AIA
AEROSPACE INDUSTRIES ASSOCIATION

THE FUTURE OF AEROSPACE STANDARDIZATION

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The Future of Aerospace Standardization

Examining aerospace standardization systems, processes and organizations; defining requirements for standards and standards systems to support the continued growth of the aerospace industry; and providing recommendations for the optimum standards infrastructure for aerospace.

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Preface

The aerospace industry has rapidly transformed into a global industry, with worldwide suppliers and prime companies functioning as expanded enterprises in international, collaborative partnerships. Standards[1] form the single largest source of technical data used globally to design, build and sustain aerospace products. These standards, as well as the processes used to develop and distribute them, need to be better positioned to support this global industry. Currently, the aerospace standards system is overly complex and, at times, duplicative. This has resulted in increased costs associated with multiple standards developers addressing similar technologies, the harmonization of regulatory requirements based on competing standards; the need for multiple conformity assessments (validation and verification) and quality management audits due to there being multiple standards; and the inefficiencies of having redundant and overlapping standards and standards infrastructures.

Also, for aerospace and defense companies to achieve technical excellence, leadership and workforces must understand the value of standards and standardization in all technical domains. The inverse is true as well; anyone in the business of standards should be well informed on and curious about which standards-related entities might affect their technologies. The three organizations of greatest consequence as overarching entities are the:

- American National Standards Institute (ANSI).
- International Organization for Standardization (ISO).
- International Electrotechnical Commission (IEC).

In the United States, there are 238 ANSI-accredited standards developers;[2] 13,136 American national standards; 103 U.S. ISO-administrated technical committees (TC) and subcommittees (SC); 91 United States-held ISO chairs, including ISO TC 20 Aircraft and Space Vehicles; 237 ISO-U.S. technical advisory groups (TAG); 169 IEC U.S. TAGs; and 26 United States-administered IEC TCs. There are many more organizations, industry associations, consortia and related entities that operate outside the ANSI umbrella, some of which are listed in Appendix B.

In the U.S. standardization system, ANSI serves in a leadership role, making the United States unique in this arena. There are many misconceptions of and misunderstandings about how the system works for U.S. aerospace and defense companies, and for U.S. businesses in other industries. Addressing these in 2003, the Aerospace Industries Association's (AIA) Board of Governors established the Future of Aerospace Standardization Working Group (FASWG). This group's charter aimed to:

- Identify the key requirements for standards systems that are intended to be used to support the global aerospace industry.
- Examine the major standards development models and organizations used then in light of the defined requirements.
- Develop a set of recommendations for migrating toward the optimum standards system(s) required for the aerospace industry.

[1] The term "standard" is defined in Appendix A. In this document, it encompasses standards, specifications, other related documents and conformity-assessment procedures, unless otherwise noted.
[2] ANSI does not develop standards.

To reach its objectives, the FASWG held four workshops from September 2003 through September 2004 seeking input. From these, the information it gathered included:

- Documentation governing standards processes and practices.
- Information regarding aerospace standards development, participation and use.
- Details of aerospace quality system requirements.
- Data regarding the impacts of e-business on the ability to integrate, collaborate and migrate technical data throughout the value chain.
- U.S. Department of Defense (DoD) requirements for integrated data in future combat.
- Expectations of the Federal Aviation Administration (FAA) and other national airworthiness authorities regarding standards for products, processes and systems.

The FASWG examined the then-current aerospace standardization system's processes and organizations. Using data it had obtained, it then defined requirements for standards and standards systems that would support the future growth of the aerospace industry. Then, the group recommended ways to ensure the optimum standards infrastructure for aerospace.

In 2016, AIA established the FASWG's successor, the Standards Governance Board (SGB). Throughout 2021, the SGB revised and expanded many of its predecessor's recommendations. The resultant recommendations are what this report presents. The focus is on strengthening the standards infrastructure in U.S. aerospace so that the industry is better able to work internationally. Ultimately, the SGB seeks to support and enable the creation, maintenance and distribution of global aerospace standards that are value-adding enablers for the industry. Additionally, the board has the overall responsibility for AIA National Aerospace Standards (NAS).

In line with the SGB's purpose and responsibility, references in this report to the aerospace and defense industries refer first to the U.S. aerospace industry. In many cases, however, they apply to aerospace as an international industry as well.

Executive Summary

The Public Sector Impetus for Change

Aerospace has been at the center of America's technological leadership for more than a century. The advances in science, technology, engineering and manufacturing represented by the civil, military and space sectors are extraordinary. Underpinning all these accomplishments is the vast wealth of technical data developed, maintained and disseminated through standards.

Standards form the single largest source of technical data used to design, build and sustain aerospace products. They are critical to the production and safe operation of aerospace products and platforms. Attesting to this, the Commission on the Future of the United States Aerospace Industry (CFUSAI), formed jointly by then-President George W. Bush and the U.S. Congress in 2001, stated in its 2002 report, "Global standards and regulations are critical to the efficient operation of the global aviation system and international markets."[3] This is still true today.

In September 2003, AIA's Board of Governors established the FASWG to follow up on the CFUSAI's report. The group was tasked with taking an in-depth look at the health of aerospace standards to identify which actions the industry needed to take to ensure these standards' health in the future. The FASWG examined then-current aerospace standardization systems and processes, and defined requirements for standards and standards systems that would support the future growth of the aerospace industry. Then, it established a set of recommendations for ensuring the optimum standards infrastructure to carry the aerospace industry into the future. The work this group completed transitioned to the AIA SGB in 2016.

A Call to Action

Most of the FASWG's findings and recommendations are still current, and many extend beyond AIA to apply to all aerospace stakeholders. This is because the recommendations are much too far-reaching and strategic to be addressed by AIA alone. Moreover, if they are to have any impact, these recommendations must be endorsed and implemented by aerospace industry stakeholder leaders. That includes government policy makers, aerospace subject-matter experts (SME), and industry CEOs, executives and senior management.

With leaders' endorsement and implementation of these recommendations, the impact will counteract the continued erosion of U.S. influence on international aerospace technical information. Without effective U.S. leadership in aerospace standardization, ever more technical data supporting this industry will be developed in venues controlled by foreign aerospace companies – potentially, by U.S. adversaries. This means that much of the software and many of the systems, parts and processes used to design, develop, manufacture and sustain U.S. air vehicles will be led and defined by non-U.S. entities. At best, they will be defined by technical documentation developed in standards committees in which the U.S. industrial presence is relegated to a single vote (one vote per nation); at worst, they will be defined by documentation developed in venues where the U.S. is merely an observer.

[3] Commission on the Future of the United States Aerospace Industry, "Final Report of the Commission on the Future of the United States Aerospace Industry" (November 2002), https://history.nasa.gov/AeroCommissionFinalReport.pdf.

This report updates the most comprehensive evaluation of aerospace standardization ever undertaken. According to the conclusions presented herein, inaction is perilous for stakeholders in the aerospace industry, which include prime contractors, suppliers in every tier, civil and defense customers, standards developers, and those who depend on the quality, safety and reliability of the products the aerospace industry produces. It is imperative, therefore, that action be swift and directed from the highest levels of industry and government. The actions need to be led from the executive suite, and their implementation must be guided at the senior VP level.

Standardization, at its most fundamental level, is tactical. However, taking an industry-wide approach to standardization makes it strategic as well. The aerospace industry must support the development of the technical documentation used to design, build, operate and maintain aerospace products both in the industry and internally. The U.S. must act if it desires to remain in a leadership position in the development of the standards that are essential to its aerospace capability.

Specifically, U.S. leadership can focus resources on critical standardization needs. Industry leaders should reconsider how engineering technical talent supports specific technologies, both internally and externally. Through robust leadership and technical excellence, aerospace SMEs lead efforts to generate standards defined by technology and market relevance. These are developed through responsive industry venues involving all stakeholders, using tools and formats that allow critical data to integrate seamlessly with all other product data.

Thus, the recommendations in this report issue an implicit call to action for the aerospace industry. They urge aerospace stakeholders to protect the critical body of aerospace technical knowledge, and to ensure that it will carry the industry successfully into the future.

The Future of Aerospace Standardization: Main Takeaways

- For aerospace and defense companies to achieve technical excellence, thoroughly understanding the value of standards and standardization in technical domains is critical.
- Industry leaders must advocate establishing integrated processes and complementary infrastructures to ensure that standards and standardization remain enablers for aerospace.
- It is imperative to reduce the proliferation and overlapping of standards while constantly assessing gaps against emerging technologies in aerospace.
- Standards must be considered holistically and compared to any applicable industry regulations, globally accepted standards, and tests and conformity assessment processes.
- Aerospace leadership must ensure effective representation in TCs and facilitate both technical and business integration into standards challenges and solutions.
- The standards developed and disseminated must be easily integrated into product definition data or other life-cycle data streams, and tools/processes must not be hampered by data-format issues or intellectual property (IP) issues.
- DoD needs to proactively support and participate in the development of industry standards, and must utilize industry standards to the greatest extent practicable.
- The roles played in international standardization by the International Civil Aviation Organization (ICAO) and other international organizations must be recognized, and these venues must be utilized to provide leadership in advancing U.S. technologies.
- Special focus must be placed on space, emerging technologies, and unmanned aerial systems (UAS), unmanned aerial vehicles (UAV) and drones.

The Future of Aerospace Standardization: Chapter Summaries

Chapter 1: A Vision of Standards Enabling the Future of Aerospace

Conclusions

To achieve a vision for aerospace standards and standardization, the AIA SGB concludes that government and industry need to recognize and advocate the critical role standards play as enablers for aerospace. Also, the SGB concludes that standards need to be developed through processes that serve and are used by the entire aerospace community. Furthermore, standards, as well as the processes and technology used to develop them, need to continually evolve to incorporate breakthroughs and enhancements in technology. This will ensure that the standards and the technical data they contain can be captured, managed and disseminated. They are integrated into the design, build and sustainment processes used by the aerospace industry. Of note, this can be achieved in ways that ensure that standards are an integral part of the digital enterprise.

Recommendation No. 1

The integral role standards play in designing, manufacturing and sustaining aerospace products makes global standards for aviation and space a critical resource for the aerospace industry. Leaders from industry, government and standards-developing organizations (SDO) need to be advocates for the integrated processes and complementary infrastructures that will ensure that standards remain enablers for aerospace.

Chapter 2: Aerospace Standardization as a Huge, Complex System

Conclusions

The aerospace industry needs to take a big-picture look at all the standards and infrastructures involved in creating and maintaining its critical technical data. The industry's goals must be to assess gaps, reduce redundant standards, prevent unwarranted proliferation and ensure support for the standards supply chain. Additionally, the proactive and strategic management of aerospace standardization activities is needed to ensure the most efficient and effective use of industry resources and talent. Every effort should be made to develop standards with organizations that offer the broadest inclusion of all stakeholders, the most cost-effective processes, and the most easily accessible products.

Recommendation No. 2

The aerospace industry needs to continually assess gaps and reduce the proliferation of standards wherever possible. Its goal should be to have a single suite of globally accepted standards, tests, and conformity assessment validation and verification processes appropriate for the needs of the industry. Additionally, the industry needs to encourage the rationalization and reduction of the number of infrastructures needed to support aerospace standardization. It should focus resources on the processes and organizations working to ensure the efficient development of the standards needed for aerospace.

