



Digital Standards Alliance™ Recommended Practice

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Digital Modeling of the Bending Process to Support Automated Compliance: Pilot Method, Evaluation, and Lessons Learned

Rationale

Aerospace organizations operate numerous distinct yet interdependent engineering, manufacturing, supply chain, and sustainment processes, each governed by requirements and parameters drawn from customer, government, internal, and industry standards. Integrating requirements and parameters from industry standards into these processes remains a largely manual endeavor that requires substantial time, effort, and domain expertise. Qualified personnel must identify, interpret, transform, implement, and verify the relevant standards information before it can be applied in context. Because most standards are still delivered as primarily human-readable documents, whether in hard copy or document-based electronic formats such as PDF, they do not carry embedded, machine-interpretable meaning. This increases the risk of inconsistent interpretation, manual error, rework, delay, increased cost, and heightened safety or compliance risk.

Digital-centric techniques are emerging to address these challenges by representing standards information in structured forms that can be interpreted, reused, and connected to downstream workflows. The Digital Standards Alliance™ (DSA), an industry consortium focused on standards data integration and digital transformation for the mobility industry, convened Lockheed Martin, SAE International®, and ASTM International to conduct a pilot to evaluate whether requirements in industry standards can be represented as structured entities with explicit parameters, allowable values, and traceable relationships. The pilot focused on a bounded aerospace manufacturing use case involving a bending-process requirement and evaluated whether such a model is feasible, useful to standards users, and capable of supporting greater machine interoperability.

For aerospace manufacturing organizations, this form of delivery has significant implications. Requirements can be presented at the point of use, process or test results can be evaluated automatically against applicable criteria, and the impact of standards revisions can be assessed computationally. Together, these capabilities reduce the need for users to search, interpret, and manually compare document-based requirements while improving traceability across execution, evaluation, and change management. In short, digital standards have the potential to move compliance from a labor-intensive, retrospective activity to an integrated, real-time capability with a continuous, auditable evidence trail.

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1. Scope

The Digital Standards Alliance™ (DSA) consortium's charter is to accelerate an aerospace industry shift toward specifications and standards built on a digitally interpretable and actionable foundation, i.e., a digital standard. The DSA approach emphasizes practical experimentation and cross-industry collaboration via pilot projects to explore and define prototype digital standards. This pilot examined a flow-down use case involving a single acceptance test requirement within an aerospace material specification. The material specification references another standard that defines the detailed requirements governing conduct of the acceptance test. This flow-down thread represents a typical use case for compliance and verification, where there are cross-references between topically focused yet distinct specifications and standards. A prototype digital model-based structure encapsulated this requirement flow-down thread to support point-of-need application within the general use case. The DSA conducted this pilot in partnership with Lockheed Martin, SAE International®, and ASTM International.

The specific thread for the pilot originated with a ductility requirement (and test) within the SAE International Aerospace Material Specification standard AMS5528J, focused on a corrosion-resistant precipitation hardening steel. The ductility requirement references the ASTM International standard ASTM E290-22, which defines the bending method. The relevant portions of both standards were incorporated into a single digital model using the AuroslQ executable intelligence platform. The modeling process identified and characterized the full set of information objects in the relevant sections of the two standards. These two standards were chosen because they represent a common pattern in aerospace manufacturing: a general process standard that defines a procedure, paired with a material-specific standard that defines the criteria that a procedure must satisfy for a given material.

2. Introduction

The aerospace industry operates within a complex web of interrelated engineering requirements. Every part and assembly produced for an aircraft is governed by a layered hierarchy of specifications, including customer requirements, internal engineering standards, government regulations, and externally published industry standards maintained by standards development organizations (SDOs) such as SAE International® and ASTM International. These standards define not only what materials and components must achieve, but how they must be tested, validated, and documented to demonstrate compliance. They are, in a practical sense, the technical foundation on which execution rests.

The scope of this standards landscape is broad. It includes heat treatment of metallic materials, torque specifications for fasteners used in safety-critical applications, tensile testing of structural materials, bending behavior of formed metals, surface-treatment processes, and thousands of other specialized requirements expressed within standards. For any process, a subject matter expert may need to identify, interpret, and implement requirements drawn from dozens of standards while ensuring that internal work instructions and quality records remain aligned as those standards evolve. This complexity is a known challenge, but its cost is often underappreciated. When standards requirements are correctly understood, faithfully implemented, and demonstrably traceable, aerospace organizations can deliver products with confidence in their compliance posture. When they are misinterpreted or mistranslated into workflow guidance, the consequences can range from costly rework and audit findings to safety issues and airworthiness risks.

Standards are authoritative consensus documents that are developed to support broad and reliable application across a range of use cases, organizations, and operating environments. To achieve this breadth, standards committees must balance specificity with flexibility, providing requirements that are clear enough to support consistent implementation while allowing appropriate judgment in context. Moving from document-based standards to digital model-based standards can make this balance more difficult because modeled standards often require explicit parameters, defined relationships, and machine-interpretable logic. As modeled standards evolve, it will be essential to preserve the intent and authority of the source standard while representing allowable flexibility in forms that digital systems can interpret and apply consistently.

This paper reports on a pilot that digitally modeled a bending process by combining ASTM E290-22, which defines the test method, with AMS5528J, which defines material-specific acceptance expectations, into a reusable, parameterized model intended to support instanced execution and automated qualitative evaluation. It describes the pilot scope, the modularization of standards content into discrete information objects, the parameter and relationship structures used to connect those objects to process steps, and the evaluation feedback received from original equipment manufacturers (OEMs) and industry reviewers. The paper also identifies recurring barriers to scalable automation, including parameter governance, clause-level provenance, consistent decomposition, and standardized relationship semantics, and concludes with practical recommendations that organizations can use when modeling manufacturing standards for downstream automation.

This recommended practice does not advocate any specific tool platform. The AuroslQ system is described as the implementation environment used in this pilot, but the findings and recommendations are framed in platform-agnostic terms. The goal is to assess what worked, what did not, and what manufacturers, standards organizations, and tool vendors would need to do to move digital standards from proof of concept to operational capability.

3. References

3.1 Applicable Documents

The following publications were referenced during the development of this document. Where appropriate, documents are cited.

ASTM International. (2022). *Standard test methods for bend testing of material for ductility* (ASTM Standard No. ASTM E290-22). <https://doi.org/10.1520/E0290-22>

SAE International. (2019). *Steel, corrosion-resistant, sheet, strip, and plate 17cr - 7.1ni - 1.1al solution heat treated, precipitation hardenable* (SAE Standard No. AMS5528J). <https://doi.org/10.4271/AMS5528J>

4. Problem Statement

Aerospace organizations increasingly rely on industry standards to define engineering, manufacturing, verification, and compliance requirements. In some industries, standards can influence a significant portion¹ of a product's design and manufacturing processes, including heat treatment, fastener torque, material testing, and other safety- or quality-critical activities.

Despite the critical role they play, industry standards are primarily delivered to users today as human-readable documents on paper or in document-centric electronic formats, such as PDF, or in XML/HTML implementations that do not provide sufficient semantic structure for automated interpretation. This paper uses document-based delivery as shorthand for formats that preserve human-readable standards content but do not, by themselves, provide the semantic structure needed for automated interpretation.

