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Workshop Report on Technologies and Use Cases for Smart Standards

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Abstract

This document reports on the activities of a workshop held at the National Institute for Standards and Technology (NIST) on March 19–20, 2026 on the topic of Technologies and Use Cases for Smart Standards. The workshop was jointly organized by the Information Technology Laboratory and the Standards Coordination Office and included 30 participants drawn from standards development organizations (SDOs), government agencies, trade associations, non-profit organizations, universities, and companies. The report provides a short summary of the presentations and discussions held at the meeting.

Key words

digital standards; machine-interpretable documents; machine-readable documents; model-based engineering; smart standards; standards development.

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1. Introduction

This document details the activities of a workshop held at the National Institute for Standards and Technology (NIST) on March 19–20, 2026, on the topic of Technologies and Use Cases for Smart Standards. The workshop was jointly organized by the Information Technology Laboratory and the Standards Coordination Office and included 30 participants drawn from standards development organizations (SDOs), government agencies, trade associations, non-profit organizations, universities, and companies. A list of participants is included in the report.

The main goal of the workshop was to identify the requirements for ongoing and future work on tools and technologies for standards digitalization. To ensure a broad coverage of perspectives, the organizers aimed to engage stakeholders from a range of organizations who play different roles within the standards ecosystem. A second goal was dissemination of research, sharing the work done at NIST, soliciting feedback on future research directions, and learning about digitalization efforts that are being conducted elsewhere.

The context in which standards operate is changing rapidly as cross-cutting technologies like artificial intelligence (AI) and internet of things (IoT) become embedded in institutional and industrial processes. The complexity of these processes drives additional complexity in standards and best practices, to the point that "flat" documents (paper, PDF[1], or similar formats) are no longer sufficient for many use cases. The standards ecosystem is currently in the midst of a shift toward more expressive digital representations, including both **machine-readable** documents and **machine-interpretable** extensions.

Whereas PDF documents are optimized for display on a page, machine-readable documents like XML[2] separate content from presentation. This allows publishers to render content into a variety of media (e.g., PDF and web), and also allows users to access elements of a document digitally and with much more granularity. Authors can also provide additional context that is not easily available in a flat document. For example, a `<title>` tag and an `<ital>` might both produce italicized output, but only one explains *why* the text is italicized. Machine-interpretable documents go further, building digital representations directly into a standard to supplement or replace existing natural-language content.

There is currently a great deal of interest in standards development for critical and emerging technologies (CETs) such as AI, autonomous systems, and quantum computing. The timelines for standards committees are compressed, and especially in these areas where best practices are not yet settled, this pressure trades off against standards quality. Tools and processes that allow for more efficient development without sacrificing detail and accuracy would be extremely valuable in this effort.

Flat documents require a significant cognitive load to read and process, since they must be consumed linearly. In immature contexts such as AI standards, there is a great deal of novel, interconnected information that must be consumed, placing an inordinate mental load on developers and users.

[1] Portable Document Format
[2] eXtensible Markup Language

On the first day of the workshop, March 19, we heard presentations from a variety of industry, SDO, and government representatives. These talks are summarized in Section 2. The remainder of the meeting was devoted to group discussion. This included a short session at the end of the first day to reflect on the presentations, a breakout session into two smaller groups, and a long full group discussion to close the meeting. A summary of these discussions, organized by topic, is included in Section 3. The report closes with a review of near-term efforts to advance efforts towards digital standards.

2. Presentations

2.1 SAE Digital Initiatives — Leslie McKay

The first workshop presentation was from Leslie McKay of SAE International, who presented on SAE's digital initiatives. These initiatives aim to transform different elements of standards, such as drawings, text, tables, and other media, into digital space. An early effort, OnQue, promoted a vision to eliminate transcription errors, support system integration, maximize reuse to lower costs, minimize change management, and digitally track requirements.

