

# **Building Connections through Standards Landscaping**

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## **Abstract**

Standards are an essential part of how we do business, from communicating requirements, to establishing best practices, to achieving quality control. As commerce and technology continues to diversify, standards, and standard organizations, have become increasingly specialized. The specialization of standards has come to the point where the standard itself could be considered an oxymoron, that is to say the continued specialization and proliferation of standards has created scenarios where multiple standards can often be identified within a single domain of interest. Recognizing the potential of future complications, some communities have begun to adopt the practice of standards landscaping, where organizations and organizational contributions are mapped to a domain's "landscape." In this paper we discuss the contributions of such landscaping exercises, and their ability to reconcile diversified communities and interests. We look at two recent examples in Smart Manufacturing and Additive Manufacturing, and discuss the impact that landscaping exercises have had on their respective communities and the standards community as a whole.

## **Importance of Today's Standards**

Standards have an immense impact on today's society for a variety of reasons. In the global economy, it has been estimated that roughly 80 % of global merchandise trade is affected by standards and by regulations that embody standards<sup>1</sup>. In the United States, the economic impact of standards is not directly tracked but is well understood<sup>2</sup>. For comparison, based on a United Kingdom (UK) study published in 2005, standards make an annual contribution of \$2.5 billion (U.S. Dollars - USD) to the UK economy and account for 13 % of the growth in labor productivity [1]. A study led by the German Institute for Standardization (DIN), based on 700 companies nationwide, found the benefit of standards to the German national economy to be greater than \$15 billion USD per year [2]. In addition, the study found that companies that participate in standards development have an advantage over their competitors when adapting to market demands and new technologies.

Though standards have long been embedded in economics, the roles of standards have not always been as complex and intricate as they are today. Standards have seemingly always been part of our everyday vocabulary, often as a unit of measurement (foot, pound, liter, mile, etc.). As society has moved forward and technology has advanced, standards have played an increasingly important role in our day to day activities, with seemingly exponential growth.

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<sup>1</sup> Arden L. Bement, "Standards and Infrastructure: Foundations of Manufacturing Competitiveness", [http://www.nist.gov/director/speeches/bement\\_032703.cfm](http://www.nist.gov/director/speeches/bement_032703.cfm)

<sup>2</sup> Overview of the U.S. Standardization System, [http://www.standardsportal.org/usa\\_en/standards\\_system.aspx](http://www.standardsportal.org/usa_en/standards_system.aspx)

Standards have become so ubiquitous that we have integrated them as jargon into our everyday lives. We have come to accept them as fundamental norms, providing mechanisms for evaluating, sharing, and trusting experiences and knowledge across the globe. Standards such as USB (hardware), JPG (image), MP3(audio), MPEG (video), and PDF (document) have permeated our day-to-day living. Their success is enabled by the trust offered by society, in that repeatable, dependable performance can be expected. However, as more and more standards become redundant in coverage but not in performance, new steps must be taken to maintain that trust.

While standards such as those listed above are widely accepted, they are much more the exception than the norm. The path to becoming a de facto standard is rarely realized, and even those examples listed above have multiple, widely accepted, alternatives. In reality, given the complexity of today's society, standards may hinder just as much as they enable. For instance, consider the role USB standards played in harmonizing the once preposterous amount of interfaces for cellular chargers. Responding to consumer demand, many manufacturers adopted USB standards to simplify power connections. As of today, mostly due to variations in power and data requirements, there are over 10 different versions of these connection standards, once again creating disconnects. As technology advanced, and manufacturers' needs differed, specializations to these standards were necessary to meet changing demands. Specialization is often necessary to achieve optimal performance from a piece of technology, and as such implementations continue to be diversified. With that said, the challenges created, and benefits offered, by specializing standards are not restricted to any one domain. In general, special interests are driving standards development perhaps now more than ever. Maintaining communication between these interest groups is critical to the evolution of today's standards.

### **Diversification and Specialization of Standards Development**

The business of developing standards is prevalent now more than ever. Many former national standards bodies have become international standards bodies. New standards development organizations are emerging in nations around the world. Existing standards organizations are continuing to diversify in order to accommodate increasing needs and expanding roles. The result of this activity is a plethora of standards development organizations (SDOs) with ill-defined swim lanes and boundaries.