While these formats are a reliable medium for preserving and distributing human-readable text, they do not provide the embedded, machine-interpretable structure needed for computational use, automated decision-making, or direct integration with manufacturing execution systems (MES).

As a result, significant work is required to move from reading a standard to executing and proving compliance with the work it governs. A manufacturer must:

- Identify the relevant adjacent standards applicable to their process, part, or material.
- Develop or update internal policies and procedures that translate the requirements of those standards into organizational practices.

¹ One major aerospace manufacturer reported that almost 40% of design requirements and over 35% of manufacturing requirements were influenced or defined by industry and internal standards.

- Create or revise work instructions that operationalize those policies in a form that production personnel can execute.
- Execute those work instructions in a manner that is demonstrably compliant with the relevant standards.
- Prove that compliance was achieved through documentation, quality records, and audit evidence that trace each action back to the specific requirement it satisfies.
- Monitor the standard for future revisions and evaluate their impact on implemented requirements, procedures, and compliance evidence.

This work is time-consuming and structurally error-prone. Translating a human-readable, document-based standard into work instructions requires interpretation of text that may depend on context elsewhere in the same document or in referenced standards. Different engineers may interpret the same requirement differently, and organizations may lack reliable mechanisms to detect when a standards revision affects requirements already implemented in procedures. This could result in unnecessary duplication of effort, inconsistent implementation, and persistent risk that compliance records do not accurately reflect the standard's intent.

The path from a requirements statement in an industry standard to a verified action can take weeks or months to traverse. For organizations managing hundreds of active standards across multiple product lines and manufacturing sites through multiple suppliers and subcontractors, it represents an enormous and largely invisible operational cost.

This pilot was structured around three research questions:

- Can the requirements of two interdependent industry standards (a general process or test method and a material specification) be faithfully represented in a single reusable, parameterized digital model that provides structured support for requirement evaluation?
- Does such a model improve usability and traceability compared to conventional document-based workflows as assessed by practitioners in engineering, specification modeling, and requirements exchange roles?
- What structural, semantic, and governance capabilities are needed to move from a machine-readable artifact to a consistently machine-interpretable and machine-actionable resource at industry scale?

With this pilot, the DSA sought to move beyond digitization toward digitalization of the bending process. **Digitization** converts analog or document-based information into digital form without materially changing the underlying process. **Digitalization**, in contrast, deconstructs and reassembles standards content into useful components and data objects so that it can be machine-readable, machine-interpretable, and fit-for-purpose.

5. Pilot Scope and Modeling Method

The DSA selected the bending process as the subject of the pilot because it is a concise, well-bounded, and broadly applicable process. Bending metal is ubiquitous in aerospace manufacturing, and the controlling criteria span a layered combination of standards. In this case, one standard defines the procedure while other material-specific standards specify the pass/fail criteria, which can vary by material.

The two standards incorporated into the pilot model were:

- **ASTM E290-22**, *Standard Test Methods for Bend Testing of Material for Ductility*, provides test methods which cover bend testing for ductility of materials.
- **AMS5528J**, an SAE Aerospace Material Specification that references the ASTM E290-22 bending process method and defines the expected bending behavior (the acceptance criteria) for the specific metal alloy it covers. AMS5528J is one of several material specifications that define the composition and properties for standard metals used in aerospace manufacturing.

Together, these standards provide a clear illustration of cross-standard dependencies found across industry standards. In many cases, these dependencies are complex, requiring standards users to reference and analyze multiple standards to identify all the relevant requirements for a single process.

These two standards were combined into a single orchestrated model because, in practice, an organization performing the bending process must apply both simultaneously: ASTM E290-22 governs the “how,” and AMS5528J governs the “what must be achieved.” Representing them separately would have reproduced the fragmentation that makes document-based workflows costly. Representing them together, with explicit cross-standard links, reflects how the process is executed and evaluated in real-world environments.

The pilot scope covered one type of bend test, the free-bend test, and the clauses, figures, tables, and definitions directly relevant to conducting and evaluating the free-bending process. Material properties addressed by AMS5528J outside the scope of the bending process (such as chemical composition, heat treatment requirements, and other mechanical processes) were intentionally excluded from this pilot model. This scoping decision reflects a practical principle for digital standards modeling: begin with a defined use case and model the subset of each standard that the use case requires, rather than attempting to digitalize the entirety of a standard before any practical value can be demonstrated. Similarly for this reason, the pilot limited scope to items characterized as “requirements” to allow a focus on those elements relevant to the actionable model for the process.

The modeling followed the steps shown in [Table 1](#).

TABLE 1 Pilot modeling steps

Step 1: Modularization	Step 2: Characterization	Step 3: Parameterization	Step 4: Modeling	Step 5: Orchestration/ Integration
Partitioning content into discrete objects— governed, composable, encapsulating —bounded where authority and use are singular.	Characterizing modules through structured symbolic metadata— actionable, standardized, specialized —enabling explicit context-of-use, interoperability, and a continuously evolving ontology.	Formalizing structured symbolic variables— semantic, deferred, threaded —created once, resolved at execution, matured by adoption and reuse.	Abstracting into structured symbolic models— structured, exchangeable, executable —to produce deterministic, interoperable, and reusable outcomes.	Configuring modules’ orchestration and interaction with the ecosystem, machines, and people— scalable, adaptive, operational —governing not a model’s content but its behavior in the world.

The modeling process identified and characterized the full set of information objects in the relevant parts of the two standards:

- **Requirements (122):** These statements are actions that must be performed and tracked.
- **Allowable statements (5):** These describe actions that can be performed, but are not required.
- **Categorization statements (14):** These define or label a category used within the standard (e.g., “there are four methods for ductility testing”).
- **Definitions (30):** These define terms within the standard.
- **Informative statements (30):** These provide additional context and information.
- **References (5):** These are references to other standards and documents.

Importantly, the modeling avoided the use of any artificial intelligence (AI) tooling. This approach was to allow clearer observation of the process, analysis of the effort, and identification of the benefits and challenges while avoiding added complexity that conversion through such tools could introduce.

The bending process was decomposed by a staff engineer at AuroslQ into 198 discrete steps across four phases: 29 steps to prepare the metal sample, 144 steps to perform the process, 18 steps to evaluate the process results, and 7 steps to report the findings. Parameters were defined and linked throughout, enabling the single model to be reused across different material standards by adjusting the relevant input values.

The resulting digital model received multi-perspective reviews from:

- A member of the technical committee that curates the standard
- Technical experts in requirements engineering from major aerospace OEMs
- Resources with expertise in requirements engineering, specification modeling, and model-based systems engineering (MBSE)

Each reviewer assessed the model from the perspective of their role and organization.

5.1 Modularization: From Documents to Objects

The foundational conceptual shift underlying the pilot methodology is the transition from document-based standards to an object-oriented model of standards information.² In a conventional document-based standard, requirements, definitions, categorizations, and procedural guidance are embedded together in a sequential prose document, or found distributed within paragraphs, tables, and figures. Their meaning depends on context established elsewhere in the document (or other documents). Their boundaries are determined by editorial convention rather than semantic structure, and their attributes are often implicit rather than explicit.

The modeling approach employed in this pilot operationalizes a different perspective: that a standard is not fundamentally a document but a collection of individual information objects, each with a defined type, set of attributes, relationship to other objects, and function in the context of process or workflow execution. This shift determines how:

- Information is extracted from source text and stored
- It can be queried and filtered, and
- It can be connected to downstream automation systems.