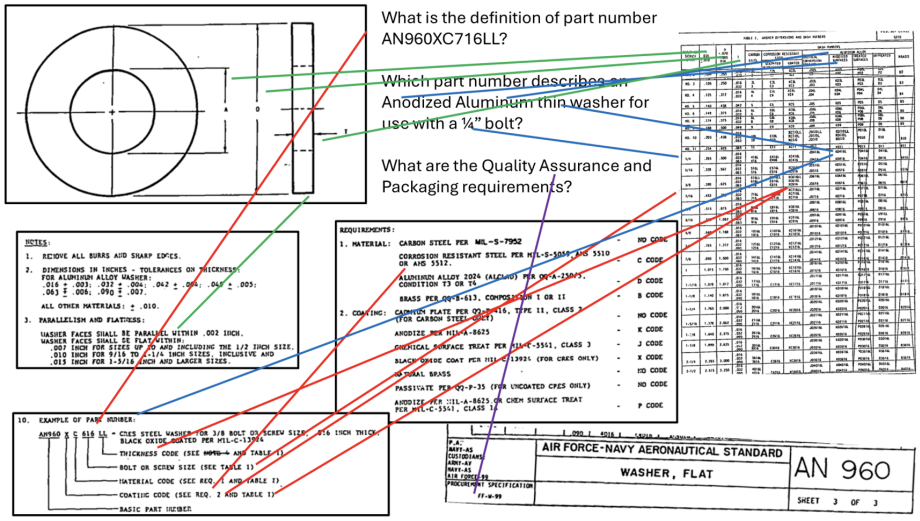
OnQue's digitalization approach included two prongs: information extraction (including metadata, sentences, and tabular data) and classification and standardization (including sentence classification, pattern recognition, and tabular data standardization). The whole system was intended to support search, comparison, analysis, and export. Through the process of implementing OnQue, SAE learned that standards as written are usually not easily readable by machines. AI tools, which can help the process, need to be able to handle ambiguity, classify information types, and recognize conflicting statements. Collaboration between SDOs, an agile approach, and requirements gathering is needed.

SAE has also undertaken several "voice of consumer" (VoC) efforts, including work with industry on standards such as product life-cycle management systems, government feedback, and standards as digital models. These efforts have identified many potential benefits to digital standards, as well as a number of gaps that need to be filled to fully realize the opportunities of digitalization. The benefits and gaps are reported in Table 1.

Table 1. SAE International's Voice of Customer research on digital standards

Benefits		
Improved Efficiency	Reusability	Increased Quality
Automated Compliance	Cost Reduction	Faster Time to Market
Competitive Advantage	Traceability	Single Source of Truth
Gaps		
Modularity	Machine Readability	Digital Licensing
Interoperability	Relationships	Ontology

Fig. 1. Murder Board — Extracting data within a standard



Based on this research, SAE envisions a future in which digital standards touch on all phases of the product life-cycle, from Research & Development and early design through operations, maintenance, and decommissioning. SAE's long-term strategy towards an integrative environment identifies six areas of importance and associated tasks: education and thought leadership, standards authoring, standards conversion, digital partnerships, business plans, and industry coordination. In particular, toward the latter element, SAE has partnered with a group of industrial partners from the transportation sector to form the Digital Standards Alliance (DSA) to accomplish these goals and create testbeds for standards across domains.

2.2 Standard Parts and Materials Digital Twin — Alton Sanders

Next, the workshop heard from Alton Sanders of Boeing, who presented work on digitizing parts and materials standards. Aerospace and other industries make extensive use of standard parts such as nuts, bolts, fasteners, and connectors, as well as standard materials such as feedstock and lubricants. The quality, reliability and interchangeability of these parts throughout the manufacturing chain relies on a corpus of standards and catalogs that, in many cases, has not been updated since the 1940s. Boeing's initial digitization and digitalization efforts have focused on identifying and organizing existing notation, terminology, and references within the company's inventory specifications. Just a few of the links needed to locate and specify a standard washer are shown in Figure 1.

Tracing and following these links to understand the specifications and distinctions among a family of parts is time-consuming and tedious. Better linking and navigation of this information would reduce friction throughout the manufacturing lifecycle, from design, production and testing to operations and disposal. In particular, Sanders proposes the US government's Federal Logistics Information System (FLIS) as a testbed for digital stan-

dards experimentation. The FLIS, which maintains digital records for commodity parts in the aerospace industry, is extensively used throughout NATO and is more detailed than similar offerings. Boeing, working with the DSA, plans to create and share a FLIS trade study in the near future, taking it as the basis for an industry-wide parts ontology.