With SDOs continuing to expand their reach, special interest groups (SIGs) have more opportunities than ever to create customized standards to fit specific needs. A SIG could potentially be associated with multiple SDOs. A partnership might be formed based on a SIG's history or comfort level with an SDO, based on the average time to publish an SDO standard, based on an SDO's standard approval process, or simply based on the traditional core competencies of an SDO. Even without the support of established SDOs, many SIGs, especially those comprised of large organizations with shared interest, have formed consortiums to develop solutions that may become de facto standards.

With options available, it is not necessary for standards development activities to satisfy the needs of all within the greater community, and instead focus on the needs of those within a smaller sub-community. As a result, larger communities are often faced with situations where several SDOs and SIGs have similar yet independent standards activities being developed in parallel yet disjoint paths. Scenarios such as these lead to expanded opportunities for overlaps and redundancies in standards.

In 1996, a National Institute of Standards and Technology (NIST) report identified 25 % to 30 % of the United States' standards as obsolete [3], and almost certainly this number has grown. The result is that manufacturers and their support network, in the form of software and device providers, are left trying to navigate the standards without a compass to help them find their way. When standards development activities are left uncoordinated, resulting overlaps and redundancy among standards can create confusion. Three practices cause overlap and redundancy.

- 1) Standards from different national, regional, and international standards systems are sometimes identical, equivalent, or in some other way related resulting in confusion as to the most authoritative source.
- 2) Standards in the same technical areas but in different application sectors are sometimes defined independently. For example, material-testing methods defined for different industry sectors sometimes are not consistent.
- 3) For the US, the third redundancy comes from the pluralistic standards system. In a pluralistic standards system, no one body is sanctioned to provide standards. The system reflects cultural individualization and ingrained belief in a market-driven economy. In US, there are 600 SDOs maintaining ongoing standardization programs. As the need for standards grows and the number of standards produced expands, more opportunity

for overlap and redundancy results. Standards organizations are not only competing with one another to write standards, they are sometimes writing conflicting standards, thus defeating the purpose.

While SIGs participating in delineated standards efforts can create confusion in a community, there is also the potential to turn a potential detriment into a positive. Instead of developing sets of standards to fit the needs of many, specialized standards are created to satisfy the needs of a select community, and therefore are more likely to be implemented. When properly managed, overlap can be controlled and standards may actually become more succinct, more comprehensive, and ultimately more useful and adoptable.

### **The Case for Standards Landscaping**

Standards coordination is not a trivial task.

The previous two sections discussed many of the challenges faced in today's standards environment. Diversity, special interests, and lack of coordination can result in segregated communities with similar interests. While segregated standards development practices often lead to overlap, they can also lead to conflict [4]. Overlapping standards may cause confusion, as the greater community might be given multiple selections when choosing a standard to adopt, but conflicting standards can be disastrous, as multiple standards may provide conflicting guidance on the same concept. When a community is left with multiple selections around a single concept, confusion and complications are bound to arise.

When standards are unable to provide the social norms and intermediaries they are intended to provide, it becomes necessary to look at the "bigger picture." For a given domain, standards may be developed in different levels of detail, with different requirements in mind, or with different information sources guiding the content. As such, standards do not always represent uniformity within a domain, but instead may be an agreement among a special interest within a domain.

Standards landscaping exercises can be used to systematically explore and analyze domains of interest. The characterization occurs by assessing the boundaries of a domain (identification of needs) and mapping current coverage (identification of available standards). The exercise itself creates groupings that result in sub-domains, or concentrated areas of focus. Each sub-domain will inherently align with some SDOs better than others, providing

insight into where the strengths of different SDOs lie. When thoroughly thought through and carefully implemented, a standards landscape provides the greater community a better understanding of where strengths lie among different standards and organizations. Landscapes help identify where gaps in domain coverage exist, and can be used to correlate these gaps with organizations for more efficient standard development in the future.

While landscapes are best developed cohesively by representatives from organizations across the greater domains, they may be developed by smaller groups as well. Having representation across organizations likely will better capture the perspectives and interests of all groups, and more accurately reflect their directions. While landscapes developed by smaller groups may limit perspectives, individual interpretations can still be made based on available literature and standards documentation. Regardless of how the landscape is developed, the exercise allows new perspectives to be gained on a domain of interest and its greater community as a whole.