Each discrete unit of information extracted from the two source standards was characterized and stored as a **module** (referred to in the AuroslQ system as a Knowledge Packet or K-PAC).

The module is the fundamental unit of this model. Modularization partitions standards information into discrete objects, but the boundaries of those objects are not dictated solely by the way the source text is organized on the page. Standards are intentionally written as human-readable documents that support consensus review, interpretation, and implementation by people; they are not typically authored to expose the semantic boundaries needed for downstream modeling. Modular boundaries are driven by the governance and use of the information, where a module is governed by a single authority or cycle, reused discretely, applied at a distinct point in a process by one user, place, object, and time. Boundary indicators include independence (usable without context), repetition (duplication with only contextual variation), dependence (used only under certain conditions), branches (decision points), volatility (changes at its own rate), and references (from elsewhere).

² It is important to recognize that the process was a conversion of existing standards. A different approach would be taken if/when authoring standards into a similar model-based configuration.

5.2 Information Characterization: The Module Taxonomy

The first phase of the modeling process was to read each relevant clause, table, and figure in the two source standards and modularize the information. In this step, the modularized information was then characterized. Characterization encodes each module with structured symbolic metadata that users, systems, applications, and other modules can leverage directly. Formalization defines each characteristic as a schema in its own right; not a label but a governed structure with a name, description, format, validation rules, and permissible values. Configuration determines how that schema behaves across the system: where each characteristic is available, where obligatory, and under what conditions it applies. Finally, application populates or derives the module-specific data. This process required disciplined judgment: the modeler characterized each element based on its function in the process, regardless of how the information was organized in the source prose.

The pilot used three characterizations that were directly or indirectly necessary for the modeling. Other standards may require further characterizations.

- **Test ("Free Bend" which was IN SCOPE and "Other" which was OUT OF SCOPE):** Enabled the modeler to know which "modules" were IN SCOPE to be modeled as the ASTM standard contained other test methods that were not in scope.
- **Type:** Characterized modules to then indicate if it was IN or OUT of scope since only "Requirements" were included in scope of this pilot.
- **Process Step:** Identified where each module would be provisioned within the chronology of the bend test, including sample preparation, test execution, evaluation, and reporting

"Process Step" was the most critical characterization performed and the only one truly used in the model (the other two just enabled the exclusion of out-of-scope items from the model).

The taxonomy used in this pilot recognized the following module types in [Table 2](#).

TABLE 2 Module types and their roles in the pilot model

Module Type	Indicators Used to Identify Type	Role in Model
Requirement³	"Must"/"Shall" or similar language used to distinguish requirements from other characterizations	Mandatory condition on the process, specimen, equipment, or outcome. Drives compliance evaluation.
Allowable	"May"/"Can" language	Permitted variation or optional condition; defines the boundary of acceptable practice.
Categorization	Categorical descriptor	Labels a specimen, test, or outcome into a defined category (e.g., type of bend, specimen geometry class).
Definition⁴	Explanatory statement	Establishes unambiguous meaning for a term used in requirements or process steps.
Informative statement	Contextual/non-normative	Provides background, rationale, or guidance; not directly enforceable but supports understanding.
Reference	Pointer to external content	Links to another standard, figure, table, or clause on which a requirement depends.

³ The pilot was liberal in applying the characterization "requirement" to include as many possible edge cases (flavors/types/variations) of a requirement in the pilot as possible since the objective was to demonstrate feasibility, which is better done across a wide variation. This pilot was not intended to define an approach to information characterization.

⁴ For this pilot, there was no distinction between definitions for normative versus non-normative terms; however, this may be something standards organizations want to do.

This characterization step of the modeling process is most dependent on subject matter experts'⁵ interpretation. Determining whether a given statement constitutes a mandatory requirement or a permitted allowable, for example, requires understanding the context in which the statement appears and the conventions of the standards organization that published the standard. The modeler must make and document a characterization judgment for each statement, and that judgment becomes part of the audit trail associated with the resulting module.

In this pilot, the modeling process identified a total of 206 non-process information objects across the two standards: 122 requirements, 5 allowable statements, 14 categorization statements, 30 definitions, 30 informative statements, and 5 references. The substantial proportion of requirements (nearly 60% of all characterized objects) reflects the normative information found in ASTM E290-22. For context, these artifacts came from around 12 pages of information from the document-based standards.

The 30 definitions identified by the modeler from the source standards were treated with particular care because definitions underpin the interpretation of every requirement that uses the defined terms. Each definition module was explicitly linked to every requirement module that uses the defined term, creating a traversable semantic dependency that allows a model consumer to access the definition of any term directly from the requirement in which it appears, without navigating to a separate definitions section. The modeler did not distinguish between normative and non-normative definitions; the pilot did not evaluate the implications of that choice.

5.3 Parameterization: Extraction and Governance

Once every statement was characterized into a module type, the next phase was to identify the parameters embedded within those objects. A parameter is any variable quantity, controlled value, or enumerated option whose value is supplied when the model is executed in a specific instance. Formalizing a variable as a parameter is a design decision that balances the benefits of reuse and adaptability against the governance effort required to name, define, constrain, and maintain that parameter consistently.

Parameters give the model reusable inputs whose values are supplied when the model is used in a specific case. This enables a single process model to be reused across different material specifications by supplying the applicable values when the model is executed. In the bending process pilot, the sequence of steps, requirement types, parameter names, and parameter types remained consistent, while the material-specific acceptance criteria from AMS5528J were represented as parameter values. This parameterization strategy avoids hard-coding those criteria into the model and allows the same ASTM E290-22-based bending process to be adapted for other material specifications that reference this standard. This produces one flexible model that can be adapted for different materials, rather than requiring a separate model for each material.

Parameters must be clearly named, defined, and governed so that users, systems, and other modules interpret them consistently. When a parameter needs to be reused or shared across models, stronger governance may be needed so it can function as a trusted, reusable information object.

Parameters are uniquely identified and linked across modules wherever the same parameter appears in multiple requirements. This linkage enables a model consumer or downstream automation system to identify all requirements that are affected by a given parameter value and to evaluate all of them simultaneously when a process result is recorded.

The pilot model was also designed with reuse in mind.

⁵ From the beginning, the pilot team dictated that no AI tools would be used to create the model. Rather, an experienced modeler created the model manually based on the information in the target standards. There were multiple reasons for this modeling approach, but primarily it was to enable the modeler to identify firsthand the various challenges and opportunities that the modeling process generated as it progressed.