Sanders' presentation also stressed the need for joint action across many institutions and the inability of any one actor to unilaterally solve these problems. End-users are unable to support multiple SDO offerings, and SDOs are unable to provide multiple output formats to different customers. Standards also refer to each another pulling requirements from across a web of interlinked documents. SDOs and end-users should work together to create standardized format for the reference, exchange, and aggregation of standards elements.

2.3 Impediments and Challenges — Robert Wheeler

Robert Wheeler of ASME presented his thoughts on impediments in the current standards landscape. He divided the challenges into several categories, which are outlined below:

- Standards publishing
  - Standards publishing is slow to change; digital workflows cannot just mimic paper books
  - There is tension among standards development, working groups, publishers, and users.
- Workgroups and volunteers
  - Work to change content in standards is driven by committees, who are experts in a given field, not in technical writing, document structure, tagging, ontologies, or graphics.
  - Most committee members write using basic word processing tools, and imposing new systems on volunteers is difficult.
  - There are many perspectives, which has advantages and disadvantages.
- SDOs and the standards development ecosystem
  - Many SDOs are small and have limited resources.
  - A large portion of standards revenue comes from resellers.
  - How do we tie together solutions? How do we support the variety of different domains?
- Broader world and AI
  - What does standards publishing become in the post-AI world?
  - How do we remain technology agnostic while supporting interoperability?

He also described several use cases for smart standards, including identifying term-definition mismatches in cross-disciplinary work, requirement inconsistencies, concept mapping, modularity, plugin support.

2.4 SC 41 Digital Standards Efforts – Jacob Collard

In one of two talks, Jacob Collard of NIST presented work on digital standards efforts in ISO/IEC JTC 1/SC 41,[3] which focuses on the internet of things (IoT) and digital twins. In 2024, the subcommittee released a reference architecture for IoT systems [1]. These are complex, dynamic, and sometimes overlapping systems, with boundaries that are often unclear. Moreover, IoT systems are relevant in such varied contexts that no single architecture could hope to capture all of them.

Instead, SC 41 proposes *architecture patterns*, structured descriptions of IoT solutions, identifying generalizable aspects of context and problem features, auxillary models, examples, and guidance that can be reused across many different applications. Patterns may also reference other patterns, so that engineers can layer together multiple patterns for a given context of use. SC 41 is currently working to build and populate a central repository of IoT patterns, including patterns that model other SC 41 standards. These patterns will provide seeds for further development, as well as improving the usebility and surveyability of SC 41's other products.

Architecture patterns are not a novel concept, their application in SC 41 is a first small step toward smart standards. They provide some structured information while allowing substantial flexibility in an area where best practices have not yet stabilized.

2.5 Linguistic Modeling for Smart Standards — Jacob Collard

Dr. Collard's second presentation focused on an ongoing NIST project to develop tools for automatically constructing semi-formal representations of linguistic content. Although the applications of these tools are broad, an initial area of interest is terminology development; structured linguistic representations can help identify inconsistencies in terminology such as circular definitions. These NIST tools have already been applied in this area to existing standards in several domains, but the ongoing work seeks to identify new application areas and use cases.

Natural language is ambiguous and context-dependent. As a result, tools that work with natural language need to be able to handle ambiguity and represent context. In standards, some of this context can be identified in document structure, supplemental models, and other content. NIST's tools represent these contexts alongside the structure of the natural language syntax, resulting in queryable graph-based term and dependency structures.

Queries over the context-sensitive natural language structure can result in the identification of informational dependencies, conflict detection, and concept maps. This supports

[3] International Organization for Standardization/International Electrotechnical Commission Joint Technical Committee 1/Subcommittee 41

collective reasoning and version management. More information is currently available in a recent bulletin on digital standards [2].