Chapter 3: Leadership

Conclusions

Standards represent a significant investment by the aerospace industry. There needs to be an integration function that can facilitate the prioritization and focusing of industry standardization efforts. There also needs to be a development of industry-wide solutions that apply both externally and internally to aerospace companies. The aerospace industry would benefit from having a forum focused on rationalizing the standards system, avoiding duplicative committee scopes and standards, and reducing the unnecessary proliferation of standards. We must recognize the potential need for aerospace-specific derivative standards in many common industry technologies.

Without effective U.S. leadership in aerospace standardization, ever more technical data supporting the U.S. aerospace industry will be developed in venues controlled by foreign aerospace industry representatives. These standards will, intentionally or inadvertently, favor foreign manufacturers – perhaps, U.S. adversaries. Therefore, the impact will affect not only prime system integrators but also the entire supply chain supporting the aerospace industry.

Recommendation No. 3

The aerospace industry needs to have leadership positioned to provide both technical and business integration in standards issues and solutions. Leadership organizations must be recognized as integrators for the industry, respected as objective without conflicts of interest, and acknowledged as having the support of both industry and government. These organizations must be able and willing to use appropriate means to accomplish aerospace standardization objectives. This includes means of allocating resources, enlisting senior management, resolving overlapping scopes among aerospace standards organizations, lobbying and so forth.

Chapter 4: Global Markets with Global Standards

Conclusions

The aerospace industry must work with world governments, regulatory agencies and the U.S. Department of Commerce (DOC), DoD and Office of the United States Trade Representative (USTR). Additionally, it must work with the standards-developing community to ensure that global industry standards are chosen based on their ability to meet technical and market needs, not on which organization developed them.

The more universally used a standard is, the more it generates industry efficiency and provides better returns on investments (ROI). Using globally recognized and accepted standards spreads the cost of development and maintenance across a larger portion of the industry. Often, more suppliers can lower costs and reduce expenses, such as those of certification efforts.

The global nature of the aerospace industry, with its worldwide supply chain and customers, demands global standards. The aerospace industry should strive to develop standards with the organizations that offer all stakeholders the opportunity to participate. It should also encourage making access to global standards easy and efficient for all.

Recommendation No. 4

The standards chosen for the global aerospace industry must be recognized internationally, with support for the development process of the developing organization. When possible, it is desirable that these standards be made the basis for national, foreign, regional and international regulations and laws. Also, the global standards should be open for input from all stakeholders in the industry per World Trade Organization (WTO) standards development principles.

Chapter 5: The Business of Standards, Using New Models and New Tools

Conclusions

The aerospace industry needs to ensure that as new standards are developed, they are based on emerging technologies' needs and market relevance. The industry needs to develop processes and tools that allow stakeholders to identify existing or emerging standards activity, and that facilitate strategic standardization decisions.

The aerospace industry needs every relevant standards developer to maintain a robust standards development, coordination, approval, configuration management and promulgation system. This will ensure that standards data relevant to every step of the design-build-sustain life cycle is easily available. Such a system would be characterized by, among other things:

- Automated document preparation, coordination, commenting and balloting that is easily understood and flexible, and that engages the global community.
- Readily available and easily accessible standards development committee websites that meet the needs of the standards developer, the standards acquirer and the general information seeker.
- Tools that facilitate the faster, better and cheaper development and promulgation of standards that are technically accurate and current, market relevant, platform independent, and globally accepted and used.
- Tools that make it easy for the entire global aerospace industry to engage in the development and/or use of standards at any appropriate point in the process.
- Solutions for IP issues that prevent standards data from being easily integrated with other product data and migrated down the supply chain.

In this system, access must be provided not just to the standard as a document, but also to the digital technical information contained in the standard. This will enable users to access the standards data as they need it, in the forms in which they need it, and to easily integrate this data into product-definition data systems. Standards must move to being managed and controlled as a collection of data elements, rather than maintained as hard copies (i.e., printed documents). This will enable users (humans, machines and various applications) to integrate the standards data that best meets their needs.

Recommendation No. 5

The business models and tools used to develop, distribute, integrate and use aerospace standards need to ensure that standards development is responsive to business and technical drivers. Development must also be based on a business case or market need, and the standardization

process must be adequately funded and supported. Also, the models must enable the tools and processes used to develop, maintain and disseminate standards to optimally use technology and the internet to ensure an efficient, effective system involving all stakeholders. Building on that, standards must be developed and disseminated in a way that enables data to be easily integrated into product definition data or other life-cycle data streams. Furthermore, the tools and processes involved in the standards' development and dissemination must not be hampered by data-format issues or IP issues.

Chapter 6: Standards and Civil Aviation

Conclusions

The aerospace industry needs to better articulate and understand the essential relationship between standards and conformity assessments. Also, it needs to harmonize the standards that form the basis for regulations and certifications, and to develop globally accepted conformity assessment schemes that are mutually recognized and cost effective. The models for global standards development established by the International Aerospace Quality Group (IAQG) and the International Aerospace Environmental Group (IAEG) have proven to be successful methods for achieving globally harmonized standards. The aerospace industry should seriously consider adapting or adopting this model for more standardization efforts.

The process for identifying qualified products and producers through the standards system can be optimized. The industry needs to establish a special task force to deal with qualified products lists (QPL). This task force will ensure that the processes surrounding the lists' invocation, development, configuration management, distribution and use are clearly understood and uniformly applied throughout the industry by all applicable standards developers.

ICAO has been functioning as an international standards developer for the aerospace industry. The industry should work with governments and regulatory agencies to ensure that ICAO standards are recognized as international standards. Furthermore, it should ensure that it maintains the right to utilize ICAO over the ISO as an aerospace-specific international SDO.

Recommendation No. 6

Policies and procedures for assessing the conformity of products and processes to standards are crucial. Qualification, certification and conformity assessments are major cost drivers, and they require improvement. The role ICAO plays in international standardization for the aerospace industry needs to be better recognized by the United States. Furthermore, the United States should use ICAO to provide leadership in advancing U.S. technology and initiating change where needed.

Chapter 7: Standards for Defense

Conclusions

Senior DoD leadership must always recognize the critical role government standards play in the commercial aerospace industry. In response, DoD leaders should involve aerospace industry stakeholders in any major standardization initiatives. This will ensure that the key technical data contained in military specifications (MIL-SPEC) and military standards (MIL-STD) is available

to support dual-use products and platforms, and to ensure a strong supply chain for DoD parts and materials.

In recognition of the global role that MIL-SPECs play in the aerospace industry, DoD is urged to establish more effective mechanisms for communicating with the industry on standardization issues. These must include discussions regarding standardization actions that impact both DoD and industry. They would involve industry stakeholders, and would help to define standardization issues and develop solutions that are mutually beneficial.

A multidisciplinary government-industry forum would develop recommendations for how standardization could best support logistics reform, interoperability, evolutionary acquisition, technology insertion and reductions in total ownership costs. Also, it would address such issues as business strategies that promote civil-military integration for the acquisition of defense products and platforms; configuration management policies and practices; technology insertion; logistics support; sustainment; and commercial parts management.

Senior DoD leadership can contribute to ensuring that industry standards are suitable for DoD use and both meet and contain DoD requirements. However, this requires acknowledging that government SMEs must participate in the industry committees that develop and maintain these standards. Also, sufficient funding must be made available; otherwise, DoD risks having neither internal nor external standards available for designing, manufacturing and sustaining military products. A closer relationship with NIST is essential, also.

Recommendation No. 7

Senior DoD and aerospace industry leadership must recognize the extent to which the commercial aviation and space industries, as well as the defense industry, depend upon MIL-SPECs and MIL-STDs. This refers to both the library of technical knowledge and the discipline of configuration control embodied in the system of MIL-SPECs and MIL-STDs. DoD needs to proactively support and participate in the development of industry standards, and must utilize industry standards to the greatest extent practicable.

Chapter 8: Space's Imperative for International Standardization

Conclusions

The commercial space industry has emerged significantly in the 21st century and includes new commercial companies. This progress has to be aligned with the new U.S. Space Force and defense interests. The benefits of industry standardization are critical to cost, quality and repeatability. Industry and government need to work together to ensure that globally relevant standards exist to meet technical needs in space. Also, their collaboration can ensure that the U.S. space industry does not continue to cede strategic standards and associated technical strength to regional (e.g., Europe) and/or international interests.

Recommendation No. 8

The aerospace industry, DoD, and the National Aeronautics and Space Administration (NASA), National Institute of Standards and Technology (NIST), and FAA need to work together.

Collaboratively, they can ensure the development of globally recognized standards that support both government and commercial space interests. The development and use of industry standards that support United States-based technology must be key strategic components of the aerospace industry's standardization strategy.

Chapter 9: Essential Standards for Rotorcraft/UASs/UAVs/Drones

Conclusions

UAS/UAV/drone technology has emerged rapidly, and the benefits of industry standardization in this area are critical to cost, quality and repeatability. They are especially critical to public safety, as these vehicles often operate at very low altitudes. Pilotless manned air vehicles add another significant level of concern.

Commercial and defense interests could have overlapping and competing technical needs that must be addressed by standards and regulation. Consequently, industry and government need to work together to ensure that globally relevant standards exist to meet UAS/UAV technical needs.

Recommendation No. 9

Industry, NASA, DoD, NIST and the FAA need to work together. Collaboratively, they can ensure the development of globally recognized standards that support government, defense and commercial rotorcraft/UAS/UAV/drone interests. The development and use of industry standards that support United States-based technology must be key strategic components of the aerospace industry's standardization strategy.

Chapter 10: Aggressive Alignment with Emerging Technologies

Conclusions

Technologies relevant to aerospace interests continue to rapidly evolve. It is imperative for U.S. aerospace companies and SDOs to quickly align and create working groups and TCs to address these technologies at the earliest stages of technological development. Early alignment will ensure that U.S. aerospace is in a leadership position. As part of this, U.S. aerospace companies will participate in discussions about what can be standardized and what must be maintained as company secrets and IP.

Ever more consortia are being developed with purviews over emerging technologies. In response, all efforts must be made to assess gaps and address the potential for overlapping standards development. Technologies must be addressed holistically across SDOs, industry associations and consortia, as technical standards are increasingly being developed by multiple providers. Also, the need for aerospace-specific derivatives of more generic industry standards must be evaluated for the value they can add. In most emerging technical domains, aerospace interests are in the minority.

Recommendation No. 10

Leadership in TCs and governing boards must act quickly on proposals to create or expand TCs to address emerging technology standards development. Aerospace companies must be involved and

seek leadership positions in these organizations – considered external outreach by some aerospace companies – to effect influence. ANSI standards development principles are most advantageous here for addressing gaps and eliminating overlap. Aerospace companies must be proactive and place their best technical representatives in the emerging technologies and TCs early in the process. Aerospace interests must be represented more aggressively in these emerging technologies, and education at all levels is essential.

Chapter 1
A Vision of Standards Enabling the Future of Aerospace

Recommendation No. 1: The integral role standards play in designing, manufacturing and sustaining aerospace products makes global standards for aviation and space a critical resource for the aerospace industry. Leaders from industry, government and SDOs need to be advocates for the integrated processes and complementary infrastructures that will ensure that standards remain enablers for aerospace.

It is believed that 39% of all aerospace engineering data and 38% of all manufacturing data is derived from standards. Standards are fundamental to all the technical and business aspects of aerospace vehicles' interoperability and interconnectivity. They are also fundamental to the common requirements for ensuring reliability, repeatability and quality, and they serve as the basis for safety and certification. Ultimately, they are one of the most powerful mechanisms for propagating change.