FIGURE 1 Parameter mapping visualization

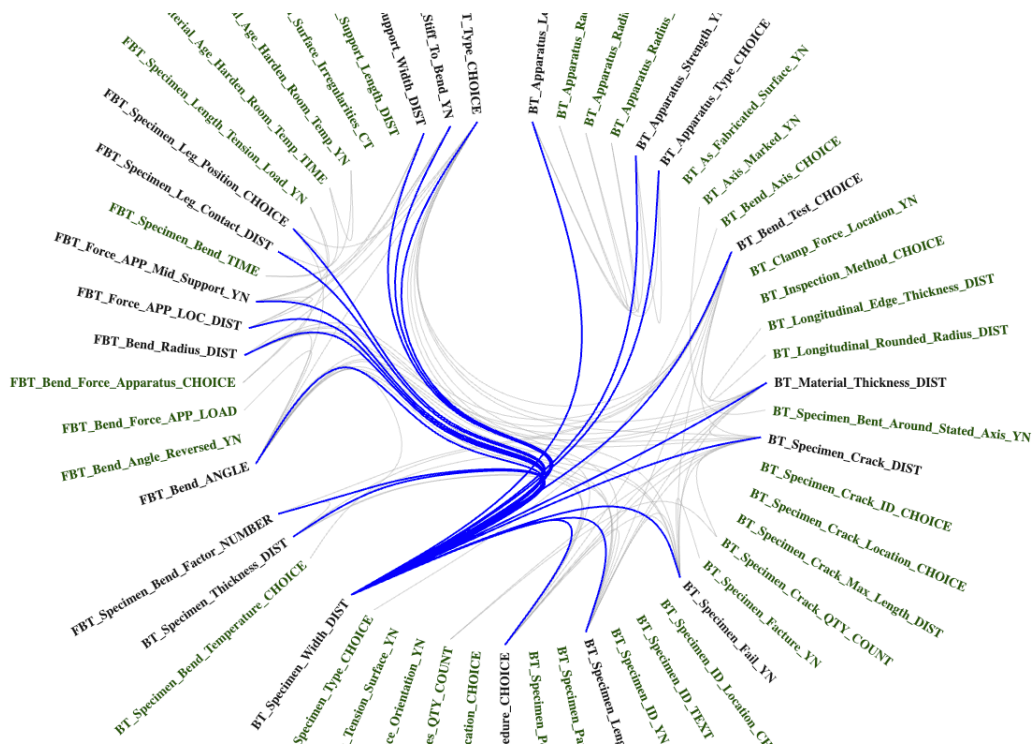


FIGURE 2 Example parameters and their relationships

Parameter	Defined In (K-PAC)	Defined In (CoP)	Maturity Level	Days in State	Response	Condition
width		ASTM				
FBT_Support_Width_DIST	ASTM-219	ASTM	Contracted	143	ASTM-89 X_ASTM-89	
FBT_Specimen_Width_DIST	X_ASTM-215	X_ASTM	Contracted	143		X_ASTM-88 X_ASTM-89
BT_Specimen_Width_DIST	ASTM-215	ASTM	Contracted	143	ASTM-129 SAE-21	ASTM-88 ASTM-89 ASTM-92 ASTM-117 ASTM-122 ASTM-127 ASTM-132 ASTM-201
BT_Material_Width_DIST		ASTM	Local	141		ASTM-133

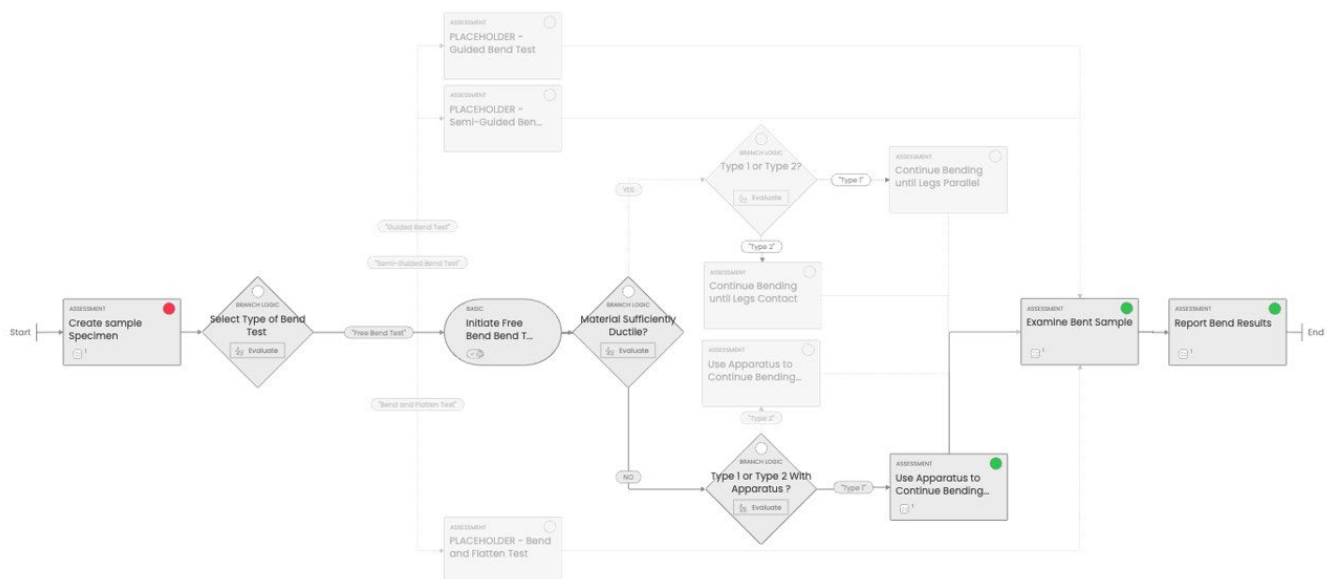
5.4 Activity Modeling: Creating Activity Objects from Modules

Following module characterization and parameter identification, the pilot team modeled the individual activities that make up the in-scope free-bend test as separate activity objects. The purpose of this phase was not yet to organize those activities into the full free-bend test model, but to define each step as a discrete reusable building block. Each activity described or implied by ASTM E290-22 was modeled separately, along with the inputs, actions, outputs, and relevant parameters needed to represent that activity consistently. These activity objects were created first so they could later be sequenced, linked, and governed as part of the complete free-bend orchestration model (described in the last step of the modeling method).

The in-scope free-bend process described in ASTM E290-22 was decomposed into 198 discrete activity objects, organized into four sequential phases.

TABLE 3 Phase structure and step counts for the pilot model

Phase	Step Count	Description
Sample preparation	29	All activities required to select, cut, measure, and condition the metal specimen prior to bending, including dimensional checks and specimen identification.
Process execution	144	The full sequence of activities in the process to mount the specimen, configure the bending apparatus, apply force, and record the bending behavior, including any conditional branching for different specimen geometries or bend configurations. This level of granularity was selected to support guided execution, conditional branching, and downstream automation.
Evaluation	18	Activities to assess the bent specimen against the pass/fail and measurement criteria defined in ASTM E290-22 and the material-specific requirements of AMS5528J and to record results against each applicable requirement.
Reporting	7	Activities to compile, format, and record the process outcome as a compliance record traceable to the applicable standard revision and specimen identity.
Total	198	

FIGURE 3 Bending test process highlighting relevant part of flow to selected requirements