2.6 ISO/IEC Vocabulary Development — John Messina

John Messina of NIST discussed his experience developing international information technology standards with NIST. The particular focus of the talk was on the process of terminology development for standards, and how that might change with the advent of digital standards. Identifying and agreeing on terminology for a standard takes about 4 to 8 months, but parts of this pipeline could be sped up and simplified through judicious application of automation.

Today's terminology development process is split into four overlapping phases: data collection and literature review (1-3 months), gap analysis (1 month), term refinement (2-3 months), and error checking (1-4 weeks).

The first phase involves the identification of relevant terminology from across a wide corpus of potentially relevant documents such as industrial patents, research publications, product descriptions, catalogs and dictionaries. Today, the provenance of these pre-standardization terms and definitions is tracked manually, but the collection process would benefit from a better infrastructure for tracking and sorting incoming references.

Gap analysis and term refinement involve the synthesis of collected terminology into a coherent framework. One often finds that different authors use different terms for the same concept, or the same term for different concepts.[4] The synthesis of different perspectives requires clarifying distinctions between different uses, which may require the definition of new concepts that are only implicit in existing terminology.

The identification of meaning is a subtle question and must be handled with care. However, better tools for organizing, clustering and comparing proposed terminology could automate away some of the most time-consuming elements of the process, leaving more time for expert judgement and less for collation and copy/paste. Similarly, many error-checking tasks, which include checks for proper formatting, removal of colloquialism and slang, and changes to simplify foreign-language translation, could be partially automated using tools analogous to spelling and grammar check.

2.7 Towards Smart Standards — Spencer Breiner

Spencer Breiner of NIST presented a view on the new capabilities afforded by digital standards, with a focus on improving the experience of standards developers. The presentation was based on a joint publication, "Smart development for smart standards" [2]. The central thesis of the presentation is that the transition to digital standards will enable standards developers to take advantage of tools from software development to improve quality and reduce development time.

[4] Aligning divergent usage is a real challenge, since all parties consider that their own preferred terminology is obviously correct.

The presentation also proposed a conceptual distinction between digital and *computational* representations. Today's efforts towards standards digitalization typically target digital representations like XML, which captures the structure of a document but does not include structure of content in the form of natural language. Digital representations support many useful mechanisms for developers, including (i) error checking and highlighting, (ii) linking and navigation within and between documents, (iii) change management and version control, and (iv) structural analysis (e.g., circular dependency)

However, today's digital representations (mostly) leave the *content* of a standard in natural language. Unlocking additional capabilities will require encoding the meaning of a standard as well as its content. Specific content that may benefit from a computational representation includes requirements, process descriptions, data exchange, and mathematical formulae. Representing concepts more formally will enable additional error checking and testing capabilities, as well as powerful collaboration mechanisms including terminology harmonization (namespace management) and automated data exchange.

3. Discussion sessions

The comments below are collated from three discussion sessions over two days. The first was a breakout session, with the attendees divided into two groups. The second and third were plenary discussions involving all attendees.

3.1 Current landscape

Despite broad recognition of the challenges associated with existing standards formats, there is substantial confusion regarding what digital standards are (or will be), as well as the costs and benefits associated with them. Although most of the workshop attendees were already aware of the ongoing transition to digital standards, many also noted a lack of awareness among their colleagues and business leadership. Workforce training and executive education will be needed, especially because the costs of digitalization are up-front, while the benefits accrue primarily over time. Leadership requires clear returns on investment in order to make this investment and measuring and communicating these returns are both difficult.

One sentiment echoed by many participants throughout the meeting was the need for a comprehensive US strategy on digital standards. One participant noted we need "much more aggressive action" in this sphere. The current national standards strategy [3] focuses primarily on critical and emerging technologies, and could be extended to include an additional plank on digitalization, taking the recently released Department of War (DoW) Digital Standards Strategy [4] as a starting point. The document outlines current DoW activities to establish a digital standards ecosystem and its relationship with ongoing changes to acquisition processes and model-based systems engineering. The report identifies several guiding principles for standards digitalization, as well as five work streams furthering these goals, including both technical and institutional efforts.