There are major drivers changing the face of the aerospace industry, and some standards systems are in danger of not keeping pace with these changes. Just as the CFUSAI called for the establishment of a national vision to steer the industry, so too does the industry need a vision for its standards. The AIA SGB acknowledges that with its vision of standards enabling the future of aerospace, presenting a body of knowledge that can help industry to achieve its goals for the future.

This vision needs to include all stakeholders and leverage global cooperation to produce and use globally recognized, accepted and utilized standards. The aerospace industry must develop a standards strategy to promote standards business models that produce and fund standards. This will enable all industry stakeholders have direct participation, fully support the process, and collectively own the product. The results of this vision must be global standards that are freely and easily integrated into the design-build-sustain process, easily used in a collaborative design environment, and easily migrated throughout the supply chain. Also, standards for the aerospace industry must facilitate global conformity assessments and certifications of aerospace products, platforms, systems and operating environments.

A standard is a set of characteristics or qualities that describes the features of a product, process, service, interface or material.[4] Standards form the single largest source of technical data used to design, build and sustain aerospace products. Complex aerospace products, such as airframes, are designed using thousands of standards that define the engineering and manufacturing processes used to build and support those products.

Standards allow the parts used in an airplane to be sourced from suppliers all over the world, with all of these suppliers meeting the same expectations of reliability, quality and safety. When a

[4] For an expanded definition, see Maureen Breitenberg, "The ABC's of Standards-Related Activities" (August 2009), https://www.nist.gov/system/files/nistir_7614.pdf.

military or commercial plane takes off in one part of the world and lands in another, global industry standards are what ensure that the landing beacon is understood by the cockpit; the gateway ramp lines up with the aircraft; and the mechanics and ground support crew service the plane in the same way, with the same parts, no matter where it landed.[5] Standards are critical to the production and safe operation of aerospace products and platforms. Attesting to this, the CFUSAI stated in its final report, "Global standards and regulations are critical to the efficient operation of the global aviation system and international markets."[6]

Most of the aerospace industry takes the role and benefits of standards for granted.

Fundamental to Product Design and Production

Standards come into play at the very beginning of the design cycle, and they are used extensively throughout production and sustainment until the end of a product's life and its ultimate disposal. Electronic data interchange standards allow design engineers to work in a collaborative environment and utilize 3D models. Numerically controlled machines and 3D printers/additive manufacturing follow standard codes to cut and machine extrusions made from materials meeting specific standards for strength, corrosion resistance and flexibility. Major components are installed using fasteners manufactured according to part standards and following standardized processes. Tools used to measure the torque applied to the fasteners are calibrated using standards.

Suppliers of parts, materials and subassemblies, such as avionics, must meet performance specifications. Parts and processes are evaluated using nondestructive inspection and test specifications. Manufacturing and production processes must be done in accordance with safety, quality and environmental standards. These examples illustrate the influence and roles that different kinds of standards have in designing and manufacturing aerospace products. No single part, process, tool or operation exists that is not defined or governed in some measure by standards.

Stakeholders' Importance in Aerospace Standardization

Government, industry, academia and SDOs all play important roles in defining, developing and using aerospace standards. The balance and acceptability of the standards depends on each segment having a part in the standardization process. All the stakeholders need to work together to deliver quality aerospace standards to support the future of the industry.

The use of standards not only makes sound economic and business sense from the perspective of an original equipment manufacturer (OEM); it is also demanded by aerospace customers and regulatory agencies. In its requirements for designing and producing commercial aircraft, the FAA cites the Code of Federal Regulations (CFR): "The suitability and durability of materials used for parts ... must ... conform to approved specifications (such as industry or military specifications...). The methods of fabrication used must produce a consistently sound structure. ... [T]he process

[5] U.S. Department of Defense, *DoD Standardization Journal* (September 2003).
[6] Commission on the Future of the United States Aerospace Industry, "Final Report."

must be performed under an approved process specification."[7] In some instances, the inverse applies as well, with government bodies conducting business in alignment with industry standards. For example, the Departments of State, Commerce and Transportation use aerospace standards when negotiating international aviation agreements and regulations.

A Rapidly Changing World

As there are many forces driving changes in the aerospace sector, there are many forces driving changes in the business of standards. Among these are the rise of consortia and other alternative models to the traditional, voluntary, consensus-based standards development process; new electronic tools that enable electronic development and distribution processes; emerging and new technologies, and the blending of these with existing technologies, requiring new standards committees or alliances among existing bodies; and the rise of horizontal management system standards (e.g., the ISO 9000 series) that impact multiple functions and areas of a product's design and operation life cycles. **Figure 1** illustrates the transitions described.

Figure 1. Paradigm Shifts in Standardization

In the past, the majority of the standards used in aerospace consisted of company-unique standards or MIL-SPECs. Then, global partnering and outsourcing, as well as numerous U.S. government-led efforts to reform MIL-SPECs (e.g., Federal Acquisition Streamlining Act of 1994, Federal Acquisition Reform Act of 1996, Defense Reform Act of 1997, Federal Activities Inventory Reform Act of 1998), shifted the maintenance of many MIL-SPECs to industry. **Figure 2** illustrates and forecasts this trend. In some cases, company- and military-unique standards were combined, showing an increasing desire to shift to global industry standards.

Additionally, ever fewer of the standards used are unique to aerospace owing to domain overlaps with electronics, communication systems, information technology (IT) and systems engineering, among others. Information technologies in particular, along with the standards used to define them, are shared by a broad range of industries and products. Thus, whereas much of the technology used to build aerospace products was once controlled by this industry, aerospace is now utilizing and incorporating technologies from other industries – some of which were never intended for use by aerospace.

Company specifications, too, are no longer always an option. Accordingly, aerospace companies must participate in SDOs, such as the organizations developing standards for IT – the fastest-growing area of aerospace standards work. While collaborating with SDOs, companies must strive

[7] 14 CFR Part 25, Airworthiness Standards: Transport Category Airplanes, https://www.govinfo.gov/app/details/CFR-2020-title14-vol1/CFR-2020-title14-vol1-part25.

to develop standards that ensure interoperability and interconnectivity. Also, they must be cognizant of the need for industry-unique representation in these SDOs. Moving outside aerospace-dominated standards bodies requires aerospace technical experts to articulate aerospace-unique requirements in such a way that non-aerospace standards developers can understand and will accommodate these requirements.

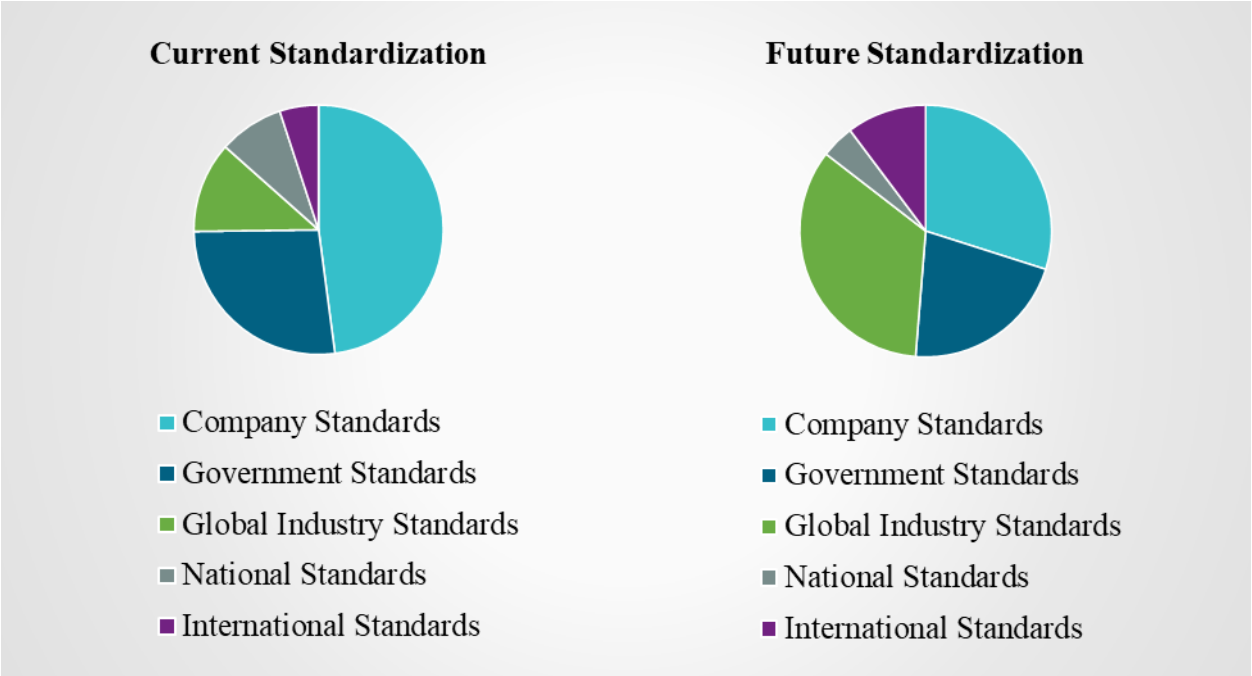


Figure 2. Standards Development After Global Partnering and MIL-SPEC Reform

In other areas, aerospace contributes to a lesser and more focused degree. Inflight entertainment systems, for example, are an area where the aerospace industry is not leading the technology, but rather is taking advantage of all the innovations in personal entertainment equipment. To do this, aerospace has to drive some very special needs into the standards for these products and this technology. Although digital communication and entertainment happen outside of the aerospace industry, the technologies – and standards – for these domains are incorporated into and managed through aerospace technical information.

Understanding these changes is critical if the United States is to have aerospace standards remain vital enablers and guarantee that aerospace remains a strong economic and cultural component. Looking ahead, the U.S. aerospace industry's dependence on global standards will only continue to grow. This is because the manufacturing and operation of aerospace products continues to become a global activity.

Also, military priorities are expanding to include network-centric operations and the blending of coalition forces in things like joint all-domain operations. Similarly, civil priorities are increasingly seeking more effective and efficient air traffic management, along with global processes for certifying and maintaining new materials and systems. Space, too, is experiencing a burst of expansion with new missions to the moon and Mars, and beyond. At the same time, the space industry is seeing increased commercial launches, bringing humans, payloads and launch vehicles from different nations together to place technology in space. How the aerospace standards

community addresses the standards needs of military, civil and space priorities will significantly impact the costs incurred by, and the ultimate success of, aerospace stakeholders.

U.S. Aerospace Standards Leadership in Jeopardy

U.S. standards have long dominated the landscape of civil, defense and space standards because the United States has dominated the aerospace industry for such a long time. The high degree to which U.S. standards have been circulated throughout the world market has been a direct result of the large market share held by U.S. aerospace products. Such standards include U.S. MIL-SPECs and industry standards developed by United States-domiciled SDOs, such as AIA, ASTM International, the American Society of Mechanical Engineers (ASME), the Institute of Electrical and Electronics Engineers (IEEE), and SAE International, among others.

Also of considerable significance are the international bodies, such as ISO, the IEC, the International Telecommunication Union (ITU) and ISO/IEC Joint Technical Committee (JTC) 1 Information Technology. In addition to these, there are many other SDOs and consortia that generate standards pertaining to the aerospace industry, both formally and informally. Since open systems have become more prevalent in recent years, de facto standards must be acknowledged as much as codified standards are.

The mission of aerospace standards is to provide interoperability and interconnectivity; reliability and repeatability; quality and uniformity; safety and certification; and a mechanism for change.