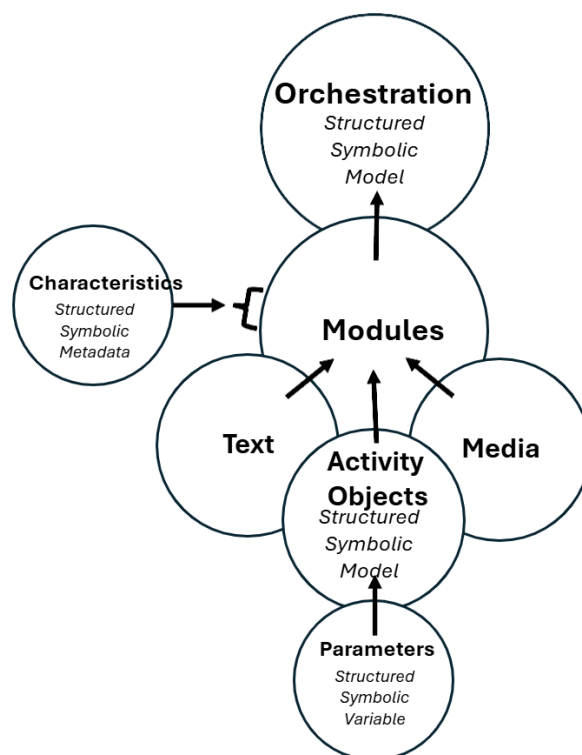
5.5 Orchestration and Integration: Representing the Entire Free-Bend Test

In the final step of the modeling method, the individual activity objects, parameters, and information created earlier in the method were organized into an integrated orchestration model. This step arranged the activity objects into the logical sequence required to execute the ASTM E290-22 free-bend test and connected each step to the requirements, parameters, inputs, outputs, and decision points needed to support execution and evaluation.

The orchestration model differs from the activity objects described in the previous section. The activity objects define the individual activities that make up the free-bend test; the orchestration model defines how those activities work together as a complete process. It captures the temporal and logical structure of the test, including the order in which actions are performed, the conditions under which certain actions are required or optional, and the points at which one step's outcome determines the next path.

Each activity object was assigned a defined position in the sequence, a defined set of inputs, a defined action, and a defined set of outputs. Where the process includes conditional logic—for example, where different specimen geometries require different preparation procedures—those branches were represented as decision points, with each branch carrying the requirements and parameters applicable to that path. Because the same governed objects can be reused in more than one orchestration, this approach supports reuse while preserving traceability to the authoritative source content.

FIGURE 4 Relationships between modeling elements



5.6 Tool Implementation and Platform Agnosticism

The pilot model was implemented in the AuroslQ executable intelligence platform, which provides a purpose-built environment for authoring, testing, navigating, and querying model-based representations of text-based source material.

The use of AuroslQ as the implementation environment is a practical detail of this pilot, not an architectural requirement of the modeling methodology. A central concern raised by reviewers and addressed in the design of the pilot was the risk of vendor lock-in: the possibility that the value of the model would be confined to users of a specific tool platform, reducing the broader utility of the digital standards content and creating a barrier to adoption by organizations using different toolchains.

This concern was addressed by designing the model to be exportable in open, platform-agnostic data formats. The model content (the modules, their attributes, their parameters, and their relationships) can be exported as JSON or XML, enabling the data to be ingested by other systems without requiring access to the authoring tool. The model owner has published documentation on its website describing the export formats and practices used to ensure that customers are not locked into the platform.

The pilot demonstrated that model content can be exported in structured formats, such as JSON or XML. However, reliable downstream interpretation requires a documented schema that defines field meanings, allowable values, and relationship semantics. A robust platform-agnostic schema should be informed by multiple standards, use cases, and modeling patterns so that it captures recurring structures rather than artifacts of one pilot or tool environment. The pilot therefore identifies schema development as an important ecosystem-level next step, not as an unmet deliverable of this individual modeling effort. The Digital Standards Alliance™ is committed to further advancing this work.

5.6.1 Modeling Effort

One objective of the pilot was to assess the effort involved. Indicative effort levels were captured across the work, with, on average, each element and parameter identification requiring 5 minutes, and then the modeling of each element requiring a further 30 minutes. Once those models were created, it took a further hour to “orchestrate” those models together into an actionable process and a further 3.4 hours to review, validate, and rationalize those models to ensure that the model functioned correctly. To give an idea of the quantity of technical content involved, this effort covered modeling 12 pages of ASTM and 1 paragraph of SAE content.

TABLE 4 Effort applied to model the scope of content

Deliverables	Quantity of Deliverables in Scope	Average Effort (manual) per Deliverable	Total Effort (manual) for Whole Pilot	Average Predicted Effort (LLM*-assisted) per Deliverable	Estimated Effort (LLM-assisted) for Whole Pilot**
Identify and Define "Module" (modularize and characterize "Modules" from the standard's original text)	175	5 minutes	14.5 hours	0.5 minute	1.5 hours
Parameterize: Identify and define variables within "Modules"	54	5 minutes	4.5 hours	0.5 minute	0.5 hour
Model: Author structured symbolic models of "Modules" using parameters	34	30 minutes	17 hours	15 minutes	8.5 hours
Orchestration of which models are consumed by the user under what conditions and in what order	1	60 minutes	1 hour	60 minutes	1 hour
Validation and Rationalization: Perform quality testing and iterate prior steps as necessary	206	1 minute	3.4 hours	0.5 minute	1.7 hours
TOTAL for Pilot: One paragraph of AMS5528 + 12 pages of ASTM E290-22 for free-bend test only			40.5 hours		13.2 hours

*Large language model

**Estimated from comparable projects

For some standards, this level of effort may be justified when evaluated against the potential return on investment. The effort could also be reduced substantially through supporting AI-enabled processes that accelerate the identification and modeling of elements and parameters. Standards organizations will need to determine how best to scale modeling efforts based on the characteristics of their standards, the types of information they contain, and how that information is used.

5.7 Evaluation Design and Results

The evaluation was conducted by reviewers representing different perspectives: the original standard technical committee, manufacturing engineers and automation practitioners, specification modeling and IT engineering, and experts in MBSE and requirements exchange. These perspectives were selected intentionally and were used to shape both the evaluation questions and the criteria applied in the review.

Reviewers were provided with a model package accessible through the AuroslQ user interface, including both the linked-object navigation views and the parameter spreadsheet view (including Excel export). The original source documents were also provided to support reference verification and clause-level comparison.

The evaluation scenarios included opening and reviewing the model, assessing its validity against the original standard, tracing requirements through their links and provenance, setting and inspecting parameters, stepping through the modeled process, interpreting evaluation outputs, and assessing the practicality of ingesting the model into downstream tools and workflows.

Quantitative measures focused on basic usability (pass/fail), estimated time-to-adapt and time-to-ingest into downstream environments, and a high-level comparison against time required to capture equivalent information from document-based standards workflows.

Qualitative measures were gathered through structured questions addressing usability, functionality, performance, workflow impact, and transferability, supplemented by open-ended feedback on problems the approach solved and new issues it introduced.

Responses were analyzed using thematic coding, and individual observations were consolidated into recurring issue categories, including traceability, parameter governance, decomposition consistency, and interoperability.

All reviewers were able to open, navigate, and use the model, meeting the baseline usability threshold for the pilot evaluation.

5.8 Constraints of the Pilot

This pilot was intentionally narrow in scope: it combined a single process (from a standard with multiple variations of that process) with a single material specification instance. As a result, the findings should be interpreted as evidence of feasibility and key design considerations, not as a broadly generalizable benchmark across other processes, materials, or standards families. However, the pilot did not identify any indications that it could not be viable when applied selectively to appropriate use cases.