One example of a well-implemented standards landscape can be seen with the Smart Grid initiative led by International Electrotechnical Commission (IEC)<sup>3</sup>. The complex domain has many special needs, and as such is best suited for specialized, comprehensive standards. IEC recognizes that the main problem with the adoption of smart grid standards lies with a lack of awareness of those standards and a lack of clear best practices and regulatory guidelines for applying them. As such, they have developed a Smart Grid Standards Mapping Tool that defines relationships between components and standards of the Smart Grid. The landscape is able to divide the larger domain into many interconnected sub-domains, and maps standards to these sub-domains. The exercise itself resulted in the development of a web-based architecture, the IEC Smart Grid Standards Map, that clearly identifies sub-domains, relevant SDOs, and relevant standards. The clickable interface provides users with direct access to standards related to each sub-domain. This complex tool ultimately provides the Smart Grid community with a well-organized view of how Smart Grid standards have been and will be developed, providing both SDOs and standards users valuable information. The result is an organized community with the ability to cohesively develop standards and ultimately to maintain the integrity of current and future electrical grids.

In the following sections we discuss the evolution of two related, yet separate, landscaping exercises currently underway within the advanced manufacturing community. These two examples are representative of some of the

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<sup>3</sup> IEC smart grid maps, <http://smartgridstandardsmap.com/>

challenges faced by larger communities as a whole, as Additive Manufacturing (AM) in itself can be considered a subset of the larger Smart Manufacturing (SM) community. This relationship speaks to the point of the challenges faced by larger communities, and the often necessity of specializing standards to ultimately produce the desired results.

### **Smart Manufacturing**

Smart Manufacturing (SM) seeks to integrate advanced manufacturing methods (e.g., additive manufacturing), operational technologies (OT)<sup>4</sup>, and information and communication technologies (ICT) to drive unprecedented gains in production agility, quality, and efficiency across manufacturers, improving their long-term competitiveness [5]. In 2014, the US President's Council of Advisors on Science and Technology (PCAST) noted that standards “spur the adoption of new technologies, products and manufacturing methods. Standards allow a more dynamic and competitive marketplace, without hampering the opportunity to differentiate. Development and adoption of standards reduce the risks for enterprises developing solutions and for those implementing them, accelerating adoption of new manufactured products and manufacturing methods.”<sup>5</sup> This quote highlights the importance of well-developed standards for SM.

In moving towards new standards opportunities, a team at NIST assessed existing manufacturing standards and identified gaps to support new efforts in SM [6,7]. In their work, the team found that numerous national, regional, and international SDOs set manufacturing industry standards. Many of the existing manufacturing standards provide “how-to” instructions for designers, engineers, builders, operators, and decision makers to conduct disciplined activities within their domains. They also facilitate communication between stakeholders across domain borders, borders of the manufacturing system hierarchy, and between lifecycle phases. The sum total of standardization efforts in the manufacturing field is immense, though the huge number of manufacturing standards is actually misleading, as many standards are never fully adopted or broadly used by the intended community. To tackle the issues of untracked and overlapping standards, a landscape development was necessary to survey the existing manufacturing standards, classify them for smart manufacturing, identify gaps, and define a strategic SM standards development roadmap.

Because of the enormous depth, breadth, and the inherent complexity associated with the new SM paradigm, it is impossible to list all of the manufacturing standards in one map like the one created by the IEC Smart Grid Initiative.

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<sup>4</sup> Operational technology (OT) is hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes, and events in the enterprise. <http://www.gartner.com/it-glossary/operational-technology-ot/>

<sup>5</sup> [https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/amp20\\_report\\_final.pdf](https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/amp20_report_final.pdf)

Instead, the NIST work focused on relating standards efforts with the concepts that drive SM. In NIST’s SM standards landscape work [6, 7], an SM standards landscape is surveyed and classified based on a definition of a smart manufacturing ecosystem that encompasses three dimensions – product, production systems, and enterprise (business) systems, shown in Figure 1. In establishing the ecosystem, this “big picture” view lays clear boundaries around what constitutes as applicable domains for SM.