Open systems are not the only way in which the standards landscape has been changing though. With the rise of strong European and international aerospace industries, there has been a vocal and deliberate standardization strategy on the part of the European Union (EU) to promote European standards.[8] Consequently, the leadership role that U.S. aerospace standards have sustained, along with the technology embodied in those standards, could soon end. European aerospace manufacturers believe that their requirements cannot be taken into account during the development of what they perceive as U.S. aerospace standards.[9] Therefore, they are actively working to develop – and in many cases duplicate – already technically acceptable U.S. standards.

Around the world, foreign competitors (including U.S. adversaries) are aggressively implementing standardization policies and developing standards in an effort to diminish the role of what are perceived as United States-dominated standards. Foreign governments and companies alike are investing significant funds in developing alternative standards and standards infrastructures. These are meant to supersede the traditional industry standards that have dominated the industry up until now. Unfortunately, fragmenting the standards landscape and duplicating parts and material standards decreases the benefits of having an industry standard. The end goal of having universally accepted and used standards has thus become harder to achieve.

[8] European Union Council, "The role of European standardization in the framework of European legislation and policies," C 066 (March 1, 2002).
[9] Daimler-Benz Aerospace Airbus, "Standardization in Aircraft Manufacture" (1995).

A Vision for Aerospace Standards

Whatever the future holds for the aerospace industry, at its foundation must be the standards defining the products, processes and systems used to capture and convey all the technical data behind industry advancements. Moreover, these standards must be available to whoever needs them, wherever and however the standards are needed. This requires answering such questions as:

- If standards are to remain enablers for aerospace, what must be done to ensure this?
- What new standards or standards types need to be created?
- How will standards be linked to the business needs of the industry?
- Are new tools needed to seamlessly integrate standards data into design and manufacturing data?
- What is the best business model for the development and distribution of standards?

The aerospace industry has not taken an in-depth, strategic look at standards; nor does it have a collective vision and strategy for continually improving the standards and standards systems supporting aerospace. ANSI set an example for this by working with all the different private and public sector entities involved in U.S. standards setting to develop the U.S. National Standards Strategy in 2000, and to update it periodically since then.[10] This strategy, since renamed the United States Standards Strategy (USSS), is available on ANSI's website. Tactical initiatives for implementing it, however, are the responsibility of each industry or market sector. In the aerospace industry, little (if any) action has been taken to support, influence or implement the USSS, despite its endorsement by Congress, DoD, NIST and the DOC.

Meanwhile, the European Commission launched an initiative regarding the challenges facing the European standardization system. This commission seeks to improve the system so that it can support a well-functioning, single market and the competitiveness of EU industries, while also protecting EU citizens and the environment. The initiative aims to address future standardization needs, striking a balance between myriad aspects: the speed and quality of standards development; broad stakeholder participation, especially at an international level; improvements in coordinating EU stakeholders and resources to highlight EU values; formal education or vocational standardization training and service standards; and the removal of barriers to the single market.[11]

The time is now to shape a collective vision for the aerospace industry, although not because any one agency (particularly one in another industry) insists upon it. Rather, the imperative exists because shaping this vision represents a strategic investment in aerospace's economic and technological strength as an industry. For this reason, the AIA SGB offers this vision for industry's consideration.

Standards as Enablers for Aerospace's Future

The mission statement put forth by the CFUSAI was, "Anyone, Anything, Anywhere, Anytime," and it was intended to set the course for U.S. global aerospace leadership. Today, aerospace needs

[10] American National Standards Institute, "United States Standard Strategy," https://www.ansi.org/resource-center/publications-subscriptions/usss.
[11] European Commission, "Standardisation strategy," https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13099-Standardisation-strategy_en.

a vision for ensuring that the tools will be there to enable that mission as a greater vision. In order to secure a brighter future for U.S. aerospace, the adopted standards vision must:

- Include all stakeholders in an international, cooperative effort to produce and use globally recognized, accepted and utilized standards.
- Produce and fund standards through business models in which all industry stakeholders have direct participation, fully support the process, and collectively own the product.
- Result in global standards that are freely and easily integrated into the design, build and sustainment processes; easily used in a collaborative design environment; and easily migrated throughout the supply chain.
- Facilitate global conformity assessments and certifications of aerospace products, platforms, systems and operating environments.

Sustaining U.S. Standards Leadership

Sustaining U.S. aerospace standards leadership needs to be an industry priority. Today, the aerospace industry is responding to many changes and drivers, from dealing with the War on Terror and a significant pandemic to strengthening the nation's global technical leadership. Aerospace standards will play a critical role in the country's and industry's respective abilities to respond to these imperatives.

The aerospace sector, comprising government, industry and regulatory bodies, as well as the supporting SDOs, must address the standards needs supporting the industry's future. Now is the time to collectively support and implement a standards vision and strategy. This vision will help to prioritize and determine the standardization requirements, and will help to focus resources and energies. Successful leadership in aerospace will not be possible without the tools required to design, build, certify, operate, maintain and sustain the industry's products; those tools are standards.

Conclusions

To achieve a vision for aerospace standards and standardization, the AIA SGB concludes that government and industry need to recognize and advocate the critical role standards play as enablers for aerospace. Also, the SGB concludes that standards need to be developed through processes that serve and are used by the entire aerospace community. Furthermore, standards, as well as the processes and technology used to develop them, need to continually evolve to incorporate breakthroughs and enhancements in technology. This will ensure that the standards and the technical data they contain can be captured, managed and disseminated. They are integrated into the design, build and sustainment processes used by the aerospace industry. Of note, this can be achieved in ways that ensure that standards are an integral part of the digital enterprise.

Chapter 2
Aerospace Standardization as a Huge, Complex System

Recommendation No. 2: The aerospace industry needs to continually assess gaps and reduce the proliferation of standards wherever possible. Its goal should be to have a single suite of globally accepted standards, tests, and conformity assessment validation and verification processes appropriate for the needs of the industry. Additionally, the industry needs to encourage the rationalization and reduction of the number of infrastructures needed to support aerospace standardization. It should focus resources on the processes and organizations working to ensure the efficient development of the standards needed for aerospace.

Many Developers, Many Standards

The aerospace standards development infrastructure is crowded and complex. The industry uses hundreds of thousands of standards, including documents from close to 150 different SDOs worldwide. That number is growing. Thousands of technical experts are sent to committees to develop standards for, among dozens of other technology and functional topics, the following:

- Systems engineering.
- Software parts.
- Materials.
- Testing.
- Quality.
- Electronics.
- Avionics.
- Propulsion systems.
- Fuels.
- Software.
- Homeland security.
- Emissions.

Few aerospace companies, let alone the industry as a whole, have examined the entire landscape of standards activities with the intent to proactively manage where standards work gets done. Each standards developer utilizes an infrastructure that must be maintained and nourished to enable it to continue to function. Each of these organizations requires time, effort and resources from various stakeholder groups. The aerospace industry has done little to encourage or promote the rationalization of the various SDOs supporting the industry, or to harmonize and reduce the number of standards. This is the case despite the fact that there is great potential for large ROIs in efficiencies and reductions in duplication. Multiplying those benefits are the cost savings to be had in the areas of certification and testing. These can all be obtained by harmonizing standards and consolidating the infrastructures used to develop and maintain them.

There are approximately 450 private sector standards developers in the United States, with at least 150 consortia as well. These organizations produce somewhere in excess of 250,000 standards. Additionally, there are between 50,000 and 100,000 federal government standards produced by standards developers in just about every cabinet, department and agency. At many aerospace companies, there are also external and internal standards groups that rival the largest private sector or government standards developers.

All of these standards developers have individual infrastructures that must be maintained and supported. By one estimate, the United States spends $1.25 billion annually on all of these standards and their supporting staff, processes and procedures. The bulk of this is contributed labor coming from the industry and government participants in standards development activities. Perhaps as many as 200,000 volunteers (including roughly 25,000 from the aerospace industry) participate in standards development activities, many participating in multiple SDOs' activities. This represents a significant commitment of research and engineering resources – resources that most companies and government agencies say are in extremely short supply. For example, it takes a staggering 9 million parts to build the C-17 (**Figure 3**), and thousands of standards to define those parts. Expenditures such as these must be made wisely, or they risk becoming *expenses* instead of *investments*. Thus, the question is: Are we spending wisely?

Figure 3. C-17s Composed of Millions of Parts

For the most part, standards development efforts are not directed – usually not even influenced – by any sort of top-down strategy. If they were, they would be led by national need, by industry sector, by company, by user group, by consumer segment or by any other broad view. Rather, standards development is largely based on needs asserted by individual participants, on a standard-by-standard basis. This is done in SDO committees, government offices and corporate standards offices. Furthermore, even where a clear need has been established, the development of a standard to meet that need is dependent on volunteer effort.

Aerospace Industry Dependence on Standards

Although the aerospace industry is responsible for producing approximately 10% of the standards developed in the United States, it uses nearly 35% in the designing, development, building, operating, sustainment and disposal of aerospace products. The aerospace industry, perhaps more than any other, governs its products' life cycles with standards. Nearly 40% of all engineering and manufacturing data is standards based. Only a few industries can claim to be more tightly regulated by standards than can the aerospace industry. Developing the right standards and ensuring their technical accuracy, currency and excellence is crucial to the health of the industry.

Multiple Infrastructures and Overlapping Work

As depicted in **Figure 4**, hundreds of company, industry, national, regional and international SDOs are involved in the development of standards used by the aerospace industry. For the most part, each of these developers is free to define its scope of activities and the standards in its portfolio. The result is a sometimes confusing landscape of overlapping scopes and often duplicative standards. This is not the fault of the standard developers, and it is in fact to their credit that they remain willing to be responsive to the needs of their constituencies.