The reviewer sample was also limited. The evaluation relied on a small pool of reviewers with differing degrees of familiarity with the authoring environment and with different role perspectives. Consequently, the qualitative results reflect informed practitioner and expert judgment, but they are not statistically representative and should not be treated as a comparative study of tools or user populations.

Empirical timing data was limited. Reported time-to-adapt and time-to-ingest values were often estimated or unavailable, and the pilot did not include a controlled baseline measurement against end-to-end document-based workflows. For this reason, time savings should be viewed as directional rather than definitive.

In addition, the model inherits limitations from legacy source documents. Digital modeling can surface ambiguity, contradiction, and missing definitions, but it cannot fully eliminate those issues without expert interpretation and, in some cases, clarifying guidance from the subject matter experts who contribute to and curate standards.

Finally, export evaluation was constrained by the maturity of downstream consumption. At the time of the pilot, fully specified schemas and independent consumer implementations were not consistently available, limiting the ability to validate interoperability claims end-to-end across external toolchains.

6. Outcomes and Implications

6.1 Strengths

Reviewers noted the value of representing interdependent standards together in a single model. By combining the process method standard with the material-specific acceptance criteria, the pilot reflected **how the requirements are applied in practice and reduced the need for users to manually reconcile cross-standard dependencies**. Reviewers also identified the model's fidelity of content capture as a strength, noting that the source standards were represented as discrete, navigable requirements and process steps, with source documentation and structured relationships that are difficult to achieve when working solely from document-based standards.

The model's **parameterization strategy** also demonstrated how a single process model could be adapted across multiple material specifications. Rather than hard-coding material-specific acceptance criteria into the process logic, the pilot represented those criteria as configurable parameter values, illustrating that the same process model could be adapted for other material specifications that reference the same underlying test method.

Another strength was that the model supported both **human review and automation-oriented use**. Reviewers could inspect source relationships, parameters, and process logic directly, while the structured representation provided a foundation for downstream system use.

The committee member's review confirmed that the model captured the standard's requirements, supported assessment of process completeness, and surfaced clarification opportunities. For example, the reviewer noted that requirements related to fixture use had been interpreted incorrectly by the modeler, revealing an opportunity for clarification in the source content. The committee member also highlighted the value of using a **model-based approach** to provide structured feedback on standards content and suggested that, in the future, a standard could be developed in a digital model first and then converted into a document-based draft for review and balloting. This would allow individuals on standards committees to focus more on technical content and less on document formatting.

Reviewers also emphasized the automation potential enabled by the model's structured representation. By combining an explicit process flow with parameterized requirements and traceable links, the model supports more **repeatable execution and a clearer compliance evidence trail** than manual workflows, which typically require reinterpretation and ad hoc documentation at each use. One reviewer questioned whether the digital model format would make it easier or more difficult for a laboratory to add evaluation and reporting requirements beyond those specified in the standard. This question was outside the scope of the pilot and was not explicitly tested.

From a performance and usability standpoint, reviewers reported no delays or stability issues during model navigation or review. Usability feedback was generally positive, with the caveat that the interface was more immediately accessible to users already familiar with the AuroslQ environment.

6.2 Potential Gaps and Considerations

The gaps and considerations discussed in this section should be understood as observations about the current maturity of digital standards modeling practices, not as critiques of the implementation vendor, authoring platform, or pilot model. The pilot successfully demonstrated that **standards content can be represented in a structured, navigable, and reusable form**. Reviewers' comments instead point to the additional governance, semantic alignment, provenance practices, and interoperability conventions needed to move model-based standards from bounded pilot implementations toward broader operational use.

Reviewers identified several gaps that would need to be addressed before the model could be relied upon as an interoperability asset or as a foundation for automated compliance at scale. A recurring theme was **parameter governance**. Reviewers could not always determine how parameters were derived from the source text, and **value constraints** were not always expressed in a way that distinguished open numeric ranges from closed, enumerated value sets.

Reviewers also raised concerns about **source traceability**. Although the model contains attribution, the reviewers found that tracing a modeled object back to its authoritative clause and revision was not always straightforward. This limits revision management and makes it harder for downstream users to treat the model as audit-ready evidence without rechecking the source standard.

A related consideration is **decomposition inconsistency**. Reviewers observed that there is not yet a stable rule for what constitutes a single discrete requirement, creating risk that different modelers will segment, name, and link requirements differently across a broader standards portfolio, even when starting from the same source content.

More fundamentally, reviewers noted a **semantics and ontology gap**. The pilot demonstrated that standards content can be represented in a machine-readable structure; however, machine readability alone is not sufficient for reliable downstream interpretation. Without a standardized information profile, controlled vocabulary, and consistently typed relationship structure, consuming systems may interpret model content differently across tools, organizations, or use cases. Reviewers also recognized that full semantic alignment may be difficult in the near term and should not delay the development and use of targeted models that meet defined organizational needs. Shared semantics should remain a goal, while near-term modeling efforts proceed selectively and pragmatically.

Finally, reviewers identified opportunities to improve navigation and **user experience when traversing deeply linked model content**. While the linked-object structure successfully exposed relationships that are difficult to see in document-based standards, users sometimes found it challenging to maintain context when following multiple levels of dependencies. Spreadsheet and Excel views were useful for reviewing structured data but less effective for exploring relationship context. Future implementations should provide stronger navigation aids, contextual breadcrumbs, and relationship views to help users move through complex dependency networks more efficiently.

6.3 Cross-Perspective Tensions

Reviewers highlighted the tension between **near-term implementation and broader interoperability**. An intuitive user interface can lower the barrier to entry and allow practitioners to begin using model-based standards content in targeted workflows today. At the same time, scaling beyond a specific tool or organizational implementation requires continued investment in shared semantics, governed data structures, documented schemas, and interoperable exports. Future approaches should therefore support practical adoption through usable consumption and execution tools, while advancing the underlying infrastructure needed for consistent interpretation across tools, organizations, and use cases.

A related tension exists between **fidelity to the source standard and automation-friendly restructuring**. Standards users and committees need confidence that the model preserves the authoritative prose, consensus meaning, and clause-level context of the source document. At the same time, automated execution requires the content to be decomposed, parameterized, sequenced, and linked in ways that may not mirror the organization of the original document. This reflects a broader tension between human readability and machine readability. Prose-based standards remain essential for consensus review, broad comprehension, and authoritative communication, while digital models require explicit structure, typed relationships, governed parameters, and defined constraints. Future approaches must preserve the human-readable authority of standards while adding the machine-interpretable structure needed for automation.

Reviewers also identified a tension between **standards-domain expertise and general modeling practice**. Standards organizations understand the technical intent, consensus history, terminology, and implementation context of the standards they develop, while modelers and tool providers may bring established methods from systems modeling or requirements engineering. Scalable standards modeling will require these perspectives to converge, including recognition that standards may require modeling rules that differ from those used for general systems models.

Another tension concerned the choice of **exchange and representation formats**. Some feedback pointed to SysML as an attractive target because it is increasingly used in MBSE contexts and offers a rich modeling vocabulary, while other feedback emphasized the practical need for platform-agnostic formats that can be implemented consistently across heterogeneous toolchains and industries. Reviewers stressed that any chosen format must be paired with a **documented schema** and **relationship semantics** to ensure that meaning is preserved outside the authoring environment.

These concerns may be addressed over time through platform-agnostic data models that support consistent upstream authoring while enabling fit-for-purpose downstream outputs for users.