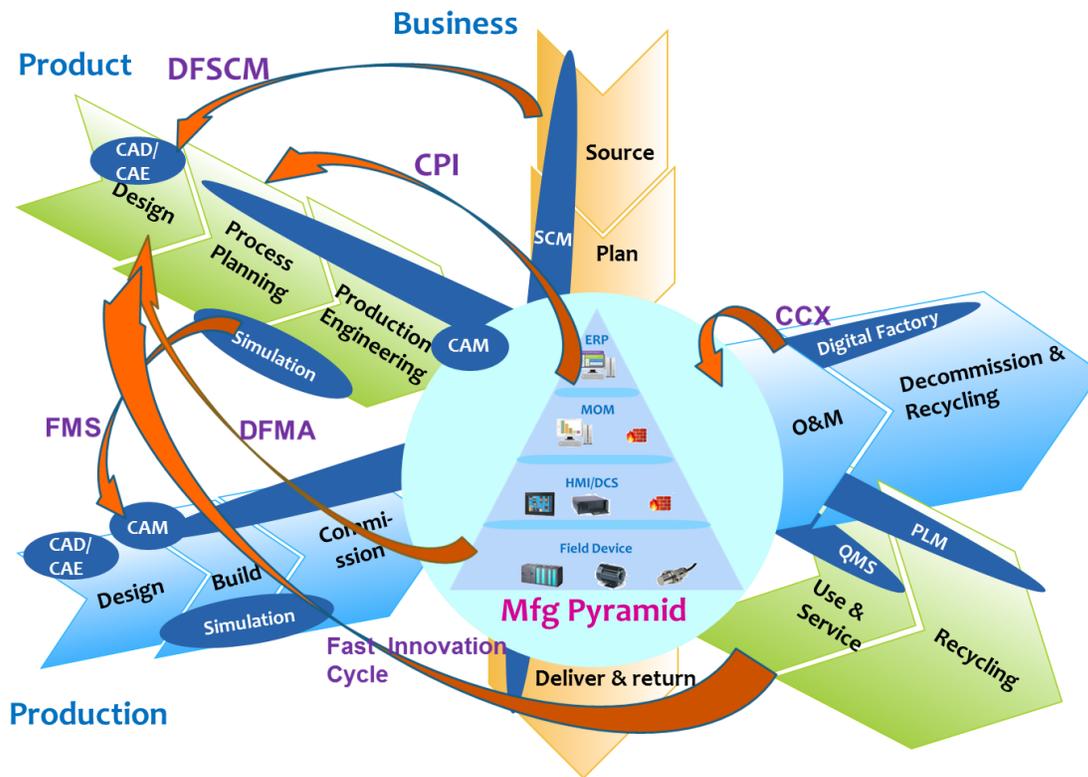


Figure 1: Smart Manufacturing Ecosystem. From [6, 7].

Based on the SM Ecosystem, the NIST team associated existing manufacturing standards with the lifecycle phases in each dimension. Some frequently used standards are classified based on lifecycle phases of products, production systems, and business activities and a hierarchy of a manufacturing operation system, as shown in Figure 2:

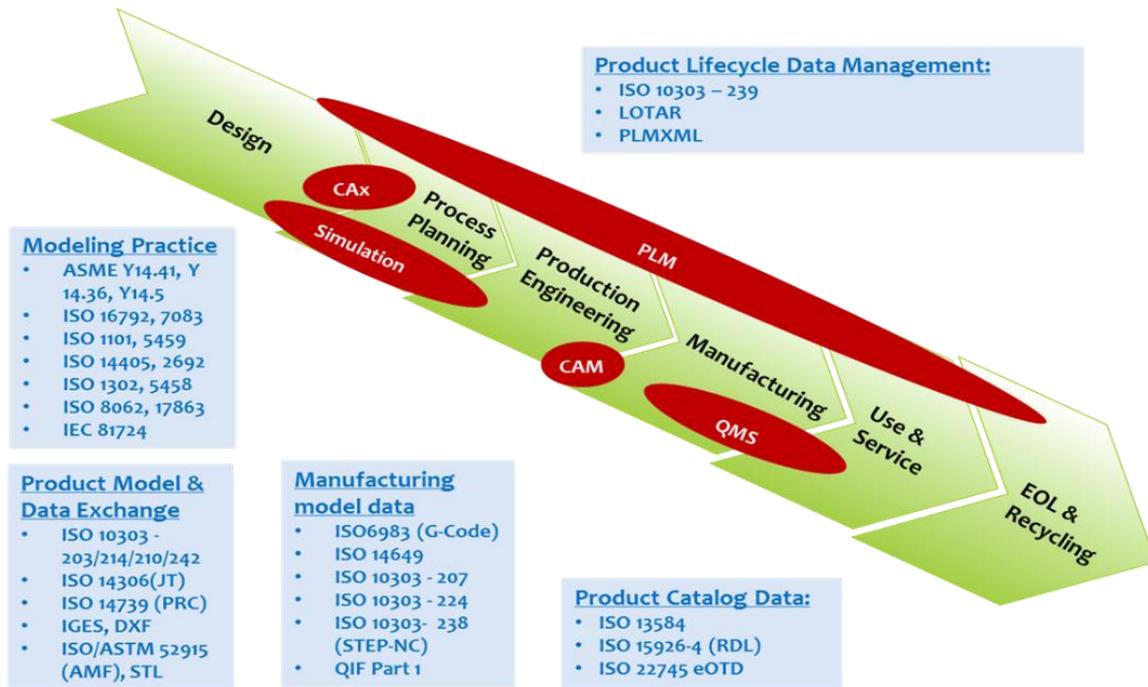


Figure 2: Smart Manufacturing Standards Landscape. From [6, 7].

Based on the same ecosystem picture, the NIST team found that new business models are forming under the new SM paradigm that change the ways how products are developed and how production systems should be engineered and operated, shown as the orange arrows in Figure 1. Specifically, to deal with IoT (Internet of Things) integration and product individualization, standards to enable the new information flows across dimensions and standards for new SM reference architecture, SM cyber-security, and mass customization are missing and the gaps should be filled by a joint SDO effort.

In parallel to NIST's effort, IEC formed a strategic group SG 8 Industry 4.0 - Smart Manufacturing 'to provide recommendations for an IEC strategy addressing manufacturing automation that will focus on ensuring real time needs of the manufacturing enterprise are sustained to achieve safe, secure and energy efficient factory operations<sup>6</sup>. In the final SG8 report, the group proposed to compile of a list of relevant standards documents and create a map of SM standards for industry use, similar to what has been developed for the smart grid standards map.

<sup>6</sup> IEC SG 8 Industry 4.0 - Smart Manufacturing, [http://www.iec.ch/dyn/www/f?p=103:85:0:::FSP\\_ORG\\_ID,FSP\\_LANG\\_ID:11072,25](http://www.iec.ch/dyn/www/f?p=103:85:0:::FSP_ORG_ID,FSP_LANG_ID:11072,25)

In ISO landscaping exercises, the ISO Technical Management Board (TMB) formed a Strategic Advisory Group (SAG) on Industry 4.0/Smart Manufacturing in June 2015, with the objectives to identify possible gaps where additional standards are needed for smart manufacturing and to make recommendations on actions to be taken by ISO TMB<sup>7</sup> [8]. This group has worked together for a year to provide a list of smart manufacturing standards, including those from ISO, IEC, and DIN. This group also proposed to work with IEC actively on improving and maintaining this standards catalogue.

None of the described individual efforts are able to completely cover all of the perspectives of smart manufacturing. In the SM community, development of a common roadmap for SM standards development and further harmonization among SDOs and standards are necessary.

The “Product” track of the SM Ecosystem was emphasized in Figure 2 as it most closely relates to the status of current additive manufacturing (AM) standards and standards landscaping efforts. AM is considered a type of SM technology, and the observable differences between the two landscapes highlights the challenges in identifying and defining domains.