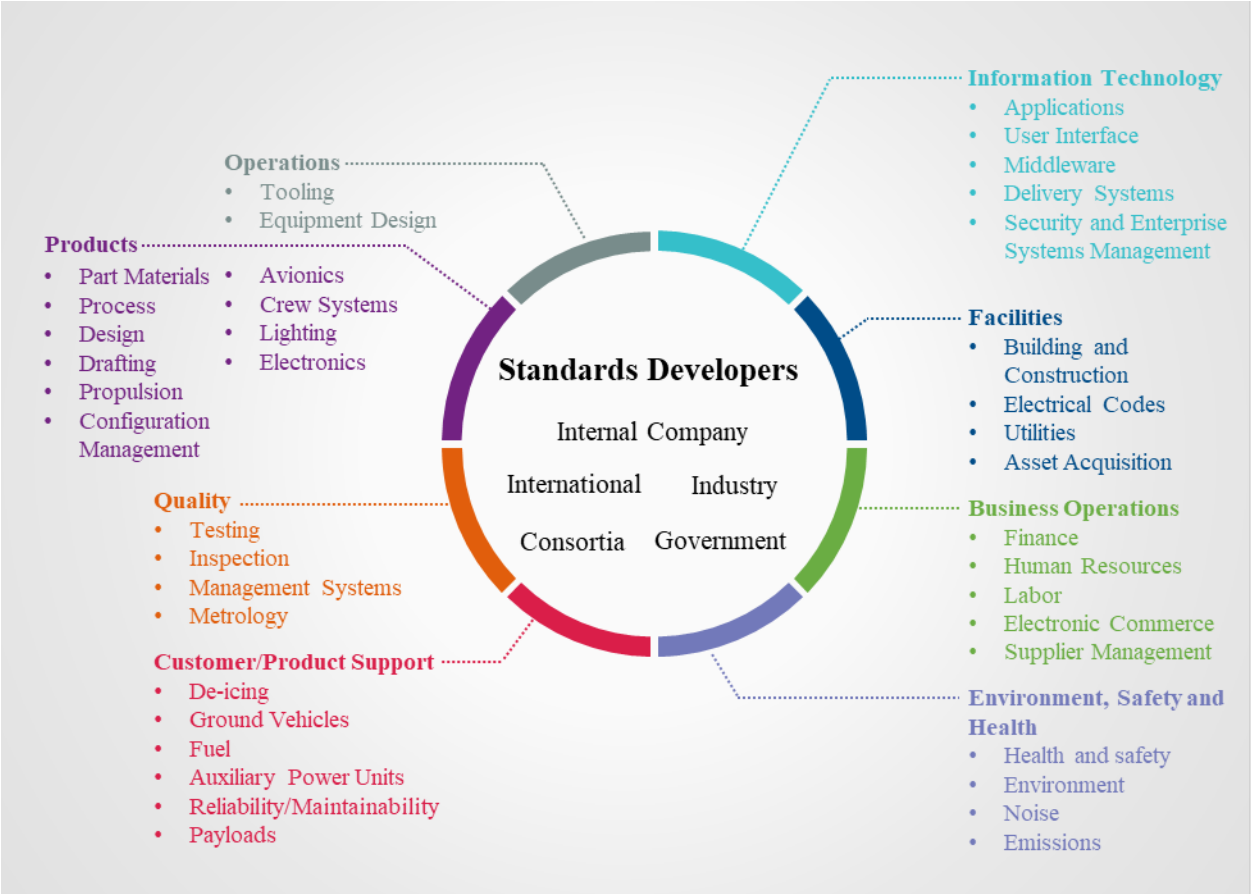


Figure 4. Breadth and Scope of Standards Used in the Aerospace Industry

Few aerospace companies, let alone the industry as a whole, have examined the entire landscape/ecosystem of standards activities with the intent to proactively manage where standards work gets done. For the most part, new standards are created in a venue by SMEs already participating in that organization. There is little effort made to determine the optimal place for a particular standard to be developed. Unfortunately, there is also no easy way to quickly determine all the standards developers that have relevant TCs, identify any relevant or duplicate existing standards, or even ascertain whether there is similar work under development in multiple venues.

Each standards developer represents an infrastructure that must be maintained and nourished to enable it to continue to function. Each of these organizations requires time, effort and resources from various stakeholder groups. An efficiently run company probably would never maintain five organizations to do its payroll; such a duplication of infrastructures does not make sense. However, the same business oversight has yet to be applied to the standards world. The table in **Figure 5** illustrates this. It was presented at the first International Aerospace Standardization Workshop, held in Montreal, Canada, in 2003. The totals for AIA, the American Institute of Aeronautics and Astronautics (AIAA), ARINC Standards, and SAE International represent the total aerospace standards developed by the organization. The totals for all others, which are not aerospace-unique standards developers, are those identified by Boeing at the time.

	AIA	AIAA	ARINC	ASME	ASTM	DoD (45)	EIA/GEIA	IEEE	IPC	ISO/IEC	SAE
Avionics			177			27	10	11			28
Bearings	51				2	97				44	89
Cargo Handling	1			87	2	13				36	61
Chemical	3				27	216					73
Composites	3				4	29					467
Computing Hardware						17	25	13			26
Configuration Mgmt.					1	5	32	4			-
Couplings, Hoses and Tubing	136			49	13	396					1,122
Data Management	2					56	2			13	-
De-icing	4					3				3	32
Drafting	6			28	1	19		2			-
Elastomers	1				6	41					187
Electrical/Electronics	155	1			2	2,420	170	32	12	54	533
Environmental		1			2	14				3	81
Fabrics					11					2	-
Fasteners	2,513			108	4	935				90	1,079
Finishes	9				11	219					210
Fire Safety											-
Fluid Power Systems	12					122				73	154
Fuels and Fuel Sys.	3			21	59	57					58
Ground Support Equipment	16					6				14	65
Human Factors		1			1	17	4	1			167
Information Mgmt.						22				51	-
Instrumentation	1					121				10	97
Landing Gear	3					12				6	81
Lighting	1					56					44
Lubricants	5				2	85					17
Mechanical Parts (clamps, rings, rods, knobs, etc.)	285					316					-
Metals	59				238	432				18	1,351
Network/Web								10			-
Nondestructive Tests	5				27	26				9	30
Non-Metallic Materials					61	490					
Oxygen	1				1	36					65
Packaging	59			7	6	87					28
Printed Wiring Boards						24			56		-
Propulsion Systems		3			1	23				1	244
Quality	5					19		2		12	16
Safety	5					6					40
Sealants					11	71					51
Seats	2					2					7
Software Engineering		4				13	25	17		7	13
Space Vehicles		17			3					27	-
Systems Engineering						41	3	14			-
Testing/Metrology	71	2			525	94		8	18	22	15
Totals:	**3,417**	**29**	**177**	**300**	**1,321**	**6,685**	**271**	**110**	**86**	**495**	**6,571**

Figure 5. Aerospace Standards by Key SDO

Functional Types of Standards and Their Distribution in Aerospace

The distribution of types of standards can vary according to programs, platforms and processes. However, on average, 50% of all standards pertain to parts/components; 20% to materials and

processes; 15% to quality; 3% to environment, safety and health; 7% to testing and certification; 3% to tooling; and 2% to business operations and facilities. Also, among the thousands of standards used by aerospace, many contain embedded references (i.e., references to other standards) that can flow down several tiers. A survey of approximately 5,000 company part standards showed an average of 8.7 standards references for MIL-SPECs/MIL-STDs and industry standards.

Thus, standards are rarely stand-alone technical documents; instead, each standard is part of a larger web of technical information. Managing and ensuring that all references are still valid and current is a huge but critical task. The greater the number of standards, the larger the web of technical information to maintain. The reference tree in **Figure 6** is an example of how a Boeing part standard is built on a foundation of industry standards and MIL-SPECs/MIL-STDs.

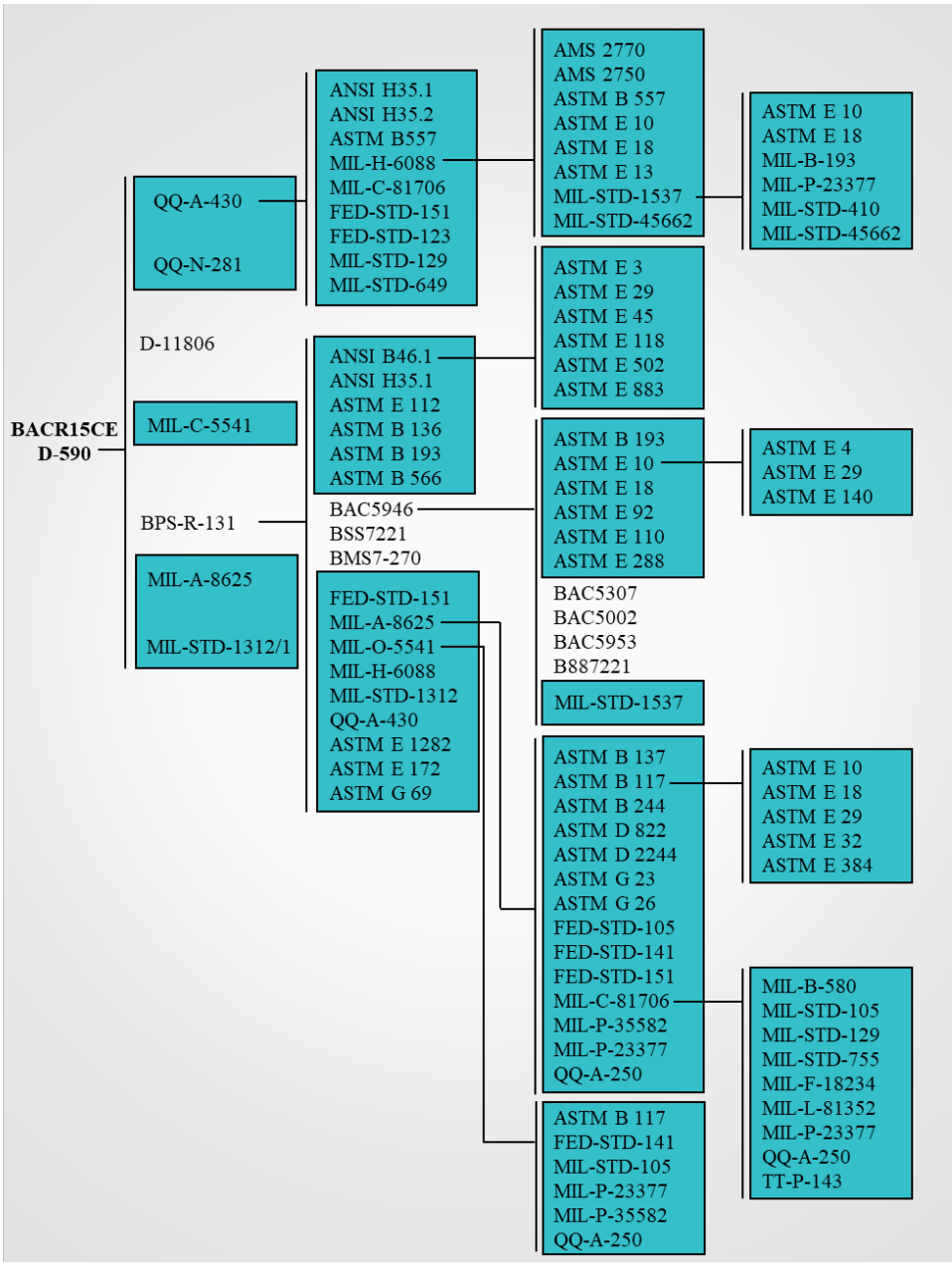


Figure 6. Typical Standards Reference Tree

Quantity Not an Indicator of Quality

Having more standards does not mean having better standardization. In fact, numerous studies have been conducted on the value of rationalizing, harmonizing and reducing the pool of standards available for new designs. Granted, there will always be a need for new parts, materials and processes, as this is part of innovation and continual improvement. However, the costs associated with adding each new part to the pool of standard parts, summarized in **Figure 7**, must be recognized. This is especially the case with environmentally friendly alternatives to hexavalent chromium and cadmium, among other such developments.