Another encouraging development is the creation and growth of the Digital Standards Alliance (DSA), a joint effort to develop digital standards primarily within the automotive and aerospace industries. The group aims to develop infrastructure and best practices for standards digitalization and to develop proof-of-concept demonstrations of the value of digital standards. For example, the DSA recently released a guide for writing "digital-ready" standards [5], identifying best practices (e.g., table layouts) for standard authors to use *now* that will support *future* efforts towards digitalization.

SDO representatives also described ongoing work within their organizations. Several work efforts focus on the development of uniform terminology and formal taxonomies with an eye toward the harmonization of existing standards. Many SDOs have already transitioned to XML documents for flexibility in the delivery of standards to multiple output channels. However, there is also a "long tail" of smaller SDOs with narrower focus and more limited resources. Shared frameworks and tools for digitalization would help diffuse transition costs and encourage uniformity across SDOs.

Several current digitalization initiatives are driven by the need to support other digitalization processes. For example, the DoW envisions parts standards that include directly embedded geometric representations. By standardizing shared digital representations, the DoW aims to simplify downstream processes in acquisitions, manufacturing, and metrology by ensuring a single source of truth and terminology. Similarly, digital standards for measurement, testing, and calibration allow independent equipment manufacturers to support an interoperable measurement certification and validation system.

3.2 Use cases & requirements

A large portion of the discussion targeted potential use cases for digital standards and the consequent technical requirements that would be needed to support these uses. Some of these are focused on end-users, while others support various facets of the development process itself.

3.2.1 User-facing

The utility of digital standards for end-users is relatively well-studied [6]. Several SDO representatives discussed internal "voice-of-the-consumer" (VOC) research. Primary among the anticipated benefits are improvements in process efficiency, especially contextualized extraction and delivery of (only) relevant information at the point of use. By setting uniform mechanisms for data exchange, digital standards are also expected to reduce friction in both market processes (e.g., quotes, procurement, and contracting) and regulatory compliance. Longer-term goals included automated conformance testing, including synthesis of multiple standards within a given context.

Broad adoption will require a more simplified and uniform interface for accessing standards data across SDOs. The identification and selection of relevant standards are also challenges, especially when multiple standards overlap. Better mechanisms for assessing

standards' quality or maturity would be of great value, but this remains a difficult problem both theoretically and institutionally.

3.2.2 Developer-facing

Though not as well-documented, there are many (perhaps more) use cases for developers, with the potential to improve both quality and timeliness of standards development processes. These fall into three rough classes: process support, digital embeddings, and content analysis.

A centralized repository of machine-readable documents allows standards developers to take advantage of powerful software development tools. Version control software provides automation and guided processes that could help standards committees track and collate and organize comments and contributions. Automated routines attached to the repositories can route submitted issues to relevant developers, and initiate processes for update and review. This should speed up change propagation so that updates to a reference standard automatically trigger updates or targeted reviews among its dependencies.

Additional benefits stem from the embedding of digital models directly into future standards, supplementing and translating (some of) the existing natural language content. Parts standards could be equipped with three-dimensional models, uncertainties, and tolerances. Metrology standards may include machine-readable instructions for performing a measurement and analyzing the resulting data. Specifying data structures or schemas within a standard eases information exchange, encourages shared tooling between many parties, and reduces the mental load on developers verifying model specifications.

Machine-readable standards are also more amenable to computational analysis. This will improve standards' quality by allowing automated testing and support that has not been available in the past. For example, terminological definitions and references form a graph that should not contain cycles. This requirement can be difficult for authors to track; experiments have identified loops involving as many 9+ steps — but once exposed in machine-readable format, problems like these are easy to catch and repair.

Natural language processing opens up a wider range of possibilities by engaging directly with the content of a standard. One target area is the identification of inconsistencies and ambiguities with existing standards, a task that goes hand-in-hand with the production of digital representations. Another is to align language across multiple sources, helping standards authors map out and maintain the subtle distinctions (or lack thereof) in a community's use of terminology. Even before a committee's work begins, there is some evidence that AI may be useful for synthesizing stakeholders' perspectives into a "zero draft" to spur committee discussions.

3.3 Institutional considerations

Workshop participants generally agreed that the shift to digital standards will require substantial changes in the business models of SDOs. The form these changes will take is less

clear, but many expect substantial changes to content delivery, customer interaction, and compression of timelines for development processes.

