They are also determining how their members' expertise might best help meet the growing need for polymer-related AM standards. The group of 1,000 members from 45 countries oversees about 500 standards.

## Additional Committees

Additively manufactured products have particular interest for aerospace, aviation, and military purposes, industries in which ASTM International has always led the way. Committees that are exploring potential AM standards – often in collaboration with F42 and others – include:

- Aerospace and aircraft (F07),
  - Aircraft systems (F39),
  - Commercial spaceflight (F47),
  - General aviation aircraft (F44), and
  - Unmanned aircraft systems (F38).
- Additional ASTM International technical committees develop standards for materials, parts, and components used worldwide to make products.

and plastics. One e-seminar, for example, covers Statistics in ASTM Standard Test Method Development, Application, and Quality Assurance.

### The Safety Equipment Institute



As AM moves into more and more product areas, certification will play a growing role. The Safety Equipment Institute (SEI) tests and certifies a broad range of safety and protective products used in work and recreational settings. An ASTM International affiliate, SEI leads

in certifying products such as sports and athletic equipment, safety and protective products used by first responders, and eye and face protection for industrial workers.

### Interlaboratory Study Program

ASTM International's Interlaboratory Study Program (ILS) helps committees create precision statements for test methods. The ILS program also helps with interlaboratory study design, volunteer labs, samples and suppliers, collecting and analyzing data, and compiling research report information.

### Journal: Smart and Sustainable Manufacturing Systems

*Smart and Sustainable Manufacturing Systems* — launched in 2017 by ASTM International — is an online publication that fosters research that crosses the boundaries of information science, systems engineering and engineering design, manufacturing, and product life cycle. Papers are encouraged from those studying and advancing AM.

### Smart Manufacturing Advisory Committee

Dozens of technical leaders from about 10 ASTM International committees meet regularly via teleconference as part of the Smart Manufacturing Advisory Committee (SMAC). They discuss technologies, innovations, and related standards work, and they hear from guest speakers on cutting-edge advances in new fields. This includes AM as well as nanotechnology, pharmaceutical and biopharmaceutical production, and more. Go to [www.astm.org/smartmanufacturing](http://www.astm.org/smartmanufacturing).



## ASTM INTERNATIONAL

Helping our world work better

Committed to serving global societal needs, ASTM International positively impacts public health and safety, consumer confidence, and overall quality of life. We integrate consensus standards, developed with our international membership of volunteer technical experts, and innovative services to improve lives — Helping our world work better.

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