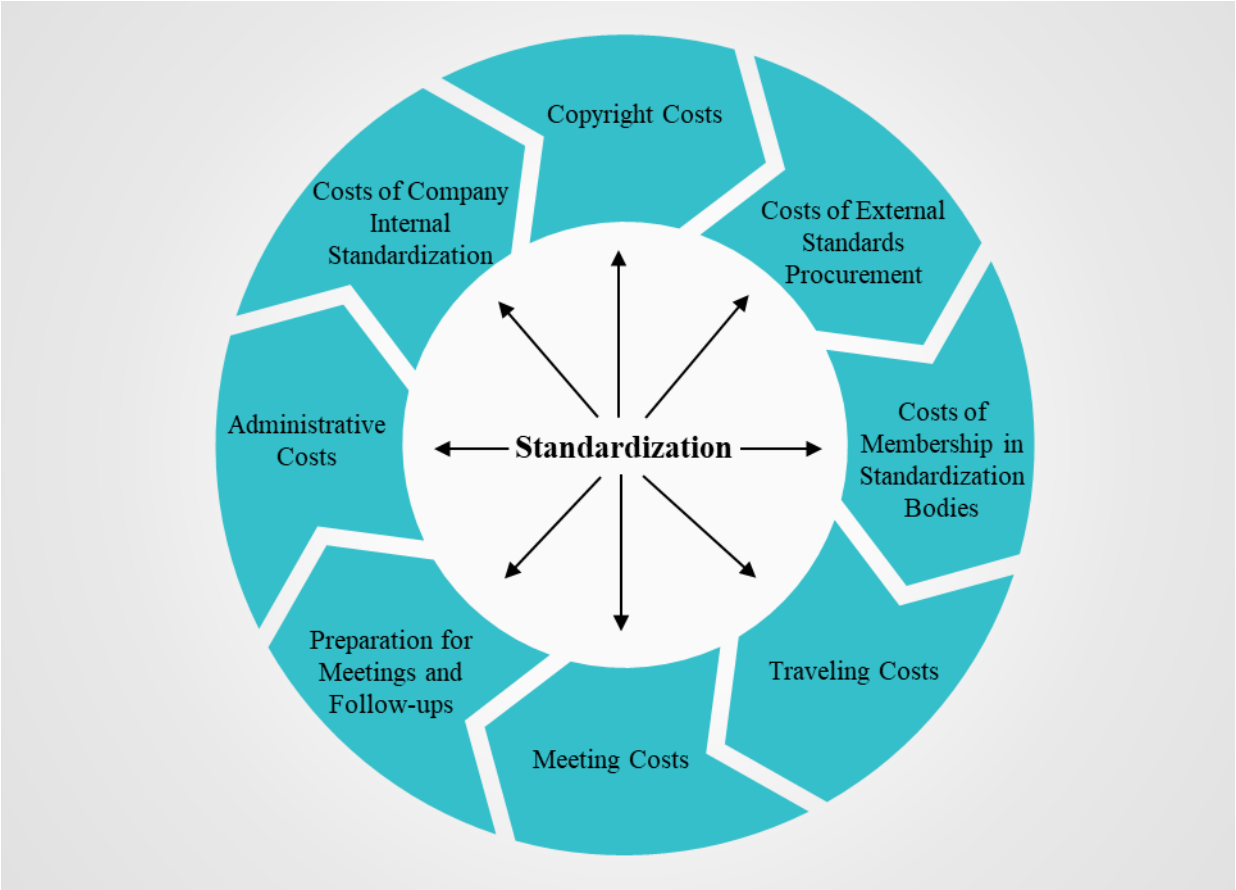


Figure 7. Cost Factors Involved in Standards

Thus, the questions to answer are:

- How many new standards are created due to inefficiencies in the standards system?
- How many standards are created when another suitable standard already exists?
- How many company standards are developed instead of using an existing industry standard?

Many aerospace companies have implemented internal programs to reduce the number of standards used to define their products. Airbus, for example, achieved a 38% reduction in the number of standards used to define the A330 and A340, compared to the number used to define

the A300 and A310.[12] Airbus has noted that the worldwide increase in demand for aircraft that operate globally calls for the worldwide availability of low-priced spares. As a result, the share of standard parts and their repeated use in aircraft must be increased, and the number of unique parts reduced. To do this, the subject of standardization, as well as the control of the proliferation of standards, must be given greater attention. With the reduction in standards goes a reduction in the cost factors involved in the development and maintenance of these standards.

The aerospace industry, as a whole, has done little to encourage or promote harmonizing and reducing the number of standards. Part of the problem lies in the fact that it is very difficult to have full visibility into all the standards – both active and in work – used by the industry. The aerospace industry is thus urged to provide users with a single reference indicating which standards exist and which standards are under development to help avoid duplicative standards. Also, efforts should be made to avoid regional duplication and develop or harmonize local standards around a single, global standard. This will greatly simplify and reduce the time and cost involved in certification efforts conducted by multiple regulatory agencies.

The industry should also work closely with key SDOs to encourage clarification on the scopes and programs of work, and to help concentrate similar types of standards within the fewest organizations. This will make the most of the resources and efforts involved in donating SMEs to the development activities. It is recommended that the industry first concentrate on the SDOs that are solely devoted to aerospace standards: SAE Aerospace, AIA, AIAA, ARINC, ICAO, the International Air Transport Association (IATA) and the FAA. The industry has the greatest influence in these organizations. Efforts to reduce standards proliferation can then extend to organizations that have aerospace committees, such as ASTM, IEEE and agencies creating MIL-SPECs. Then, industry can reach out to organizations that develop standards used by multiple industries, such as ASME, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and the American Welding Society.

The aerospace industry has spent vast resources over the years working to overhaul its manufacturing processes. It has introduced such concepts as lean manufacturing and systems engineering, and it has restructured its supply chains. Each year, billions of dollars' worth of parts, materials, subassemblies, processes and tests are defined and governed by standards. It is surprising how little attention has been given to the strategic management of these critical documents or the processes and infrastructures used to develop and distribute them.

As an industry, aerospace does a fairly good job of managing standards as individual technical documents. However, it fails to take a big-picture view that looks across all standards types and all standards developers. There is great potential for large ROIs in efficiencies and reductions in duplication, not to mention the cost savings in the areas of certification and testing. These can be achieved by harmonizing standards and consolidating the infrastructures used to develop and maintain these documents.

Conclusions

The aerospace industry needs to take a big-picture look at all the standards and infrastructures involved in creating and maintaining its critical technical data. The industry's goals must be to

[12] Daimler-Benz Aerospace Airbus, "Standardization."

assess gaps, reduce redundant standards, prevent unwarranted proliferation and ensure support for the standards supply chain. Additionally, the proactive and strategic management of aerospace standardization activities is needed to ensure the most efficient and effective use of industry resources and talent. Every effort should be made to develop standards with organizations that offer the broadest inclusion of all stakeholders, the most cost-effective processes, and the most easily accessible products.

Chapter 3
Leadership

Recommendation No. 3: The aerospace industry needs to have leadership positioned to provide both technical and business integration in standards issues and solutions. Leadership organizations must be recognized as integrators for the industry, respected as objective without conflicts of interest, and acknowledged as having the support of both industry and government. These organizations must be able and willing to use appropriate means to accomplish aerospace standardization objectives. This includes means of allocating resources, enlisting senior management, resolving overlapping scopes among aerospace standards organizations, lobbying and so forth.

Leadership Deficit

We perceive there to be little leadership in aerospace standardization, even though the SDOs and government standards developers and regulators define organization and management well. The standards and their development are generally managed well, also. What is lacking is industry-wide leadership for standardization, and it seems only the immediate shortfalls are addressed.

Few top executives pay attention to the opportunities for market influence through standards. If they did, they would be insisting on a strategic approach to analyzing standards opportunities and needs. Then, they would strategically deploy their standardization resources to influence the standards that present the greatest advantages to their respective companies or nations. Such an approach would offer a means of improving the efficiency of many engineering activities in the design-build-operate-sustain-dispose cycle. Also, it would provide a potential competitive edge in product development, marketing and sustainment.

There are hundreds of SDOs, thousands of standards, millions of dollars spent on developing and acquiring these standards, and billions of dollars' worth of impact. Despite that, there is no single person or organization at the helm. Rather, standardization priorities are established ad hoc, based not on industry need but on whatever someone needs at the moment, or on whatever technical skill is available in a standards committee.

Standardization decisions that can affect safety, corporate profitability and U.S. trade are often made by technical specialists, mid-level engineers and technicians who cannot see, or are not privy to, the big picture. What is needed to resolve this is company internal communication and decision support. Also necessary is a single body that can involve all stakeholders, establish a U.S. position, and advocate that position in international forums. This body will provide a unified voice for U.S. industry when dealing with standards issues involving, for example, regional bodies like the EU.

Establishing Aerospace Standardization Leadership

There is currently no unified leadership in aerospace standardization that can function in an integrator/advocate capacity. Instead, aerospace standardization efforts are executed by multiple

individual SDOs. What is needed is a single aerospace organization that actively promotes developing globally relevant standards in a manner that prioritizes the technical suitability and market relevance of a standard. The aerospace industry needs a body to be the lead advocate for standards as tools supporting open and fair international trade. This body will provide education, awareness and advocacy for aerospace standards with industry, government, consumers and trade bodies. It will address industry standardization issues, opportunities and challenges, and will work with all stakeholders to prioritize and respond to standards issues critical to aerospace.

To prove highly effective, this body will represent a U.S. aerospace presence (or formal position) in international forums, and will promote aerospace standardization in the appropriate venues. It will advocate standards as supporting open and fair international trade, and will work to ensure a level playing field for the development of globally relevant standards. This will mitigate the efforts of countries to use domestic or regional standards to promote or gain a competitive trade advantage.

It takes leadership to create and sustain the strong partnerships needed among all stakeholders – industry, government, standards developers and academia – to enhance the development, delivery, management and utilization of aerospace standards.

While doing so, the body will remain compliant with the WTO's criteria for developers of international (global) standards. Yet, it will be ensuring that aerospace standards are developed by United States-domiciled international standards developers, such as SAE International, ASTM International and the IEEE. To satisfy the non-U.S. entities in aerospace, the body will ensure that global aerospace organizations (IAQG, IAEG, ICAO, etc.) do not misinterpret U.S. standards bodies (ISO, IEC, ITU, etc.) as dominating international standards.

Creating an Aerospace Forum for Standardization

The need for leadership is apparent, and the importance of leadership is obvious. Despite that reality, the position of leadership is vacant. What the aerospace industry needs is a forum where all the stakeholders can come together to address standardization issues. This forum would not address or resolve *all* issues; nor would it be a standards-developing body. Rather, it would provide a place where the industry could unite and articulate a need to standardize an emerging technology or develop an aerospace-industry derivative. In doing so, the forum would enable determining the best plan, including the best mechanism (e.g., SDOs), for undertaking standardization work.

This forum would also offer a place where industry could prioritize standards issues critical to aerospace to ensure the proper focus and attention of senior leaders. It could facilitate the creation of a U.S. aerospace standardization strategy, perhaps starting with this document. Also, it could ensure that this strategy supports the National Standards Strategy developed by the ANSI Federation, and could integrate it with other national and international standards strategies.

Speaking with One Voice

Establishing the forum previously described would give the industry a single voice that it could use in SDOs. This would replace the current system, in which individuals and companies act in

isolation to define requirements that ultimately carry little weight, given their lack of industry-wide backing. Through this consolidated approach, the industry could help to:

- Rationalize the standards system.
- Avoid duplicative committee scopes and standards.
- Reduce the unnecessary proliferation of standards.

Speaking with one voice, however, requires having a single focal point for all the organizations, committees and standards supporting aerospace. Representing aerospace, this focal point would assemble the complete index of active and in-work standards. Doing so could prevent initiating standards development efforts for subjects already addressed in existing or in-work standards.

Educating, Promoting Awareness and Advocating

The aerospace standardization body previously described can help to articulate and promote the value and benefits of standards to the industry. This body will collect case studies and develop educational materials that communicate the impacts of standards to senior leadership. These will provide the skills and knowledge necessary for those participating in the development, maintenance, distribution and use of standards. In the process, the standardization body will utilize a wide variety of venues and media. Through these, it will advocate standards, raise awareness of the benefits of standardization, and advocate the policies necessary to ensuring the appropriate level of industry support for standards.