3.3.1 Content Delivery

Although traditionally conceived as linear documents, in some ways standards resemble "choose your own adventure" stories, since many clauses are only relevant in limited contexts. One major goal for digital standards is filtering by context so that end-users can be presented with precisely the relevant information needed for a particular task. This encourages atomization of standards' content, since each definition and requirement must be individually identifiable and accessible via an API[5].

If this is the case, today's linear documents may be superfluous. However, today standards are issued "as a whole," and it is the user's responsibility to identify relevance. This is no small challenge, and the consequences for omitting a requirement may be severe, so serious considerations about liability and division-of-labor are warranted. A corporate representative emphasized the need for rapid policy action, given that software companies today are already marketing products with capabilities like these, regardless of licensing and intellectual property challenges.

3.3.2 Customer Interaction

Historically, the business model of SDOs has been based on the publication and sale of standards documents, even as those documents migrated from paper to PDF. As access shifts from downloads to API calls, this becomes more difficult, especially when fragments of multiple standards are aggregated. SDOs will need to experiment with other revenue streams, such as metered or subscription-based access.

As noted above, customers are much more likely to adopt digital standards if access and billing mechanisms are interoperable across SDOs. This will require SDOs to work with each other and their customers to agree on access and exchange mechanisms for standards data. It would also be helpful to establish a more uniform intellectual property regime for the standards ecosystem, in place of today's patchwork of SDO-specific rules and limitations. The assembly of a test set of unencumbered standards for experimentation and technological benchmarking would be a good first step in this direction.

3.3.3 Development Timelines

User demand for up-to-date standards, especially in critical and emerging technologies, has already led to demands for substantially shorter timelines for standards committees across many organizations. As standards become more like software products, this trend is expected to continue, especially when bugs or security vulnerabilities built into the standard need to be patched. At the same time, rushed committees lead to bad standards, and "getting it right" is ultimately more important than "getting it quick".

[5] Application Programming Interface

Better mechanisms for aligning on and incorporating provisional and pre-standardization recommendations could also help alleviate pressure on standards committees. Standards already distinguish between requirements and recommendations, but a clearer separation between "core" material (settled best-practice), and "peripheral" specifications (subject to change) would help with faster dissemination of new methods without locking into suboptimal decisions.

4. Next Steps

While it is clear that the move towards digital standards is gaining steam, there is still much work to be done before the standards ecosystem reaches a new equilibrium. Fulfilling the promise of digital standards will require large-scale coordination, institutional change, technological development, and workforce development. These four areas are all ripe for additional progress.

As mentioned above, workshop participants explicitly called for the development of a U.S. national strategy for digital standards. Digitalization should be included as an explicit plank in ANSI's national standards strategy, complementing the current focus on critical and emerging technologies. Indeed, support technology for standards development is needed to shorten standards development timelines.

To date, most digital standards pilot projects have been internal to a single SDO, but most participants agree that a successful digital standards ecosystem will require representations and tooling that are interoperable across SDOs. This will require coordination across SDOs and their end-users, possibly mediated by government or other neutral parties. Shared development and off-the-shelf tooling will likely be necessary for adoption by small- and medium-sized businesses (and smaller SDOs), who do not have the resources to implement custom software products.

At the same time, we still do not know precisely *what* digital standards will be, or how to produce and maintain them. More experimentation is needed, along with broad dissemination of results and best practices. The Digital Standards Alliance (DSA) is one forum for this type of activity, coordinating to identify and address gaps in existing practice. Current work aims to address the integration of computer aided design and manufacturing, automated compliance mechanisms, and persistent identifiers for standard elements, among other projects. DSA and other forums for coordination and exchange can speed up development and encourage coherence between parallel digitalization efforts.

Finally, a great deal of work is needed to prepare today's workforce for digital standards. Education and training for digital standards are needed from the shop floor to the executive suite. The meeting's participants called for additional workshops and events like this one to help spread the word about the future of digital standards, ideally casting a broader net to bring in more participants from *outside* the existing digital standards community.

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