### **Additive manufacturing**

While additive manufacturing (also referred to as 3D printing) is still an “emerging technology,” many of the associated technologies have matured to the point where it has become a viable alternative for creating both polymer and metal parts. Defined as a “layer by layer manufacturing process” first invented in 1984, today’s AM processes are far removed from their “solid freeform fabrication” and “rapid prototyping” predecessors. Recognizing their growing maturity, a National Science Foundation-sponsored workshop was held in 2009<sup>8</sup> to assess AM processes as viable production alternatives, for both metals and polymers. One of the primary outcomes of this workshop was its support for the first standards committee to focus solely on AM technologies, ASTM Committee F42, also established in 2009.

In many ways, the establishment of ASTM F42 solidified the importance and allure of AM technologies and their promise. The committee was established to create a united front to address standards needs for the growing AM

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<sup>7</sup> ISO Technical Management Board Strategic Advisory Group Smart Manufacturing /Industrie4.0, [https://www.ansi.org/news\\_publications/news\\_story.aspx?menuid=7&articleid=1862af9b-7157-44fa-b43b-ee3b3e9029ba](https://www.ansi.org/news_publications/news_story.aspx?menuid=7&articleid=1862af9b-7157-44fa-b43b-ee3b3e9029ba)

<sup>8</sup> <https://wohlersassociates.com/roadmap2009A.pdf>

community. With the broad range of AM technologies, and their still relative immaturity, the F42 group assumed the daunting task of developing standards for what has been a wide and diverse set of technologies. Addressing these technologies requires not only expertise in the processes themselves, but also in the materials used and methods used to enable them. Given the relatively broad scope, ASTM F42 formed four separate subcommittees <sup>9</sup>, appropriately aligning with those areas outlined in the NSF Roadmap.

The first challenge in standards coordination came with the advent of ISO Technical Committee (TC) 261 on Additive Manufacturing in 2011. ISO TC 261 was formed, similar to ASTM F42, to develop international standards in support of AM. While ASTM F42 was formed based on the efforts of AM experts from mostly U.S. organizations (recognizing that ASTM International develops international standards), ISO TC261 was founded by AM experts from mostly European organizations. Based on their common interests and scopes, the two standards bodies quickly realized the potential for conflicting standards documents. To address potential duplication and overlap, a unique, first-of-its-kind arrangement between ASTM F42 and ISO TC 261 was formed in 2012 to develop AM standards jointly.

The novel partnership between ASTM F42 and ISO TC 261 was lauded as a step in harmonizing standards development efforts. Given the universally recognized complexities of AM processes, this joint effort promised to provide a single outlet for all standards that were AM. Benefits of this approach included better utilization of resources to address these complex topics (no duplication), complementary efforts between International standards bodies, and the promise of “one set of standards” to support industry needs.

The joint ASTM and ISO effort was promoted heavily and praised by participants and observers alike. This collaboration proved that cooperation was possible, and that emerging domains, such as AM, can greatly benefit by sharing knowledge to develop high-priority standards to meet the needs of industry. The joint working groups of ASTM F42 and ISO TC261 are developing AM standards that address the requirements of the AM community. However, as the joint committees began to release their first standards, other communities took notice that opportunities still existed to speed up AM standards development by addressing other standards gaps or by addressing specific application perspectives.

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<sup>9</sup> <https://www.astm.org/COMMIT/SUBCOMMIT/F42.htm>

Between 2014 and 2016 several new standards committees were formed to address perceived gaps in AM standards development. These new committees were formed primarily to address specific aspects of additive manufacturing in which the given community had a specialized interest or expertise, for example, dimensioning and tolerancing, electronics packaging, or aerospace specifications. Many factors drove the formation of these standards groups, including special interest groups (SIGs), regulatory interests, and desires to accelerate developments across a broad array of AM subtopics. In some cases, the new AM standards efforts aligned with existing communities that had already established expertise in a topic area, and this expertise was then applied to AM standards development. In other cases, seemingly redundant efforts were initiated in an attempt to satisfy the particular needs of a SIG. In the end, new standards efforts relevant to AM began in the American Society of Mechanical Engineers (ASME), SAE International, the Institute of Electrical and Electronics Engineers (IEEE), the American Welding Society (AWS), the Association for Connecting Electronics Industries (IPC), Underwriters Laboratories (UL), and different technical committees of the larger ISO community (e.g., ISO TC184). With these new efforts, AM standards coordination became much more difficult, overlapping scopes and activities became apparent, and the potential grew for conflicting standards among these efforts.