6.4 Implications

The pilot demonstrates that it is **feasible to combine a process method standard and a material specification into a reusable digital package**. In doing so, it also demonstrates that the effort required to model a bounded standards use case can be quantified and that the act of modeling can make opportunities for clarification in legacy standards text visible in ways that are difficult to surface through conventional document-based review alone. As a result, the pilot implies that **standards modeling** should not be treated as a direct application of general systems modeling practice. Standards carry consensus intent, normative and informative distinctions, clause-level provenance, revision history, and compliance implications that may require standards-specific modeling rules. Standards organizations are therefore essential participants in defining how standards should be decomposed, characterized, parameterized, and reviewed.

The effort estimates captured during the pilot indicate that digital modeling should be applied selectively, based on the value a modeled standard is expected to provide. While the effort required for this bounded use case was quantifiable and not prohibitive, the business case will vary by standard, use case, and intended downstream application. Standards organizations should therefore establish **prioritization criteria for digitalization**, considering factors such as expected reuse across organizations or processes, frequency of use, revision cadence, safety or compliance criticality, and the degree to which structured representation would enable automation, interoperability, or more efficient implementation. Reviewer feedback also indicates that **shared semantics** are a key enabler of broader interoperability and downstream automation. The pilot demonstrated that a bounded standards use case can be modeled and used effectively within a defined implementation context, which may be sufficient to meet some organizational objectives. Consistent interpretation across tools, organizations, and standards portfolios will require additional alignment on requirement decomposition, controlled vocabularies, and relationship semantics. Organizations should therefore select an **implementation approach** that fits their near-term objectives while considering whether additional semantic structure is needed to support reuse, scaling, or cross-tool interoperability.

The pilot also underscores the distinction between converting legacy document-based standards and establishing **digital-first authoring practices** where appropriate. Converting existing documents is valuable because it can make relationships, dependencies, assumptions, and opportunities for additional clarification more visible for digital use while enabling near-term reuse. However, modeling cannot, by itself, resolve every interpretive question that may arise when authoritative prose is transformed into structured, machine-interpretable content. Some questions will continue to require expert interpretation or committee guidance. Over the long term, digital-first authoring by standards development organizations is the more durable enabler of consistency and automation, but progress is likely to be incremental and will require transitional approaches. In the interim, modeling can function as a **structured feedback mechanism** for standards development by revealing where added clarification, consistent terminology, or explicit decision criteria would improve downstream digital use.

SysML 2.0 was raised as a promising but still evolving candidate for representing or exchanging digital standards content, particularly in MBSE-adjacent environments. At present, its uneven adoption and inconsistent implementation across industries and modeling tools suggest the need for a **platform-agnostic baseline** representation with SysML treated as one (important) export target rather than the primary format. This approach aligns with the broader finding that the decisive factor is not the data format itself, but whether the exported content carries explicit semantics, documented schemas, and consistently typed relationships.

Finally, the pilot has implications for standards committees and authoring workflows. Reviewers noted that document-based standards may contain implicit context, overlapping provisions, or wording that is manageable for human readers but becomes difficult to interpret consistently when transformed into structured data intended for automation. Addressing this will require a **digital-first mindset in standards development**, along with the skills, methods, and supporting toolchains needed to write, validate, and maintain standards in forms that are both human-usable and reliably machine-interpretable. This presents a dual challenge for standards organizations: maintaining and improving legacy documents while also introducing new approaches to standards authoring. Some reviewers commented that **enhanced editorial support** may help with the transition from prose to digital as the industry evolves.

7. Summary Observations and Recommendations Playbook

Recommendations are organized as a practical adoption playbook to help teams move from document-based standards workflows to repeatable digital modeling approaches that support guided execution, input validation, automated evaluation, and audit-ready compliance evidence.

7.1 Summary Observations

TABLE 5 Observations and implications of the work

Area	Description
Core finding	Manufacturing standards can be transformed from static documents into reusable digital assets supporting guided execution, automated evaluation, and stronger compliance traceability. The pilot effort estimate was not prohibitive, but viability will depend on the use case, standards complexity, process complexity, and value of the modeled process to the user.
Critical success factor	Successful automation at scale depends on disciplined governance practices more than on any single tool interface. Critical governance practices include managed parameters, consistent decomposition, explicit requirement-to-workflow links, trusted provenance, and ongoing evaluation of the balance between near-term value and long-term interoperability.
Repeatable adoption path	Start with one high-value use case; define an information profile and governed parameter catalog; embed validation and change management; publish tool-agnostic outputs with documented schemas.
Long-term trajectory	Long-term progress depends on standards organizations advancing digital-first authoring and offering authoritative digital standards outputs and enabling their users to integrate those outputs into their digital ecosystems. Manufacturers will then be able to realize near-term automation and compliance benefits by applying those authorized outputs and related implementation practices to targeted workflows as they become available.
Digital standards adoption is socio-technical change	Digital standards adoption is not primarily a file-format conversion exercise. It requires coordinated changes in standards authoring, modeling methods, tool capabilities, committee review practices, data governance, and downstream implementation workflows.

The evaluation also makes clear that targeted model-based implementations can provide value within a defined use case. For some organizations, a near-term implementation designed around a specific workflow, standard, or compliance objective may be sufficient if it delivers the intended operational benefit without requiring broader reuse or cross-tool interoperability. Other organizations may choose a phased approach, using a bounded near-term project to demonstrate value, build experience, and address an immediate need either before or in parallel with work toward a more robust implementation. In those cases, the near-term project should be structured so that it does not foreclose future scaling, including future alignment on requirement decomposition and characterization, governed parameters with explicit constraints, trusted clause-level provenance, and relationship semantics that remain meaningful when exported and consumed outside any single authoring environment.

While digital-first authoring and targeted digitalization of standards by standards organizations remains the long-term enabler of industry-scale interoperability, manufacturers can begin capturing near-term value by applying these practices to targeted standards workflows today. Standards organizations are motivated to work with manufacturers to provide digital standards that meet their needs for promoting efficient production and more automation.

Modeling standards can also benefit standards organizations by providing an additional lens for review and improvement. Prose-based standards remain authoritative, technically rigorous, and well suited for consensus development and human interpretation. Model-based representation does not replace that value; rather, it can complement established review practices by making requirements, definitions, parameters, relationships, and process dependencies explicit for digital use cases. In doing so, modeling can help identify opportunities to clarify language, reduce duplication, strengthen definitions, or make assumptions more visible when content is intended for structured reuse, automation, or machine interpretation.

There are unanswered questions about the authoring format for future digital model-based standards. Some candidates include SysML, ReqIF, and JSON-LD. There is even a case to be made for multiple formats tuned to high-value use cases associated with the standard. Whether expressed in the preceding formats or some other format, addressing these questions can spur innovation rather than be a barrier to progress. The most important near-term step is not to settle on a single format, but to establish and document the semantic commitments, such as the information profile, the parameter governance, the relationship types, and the provenance requirements. A well-defined semantic commitment expressed in an imperfect format is more useful than a perfectly structured file whose field names are undocumented and whose relationship semantics are implicit.

7.2 Recommendations for Modelers

The following recommendations were identified for modeling standards that were originally published as a document. Though there is a lot of evidence to support that many standards would benefit from using a model-first approach to development, the reality is that there are large libraries of standards that exist today in document form only.