This body can also proactively offer standards participant training to newly assigned points of contact (PoC) for representatives to SDO committees. With an ever-changing workforce, these representatives must be made to understand the ecosystem of aerospace standards and standardization. Providing this training can flatten the learning curve that exists when they are new to complying with committee rules, representing individual aerospace company positions, and completing any related training. At times, even the best experts do not know how best to effect influence on technical insertions in emerging or revised standards. Training can be accomplished at the individual company level or through generic approaches offered throughout the aerospace industry.

"It has been said that learning to be a standards engineer is akin to repairing the exterior of an airplane wing while in flight. Both activities are exciting and well above the crowd."

– Alan Batik,
"The Engineering Standard:
A Most Useful Tool"

Conclusions

Standards represent a significant investment by the aerospace industry. There needs to be an integration function that can facilitate the prioritization and focusing of industry standardization efforts. There also needs to be a development of industry-wide solutions that apply both externally and internally to aerospace companies. The aerospace industry would benefit from having a forum focused on rationalizing the standards system, avoiding duplicative committee scopes and

standards, and reducing the unnecessary proliferation of standards. We must recognize the potential need for aerospace-specific derivative standards in many common industry technologies.

Without effective U.S. leadership in aerospace standardization, ever more technical data supporting the U.S. aerospace industry will be developed in venues controlled by foreign aerospace industry representatives. These standards will, intentionally or inadvertently, favor foreign manufacturers – perhaps, U.S. adversaries. Therefore, the impact will affect not only prime system integrators but also the entire supply chain supporting the aerospace industry.

Chapter 4
Global Markets with Global Standards

Recommendation No. 4: The standards chosen for the global aerospace industry must be recognized internationally, with support for the development process of the developing organization. When possible, it is desirable that these standards be made the basis for national, foreign, regional and international regulations and laws. Also, the global standards should be open for input from all stakeholders in the industry per WTO standards development principles.

Aerospace is a global industry with supply chains and customers all over the world. To support the defense and commercial industries' vision of designing, building and operating anywhere, global standards are necessary. These are defined as the standards recognized throughout the world as technically suitable, accepted as meeting the pertinent design and certification requirements, and used throughout the industry. The aerospace industry needs to assert the right to choose its standards based on technical merit and suitability for use. It must be at liberty to choose these regardless of whether an industry-relevant standard was developed by an organization with the word "international" in its name.

Global Trade and Global Partnering

Over 80% of all trade is directly impacted by standards,[13] and standards are vital – now more than ever – to facilitating global trade. They can open new markets, reduce trade barriers and assure aerospace customers of receiving consistent quality, interchangeability and sustainment. It is important to remember that aerospace products are not constrained by geopolitical borders. For example, most commercial jetliners are sold to customers in countries other than those in which they were manufactured, and aerospace products orbit the earth and fly across the skies. Since aerospace customers, design partners and suppliers come from all over the world, the industry's focus must be on global standards rather than local, regional or national standards.

Global standards form a common language that allows for a more effective integration of products and services into international markets. The more widely a given standard is used, the more valuable it becomes to the aerospace industry. Communication, compatibility, economies of scale and other benefits of standards all increase as those standards become globally recognized, accepted and used. This is because they are a significant part of the common technical language articulating the requirements necessary to design, build and support aerospace products consistently and with high quality worldwide. They help to define new, emerging technologies; establish widely accepted requirements; set criteria for international quality assessment systems; and meet a fundamental need as the international language of trade.

[13] Benjamin Wu, Deputy Under Secretary of the Technology Administration, U.S. Department of Commerce Aerospace Standards Roundtable, September 4, 2003.

The development of global standards in forums (e.g., ICAO, ARINC) and SDOs (e.g., SAE International, ASTM International, IEEE) is critical to giving U.S. aerospace companies a competitive advantage.[14] The impact of that approach was demonstrated by the EU, whose leadership acknowledged that a strong standardization system is key to the functioning of the EU market, the protection of health and safety, the competitiveness of industry, and the promotion of international trade.[15] While supporting global trade, standards can also enhance domestic competitiveness. To achieve that, EU leaders set forth an aggressive standardization policy.

"Strong and effective U.S. leadership and participation in international standards organizations are key to the long-term competitiveness of U.S. products in global markets."

— U.S. Congress, National Competitiveness Act of 1993

ISO and the IEC are two of the most widely recognized SDOs that develop standards intended for international use. These organizations have a one-nation-one-vote policy, so the EU is actively promoting them as the only developers of "true" international standards. However, the aerospace industry has a longstanding precedent of using other organizations – ICAO, ARINC, the IATA, SAE International, IEEE and ASTM International – to develop standards for international use. Most of these bodies provide aerospace participants with a more level playing field via direct industry participation. As such, the aerospace industry needs to protect its ability to develop global industry standards in the forums that best serve its needs.

Global Standards Best for Key Areas

Global standards on safety are necessary in order to support the free trade of aerospace products. The aerospace industry needs to advocate for global standards for safety certification as a way to prevent some governments' use of safety certification to enhance their domestic competitiveness.[16] Global standards are also essential to the creation and operation of systems-of-systems solutions to aerospace challenges. Examples of these challenges are satellite navigation, a modernized air traffic management system and network-centric warfare.

Environmental considerations are another standardization area that has become significantly important and plays a growing role in certification, trade and regulatory policies. The EU has said that standards have a high potential to support sustainable development, comprising economic, social and environmental aspects. The preference, however, should be for standards to precede regulation, and for standards to be incorporated by a regulation if a regulation is created.

Getting ahead of the United States, the EU Commission listed standards as a tool for establishing a framework for the continual environmental improvement of products throughout their life cycles. As a whole, Europe has taken a strong position in response the Commission's publication "Integration of Environmental Aspects into Standardization." This document urges stakeholders

[14] Commission on the Future of the United States Aerospace Industry, "Final Report."
[15] *Official Journal of the European Communities* 66 (March 15, 2002).
[16] Commission on the Future of the United States Aerospace Industry, "Final Report."

to integrate environmental protection into standardization.[17] Also of note are the policies contained in the EU regulation Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and its many international derivatives. These elevate environmental compliance for the aerospace industry to a much higher level than earlier environmental regulations had.

Aerospace Standards Serving a Global Customer Base

The United States has long been a world leader in aerospace technology, products and services. Other countries challenge this role by directing resources to promote an indigenous aerospace industry. For example, EU research programs and standards efforts are driven by policies seeking world leadership for its civil aeronautics industry. EU member states are also placing increased emphasis on integrating and coordinating national research and standards programs. As a result, U.S. SDOs stand close to losing the advantages they have held in aerospace standards.

Standards enable the interoperability of systems throughout the world. Yet, there is no single national or international body that provides a common focal point for government, industry and academia to address aerospace standards issues. A national aerospace standards vision is needed to direct aerospace standards efforts. Although the United States' defense industrial base is strong today, the nation will be at risk if it continues to proceed without a policy that supports essential aerospace capabilities. Aerospace standards are an integral element of aerospace capabilities, so they must be prioritized in support of essential aerospace capabilities. The United States has had unlimited opportunities to revolutionize aerospace in the 21st century, open up new markets, and launch a new era of U.S. global aerospace leadership. Leadership in aerospace technology and products will require corresponding leadership in aerospace standards.

The World Trade Organization and Standards

The WTO has long recognized the critical role standards play in the global economy. In fact, the organization has developed a set of criteria for what constitutes an international SDO. These are based on ensuring that due process is followed with regard to:

- Openness (all stakeholders have the opportunity to participate).
- Transparency (all work is visible to and accessible by stakeholders).
- Impartiality and consensus (all comments are attempted to be reconciled, and all processes are conducted with impartiality toward the participants).

The aerospace industry needs to work with the global community to help dispel a misconception that international standards are only those coming from ISO, the IEC and the ITU. The aerospace industry has its own international organizations, such as ICAO and the IATA. Additionally, it relies heavily on industry standards developed by SAE International, IEEE and ASTM International, among others. Such industry organizations as these, although domiciled in the United States, meet all the criteria established by the WTO for a developer of international standards. The industry needs to confront the obstacles of culture, distance, regionalism and historic perception of industry standards developers based on where they are domiciled. The focus should be placed on working with all stakeholders to develop the most technically accurate and

[17] EU Communication COM (2003), 302.

relevant standards, wherever it best makes sense, as long as the developer meets the WTO's criteria.

Global Standards, Not Just International Standards

The aerospace industry needs to rise above the arguments of what constitutes an international standard and focus instead on the idea of global standards. A global standard is one that is:

- Globally recognized (all stakeholders around the world acknowledge its technical accuracy and relevance).
- Globally accepted (regulatory agencies and customers around the world recognize the standard as meeting the applicable requirements).
- Globally used (all stakeholders use the standard).

The aerospace industry needs to ensure that it maintains the right to determine which standards meet the global needs of the industry. It must assert itself in the face of strong EU and other regional standards politics. These often promote standards developed by the European Committee for Standardization (CEN), European Committee for Electrotechnical Standardization (CENELEC) or ISO over those developed by a United States-domiciled global standards developer. AIA, in conjunction with key aerospace standards developers (SAE International, ASTM International, ASME, IEEE, etc.), needs to work with ANSI, the U.S. DOC and the USTR. Doing so can ensure that foreign legislature does not unfairly state a preference, or order of precedence, for standards that would result in a barrier to trade.

A global aerospace industry needs to have standards that are not dominated by the United States, Europe, Japan, China or any other regional or political entity. The industry needs to have standards that are dominated by technical excellence and market relevance. In greater proportion than ever before, standards used in aerospace are not unique to aerospace, even where aerospace derivatives could be warranted. Technically excellent, market-relevant standards come from many developers, many nations, and many market and technology sectors. These standards are – and must continue to be – the technical documentation of choice for aerospace engineers, designers, maintainers and operators.

Conclusions

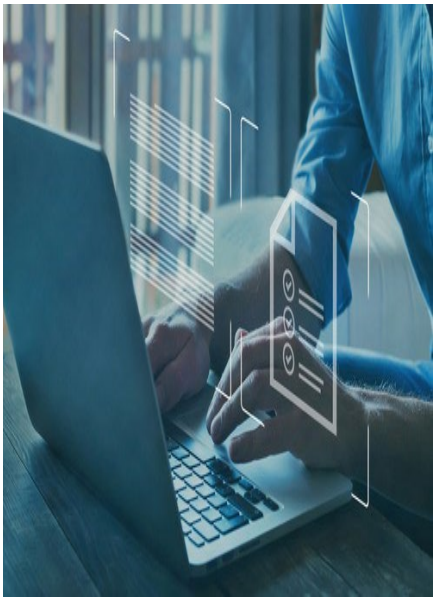
The aerospace industry must work with world governments, regulatory agencies and the U.S. DOC, DoD and USTR. Additionally, it must work with the standards-developing community to ensure that global industry standards are chosen based on their ability to meet technical and market needs, not on which organization developed them.

The more universally used a standard is, the more it generates industry efficiency and provides better ROIs. Using globally recognized and accepted standards spreads the cost of development and maintenance across a larger portion of the industry. Often, more suppliers can lower costs and reduce expenses, such as those of certification efforts.

The global nature of the aerospace industry, with its worldwide supply chain and customers, demands global standards. The aerospace industry should strive to develop standards with the

organizations that offer all stakeholders the opportunity to participate. It should also encourage making access to global standards easy and efficient for all.