Realizing that AM standards efforts had become increasingly diverse and complex, and that this diversity could potentially slow the standards development progress being made by the AM community, a new effort was launched to help resolve a potentially volatile situation. Led by America Makes<sup>10</sup>, the National Institute of Standards and Technology (NIST), the American National Standards Institute (ANSI), and others, a group of AM leaders looked to synthesize the seeming proliferation of standards efforts. A partnership was formed between ANSI and America Makes, and together the organizations looked to bring together SDOs and community leaders to assess AM standards development. To date, this effort, dubbed AMSC<sup>11</sup> (Additive Manufacturing Standardization Collaborative) has brought together AM experts and representatives of standards bodies to meet on a bi-weekly basis in several different focus groups. While the primary mission of these interactions is to identify where AM standards gaps still exist, the open communication between the different standards bodies has shed light on the activities of the community as a whole.

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<sup>10</sup> <https://www.americamakes.us/>

<sup>11</sup> [https://www.ansi.org/standards\\_activities/standards\\_boards\\_panels/amsc/](https://www.ansi.org/standards_activities/standards_boards_panels/amsc/)

The final deliverable of the AMSC effort will be a roadmap report that outlines what organizations are involved in AM standards development, what standards they are developing, and what standards needs still exist. In essence this document will provide not only a standards landscape, but a standards roadmap as well. While such a document does not prevent overlapping or conflicts between standards in the future, it provides insight for organizations to make earnest efforts to avoid such complications. Figures 3 and 4 provide a simplified look at how some of the landscaping appears, with multiple SDOs associated with different swim lanes. Notice that, similar to what was seen with SM, the landscape can be decomposed into multiple tracks: Application area (Figure 3) and Product Lifecycle (Figure 4). When the AMSC effort is completed, a comprehensive roadmap will be available - one that is able to identify and associate specific standards and standards efforts with identified sub-domains.

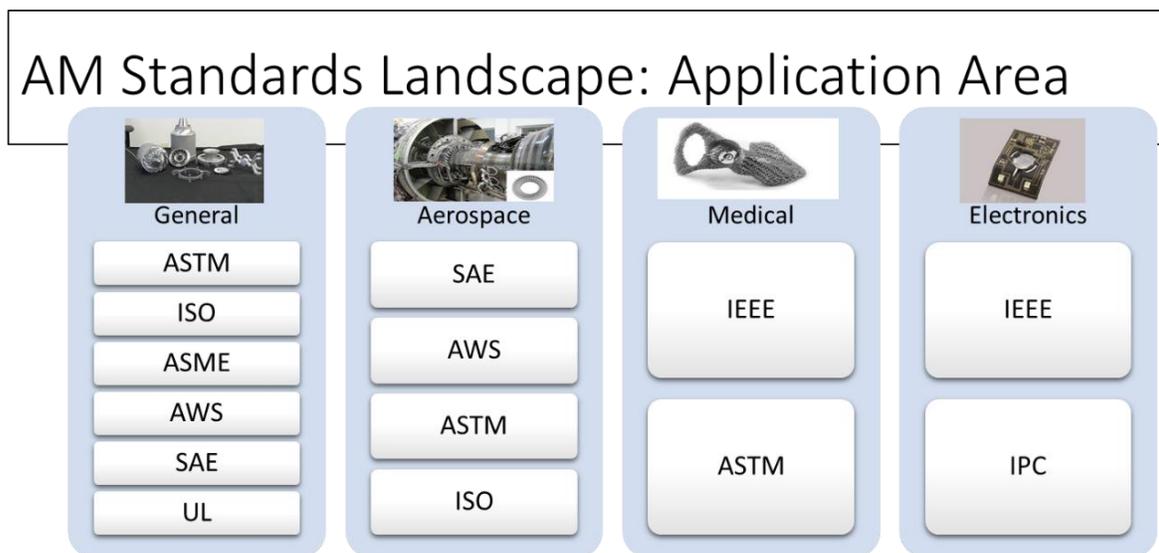


Figure 3. SDO standards efforts aligned with application areas.