TABLE 6 Recommendations for modelers

Recommendation	Description
Start with a bounded use case.	Define the intended execution, evaluation, or integration outcome the model must support before selecting source content.
Define the evidence model early.	For compliance-oriented implementations, identify what evidence must be generated, which process steps produce it, which requirements each step satisfies, what source clause and revision a step traces to, and how information will be preserved for audit, quality review, or certification use.
Model only the standards content needed for that use case.	Limit scope to the clauses, tables, figures, definitions, parameters, and process steps needed to support the intended workflow. Modelers should preserve enough surrounding prose, rationale, definitions, notes, and clause context to allow reviewers and users to understand why a modeled element was characterized, parameterized, or linked in a particular way.
Define module boundaries consistently.	Define module boundaries consistently based on how the information is governed, reused, conditioned, referenced, changed, and applied at the point of use, not simply on how the source prose is organized.
Govern parameters and relationships explicitly.	Name, define, type, constrain, source, and manage parameters so they can be interpreted consistently and reused safely. Relationship types should also be defined consistently, including links across requirements, parameters, process steps, authoritative source clauses, and decision points. A governed parameter catalog should include definitions, units of measure, data types, allowable ranges, and closed value sets. Design a mapping layer that aligns standard-defined parameter names to the local variable names used in foundational business data systems (manufacturing execution system [MES], quality management system [QMS], product lifecycle management [PLM]), and automation environments.
Apply consistent decomposition rules.	Ensure that every modeled object links to the authoritative source clause and the specific standard revision from which it was derived so that audits and revision-management workflows can be supported without reinterpreting the document-based standard. Decomposition rules should make clear when a statement becomes one module, several modules, or part of a larger governed object.
Capture unresolved ambiguity as a governed modeling exception.	Preserve provenance and document interpretation decisions when source text cannot be modeled without interpretive judgment. Document the issue and modeling decision or open question so that it can be reviewed by subject matter experts or committee members rather than silently encoding an assumption.
Validate for intended use and downstream consumption.	Validate modeled content with subject matter experts, process users, and downstream system stakeholders. The review should confirm technical intent, decomposition consistency, execution logic, parameter behavior, traceability, export assumptions, and fit-for-purpose usability.

7.3 Recommendations for Standards Organizations and the Broader Ecosystem

Standards organizations and ecosystem partners should focus on the governance, semantic, authoring, and interoperability foundations needed to scale digital standards beyond individual pilots or tool environments. Standards organizations are uniquely positioned to define how standards should be modeled because they understand the purpose, structure, terminology, consensus intent, and implementation context of the standards they develop.

TABLE 7 Recommendations for standards organizations

Recommendation	Description
Prioritize high-value digitalization use cases.	Focus on standards or clauses with high reuse, frequent application, safety or compliance criticality, revision impact, or clear automation potential. Establish portfolio-level criteria for determining which standards are most appropriate for digitalization.
Define standards-specific modeling rules.	Establish guidance for how standards content should be decomposed, characterized, parameterized, sourced, reviewed, and revised so modeled content preserves consensus intent, normative meaning, and clause-level context. Work with standards consumers, modelers, and tool providers to establish modeling rules for different types of standards, including how requirements should be decomposed, how normative and informative content should be characterized, how parameters and allowable values should be represented, and how source intent should be preserved. These rules may require approaches that differ from general systems modeling practices because standards modeling must preserve authoritative prose, consensus meaning, clause-level provenance, revision history, and downstream compliance use. Standards organizations should also define the skills required for modelers, including standards interpretation, domain knowledge, requirements decomposition, parameterization, process modeling, and digital traceability. Modeled content should be reviewed by both modeling specialists and standards subject matter experts before it is treated as authoritative or used in automated workflows. Style guides, templates, and other tools should be considered to enforce accurate and robust standards modeling practices.
Promote digital-first standards authoring.	Use modeling feedback from legacy standards to improve future drafting, while developing authoring practices that preserve human-readable authority and add machine-interpretable structure from the outset. Promote digital-first and model-based authoring methods where they are appropriate to the intended use of the standard. This added structure can improve accuracy, completeness, consistency, integrity and traceability, while preserving the technical rigor, consensus judgment, and human readability that remain essential to high-quality standards.

Recommendation	Description
Establish shared semantic and interoperability foundations.	Create controlled vocabularies, parameter catalogs, relationship types, information profiles, and platform-agnostic schemas that allow modeled standards content to be interpreted consistently across tools, organizations, and use cases. Export formats alone are not sufficient; exported content must carry documented meanings, allowable values, provenance metadata, relationship semantics, and revision information.
Advance platform-agnostic interoperability.	Treat export formats as only one part of interoperability; schemas should define field meanings, allowable values, relationship semantics, provenance, and revision metadata. Consider publishing standards data in interoperable formats (e.g., JSON or XML) and publish the associated schemas, including field meanings, allowed values, and relationship types, supported by conformance examples that demonstrate correct implementation.
Provide committee support from editors to enforce style guide requirements and document quality.	SDOs should have a staff of editors that can work alongside committees that are writing standards as documents. Editors can focus on adherence to style guidelines and provide an additional review of how information is organized and communicated to improve the overall quality of the resulting standard. Committee members can then focus on the information being communicated rather than how it is organized and formatted in a document.

8. About the Digital Standards Alliance™ Consortium

The Digital Standards Alliance™ (DSA) is a non-profit, customer-led membership consortium that will accelerate improvement in the usability, data integration, and interoperability of digital standards of interest to the mobility community. It will achieve this through discovering, developing, collating, and promoting best practices for the authoring, production, and use of digital standards across the entire product development lifecycle (R&D [research and development], design, simulation/testing, verification/validation, certification, procurement, manufacturing, operations, and sustainment).

By collaborating with industry leaders, standards development organizations (SDOs), government entities, and academic institutions, the DSA aims to coordinate a transformative digital evolution around common use cases and services. It aims to act wholly as a resource to the standards industry to support them in accelerating their digital transformation.

The charter members of the DSA are Aerospace Industries Association (AIA), The Boeing Company, Lockheed Martin Corporation, and SAE International®.

The alliance is formed under the established legal framework of SAE Industry Technologies Consortia® (SAE ITC). By providing a comprehensive legal framework for precompetitive collaboration between subscribing members along with a suite of strategic and operational services, SAE ITC's tried-and-tested approach means its consortia can quickly impact their industry.

9. Contact Information

To learn more about the Digital Standards Alliance™ Consortium, please visit

<https://www.sae-itc.com/programs/dsa>.

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11. Abbreviations

AIA	Aerospace Industries Association
AI	Artificial intelligence
AMS	Aerospace Material Specification
ASTM	ASTM International (formerly American Society for Testing and Materials)
DSA	Digital Standards Alliance™
JSON	JavaScript Object Notation
JSON-LD	JavaScript for Object Notation for Linked Data
K-PAC	Knowledge Packet
MBSE	Model-based systems engineering
MES	Manufacturing execution system
OEM	Original equipment manufacturer
PLM	Product lifecycle management
QMS	Quality management system

ReqIF	Requirements Interchange Format
SAE ITC	SAE Industry Technologies Consortia®
SDO	Standards development organization
SysML	Systems modeling language
XML	Extensible markup language