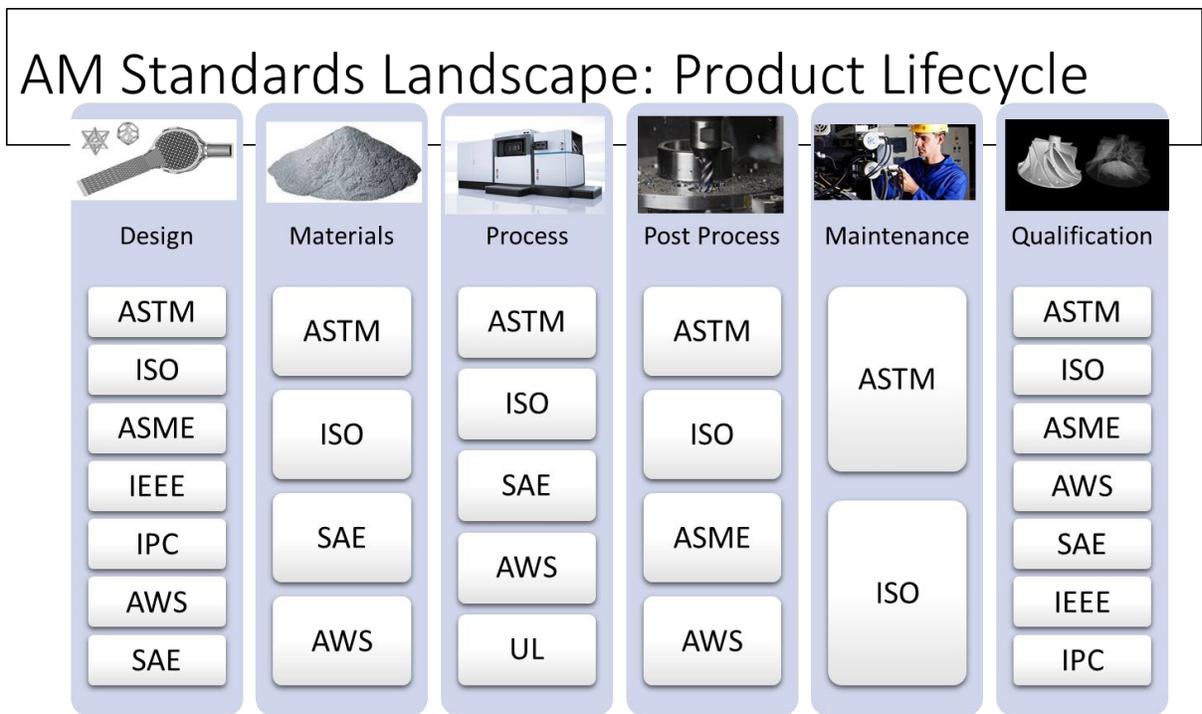


Figure 4: SDO standards efforts aligned with AM product lifecycle phases.

## Discussion

The role of standards has evolved significantly as technology has advanced and society has matured. Standards have become more essential than ever, to the point where society often takes the services they provide for granted. The ability to trust an item or action to perform as intended is something that is rarely attributed to a standard, but is often the result of one. It isn't until interfaces begin to fail, and communications begin to drop, that we are reminded of the roles that standards play. While complementary and compatibility are qualities that can be enforced in controlled environments, they are concepts that are rarely embraced in standards development. As SIGs continue to form to develop customized standards to meet specific needs, it is important to remember that cooperation is necessary. When cooperation does not exist among standards development efforts, overlaps and conflicts can occur in the resulting standards documents, leading to potential confusion and misunderstanding for the end users of these standards.

While diversity in content is important, the ability to overcome diversity can be just as important. Landscaping exercises provide communities with a mechanism to systematically organize and align their interests. Commitment

to landscaping exercises benefits all involved, as potential conflicts can be avoided and novel opportunities for advancement can be identified. In the SM community, landscaping exercises unmasked the amount and complexity of standards that fall within the larger SM domain, and hinted at the extraordinary amount of collaboration that will be needed to move forward successfully. In the AM community, standards landscaping is just beginning but the impacts are apparent, with communities better understanding where their efforts are best focused. While SM and AM are just two examples, the values of standards landscaping exercises are apparent, and are exercises that should be readily adopted to facilitate the effectiveness of standards development.

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