Chapter 5
The Business of Standards, Using New Models and New tools



Recommendation No. 5: The business models and tools used to develop, distribute, integrate and use aerospace standards need to ensure that standards development is responsive to business and technical drivers. Development must also be based on a business case or market need, and the standardization process must be adequately funded and supported. Also, the models must enable the tools and processes used to develop, maintain and disseminate standards to optimally use technology and the internet to ensure an efficient, effective system involving all stakeholders. Building on that, standards must be developed and disseminated in a way that enables data to be easily integrated into product definition data or other life-cycle data streams. Furthermore, the tools and processes involved in the standards' development and dissemination must not be hampered by data-format issues or IP issues.

The technical data contained in standards enables the designing, building and sustaining of aerospace products. To maintain that ability, however, the tools, processes and formats used to write, manage and distribute that data need to evolve. As the aerospace industry quickly incorporates e-enabled processes, digital simulation and verification, and integrated product data and definition, standards must adapt. They must migrate to formats that allow them to be assimilated into product data design and management systems, and they must migrate digitally throughout the supply chain. The tools and processes need to take advantage of new technologies to achieve efficiencies in the development and release cycles of standards data.

Different Models, Same Key Criteria

The aerospace industry uses standards developed in a wide variety of venues utilizing many different business models, as **Figure 8** shows. A business model contains the elements of:

- Membership (who can participate).
- Consensus building (who can vote, and how balloting takes place).
- Funding (how the standardization process is paid for).
- Product (the final format of the resultant standard).
- Distribution (how the standards are distributed, accessed or integrated into design).
- Ownership of IP (which organization retains the copyright for the resultant standard).

Regardless of which business model is used by aerospace, the critical components are that the standards are technically accurate, current, suitable for their intended use, configuration managed, and accepted by regulatory agencies and customers.

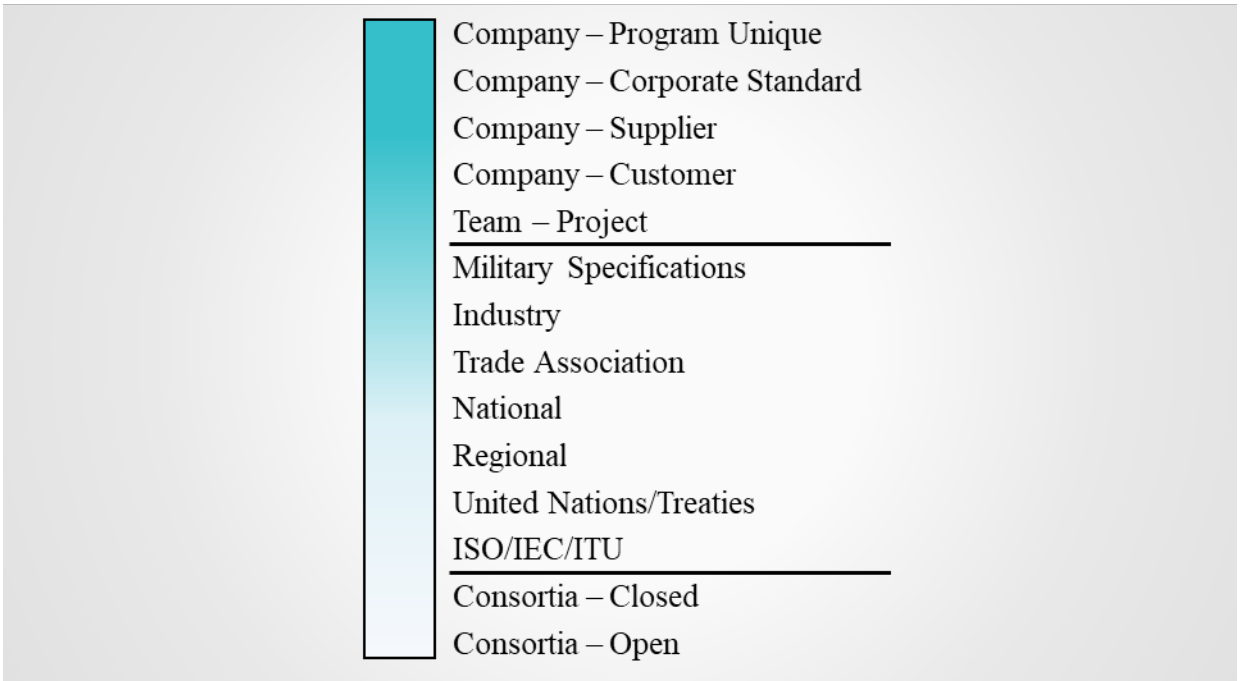


Figure 8. Models of Aerospace Standards Development

Making Business Decisions Regarding Standards Development

Standards are all too often considered just documents containing technical requirements, with little thought given to the business of their development and maintenance. If an aerospace company approached standards development with the same mindset used for other corporate activities, it would apply the same business decision criteria to standards:

- Cost (participation, travel and purchase).
- Control (ability to influence).
- Flow time (development time).
- Time to market (time to publish).
- Market relevance (clear business case for standardization).
- Market acceptance (global relevance).
- Dynamic nature of the technology (evolving vs. basic and stable).
- Maintainability (processes allow for rapid updates in a configuration-managed way).
- Ease of use (process used to create standards is easy and accessible to all stakeholders, and the resultant standards are easily accessible and provided in a value-adding format).
- Global (involves the global stakeholders and contains global requirements, supporting global platforms and global customers).
- Access to customers, suppliers and competitors.
- E-enabled platform (supports e-business and enables integration, migration and collaboration using the technical data from the standard).
- ROIs (benefits of using an industry standard vs. costs to develop and/or acquire the industry standard, or vs. the cost to develop the standard internally, and the value to internal programs of standardizing).

If an aerospace company, or the industry as a whole, applied these criteria when choosing which organization should develop a new standard, a set of preferred standards suppliers might emerge. These would likely have minimal participation fees, a strong aerospace focus and a mechanism for obtaining direct industry input. They would also provide the resultant standards in a way that rendered them easily integrated into the rest of the engineering product data. As the companies and industry would evaluate the tradeoffs, funding levels might undergo changes. They might come to reflect the importance of standards as part of product data, shifting the focus from the cost of licensing standards to the benefits derived from standardization.

Applying business drivers to standards development means that new standards work will be placed in whichever venue can deliver a standard that meets the core requirements and best addresses the business drivers. In the process, pressure will increase for all standards venues to examine their processes and make changes to be responsive to the business drivers impacting their constituencies. Any venues that allow participation from all global stakeholders will become those that are preferred. Also, the standards will be in a format that allows users to access the technical data however best facilitates the integration of standards data into other design and manufacturing data. Standards will not be developed without a clear understanding of the business drivers and market relevance for the standardization activity.

Funding the Aerospace Standards Infrastructure

Standards are not free. No matter where, how, or by whom they are developed, standards consume resources in their development, coordination, approval, publication, maintenance, indexing, interpretation, appeals, administration and management. Each organization responsible for each element of the standards life cycle supports the operation in some way. The business models are many and varied. For company standards, the individual company bears all the costs of standards development, maintenance and distribution. For MIL-SPECs, taxpayers fund these activities. For standards developed by private sector or industry standards developers, three broad mechanisms are used to pay for the infrastructure: document sales, participation fees and membership fees. Most organizations use a combination of these mechanisms to form a business model that allows them to pay for all the processes and infrastructure costs for the standardization life cycle.

The standards developed by an SDO are typically copyrighted and sold to users. In aerospace companies, this is often done through a third-party reseller. The sales take place in many different ways, from the straight retail sale of a single document (soft or hard copy) to an individual user, to the sale of corporation-wide access to online libraries of standards from multiple developers. The business arrangements for these are very different, but the model is still the same: the standards user pays for access to copyright-protected IP.

Organizations' dependence on selling documents varies dramatically, ranging from 0% to almost 90% of an organization's total revenue. The point being made is not the fact that standards cost money; all elements of the infrastructure needed to design, build and sustain aerospace products cost money. The significant issue is whether or not a given standards developer's business model for selling the standards is the most efficient and cost effective for the price.

Expense to Acquire Standards vs. Investment to Use

Standards are tools that must be paid for in order to reap the benefits of their use. Because the standards infrastructure is mostly paid for through sales of standards, the focus tends to fall on the acquisition costs of these standards, often set by third-party suppliers. This focus ignores the benefits reaped by using industry standards. These benefits can lead to reductions in procurement, manufacturing, certification and conformity assessment costs – all of which can outweigh and render negligible the initial costs of procuring the standards.

Focusing on the costs to acquire industry standards also tends to ignore what it would cost a company to develop the same standard in house. Furthermore, it overlooks the impact that in-house standards development would have on procurement, manufacturing, certification and other life-cycle components. If standardization is not paid for by buying the *product*, then it must be paid for by buying the *process*.

Aerospace companies that support standards development provide technical experts who serve as technical consultants. In doing so, these companies incur significant direct expenses in human resources for time and travel, and indirect expenses in donating their IP to the resultant standard. Most SDOs require committee participants to sign some type of release form, and this transfer of IP is a key enabler of the aerospace standardization process. It is also a main reason why the aerospace standardization system represents a very large knowledge and experience base; it contains nearly 100 years of aerospace intellectual capital.

This donation of IP is how a company can ensure that its technical requirements are contained in a standard and vetted through the process of an industry-wide review. If the business case for donating technical content is not there, then the company should seek other ways of documenting these requirements in company data systems. Otherwise, the cost recouped by the SDO for managing the standardization process is far outweighed by the standardization benefits to the industry and any participants in the process.

Tools for Standards

Tool Delivery and Development Supporting Current and Emerging Industry Trends

Any consideration of tools and applications depends on an overview of the landscape and environment in which the tools are used. Aerospace and all other industrial sectors are in the midst of an information-handling revolution as significant as the advent of movable type. This has contributed to dramatic changes in the way the industry functions. There now exist all-digital designs and a reliance on digital systems for such technologies as autonomy and digital twin verification. The aerospace industry's use of emerging information management and e-business tools to develop, distribute and integrate standards must align with the rapid advancement of internal product data and various system tools. The industry must more rapidly embrace these evolving technologies.

Aerospace companies are now large-scale systems integrators. They have shifted significant portions of the design and production processes out into the supply chain, operating through partners, contracting firms and/or long-term suppliers. Customer-driven design, testing and delivery requirements are emphasized, as are increases in design flexibility, speed and agility.

There is also a convergence of supporting sectors, such as IT, telecommunications and cybersecurity. Consequently, the industry is in need of cost, quality and speed metrics. Coupled with the decentralization of functions, collapsing design-cycle times and inter-company manufacturing costs, the need for greater collaboration within and among companies is clear. Companies must be able to exchange all types of information with all of their suppliers, partners and customers – instantaneously. This requires data integration at all levels.

Standards are a significant part of this business technology information exchange. The significance of the flow of standards information, as well as its integration into business processes, is clear. Companies routinely need to share standards information as a part of product designs and other digital files with suppliers, and they expect reciprocal information as well. External linkages with customers, suppliers and partners are evolving rapidly, and additional complexities are being introduced. Throughout this process, having a reliable standards data exchange is requisite. To facilitate these linkages, standards convey the information needed on a product's functional compliance, safety and suitability. They also facilitate understanding between buyers and sellers, or between suppliers and customers, and facilitate mutually beneficial transactions.

Myriad changes have impacted the aerospace industry, including global outsourcing and partnering, the use of the internet to e-enable business, simulation and additive manufacturing/3D modeling, and integrated product data systems. These have made how the industry develops, distributes and integrates standards data become increasingly critical. Standards form the single largest source of technical data. Consequently, not having optimized products and processes for conveying this data ultimately restricts the designing, manufacturing and sustainment of aerospace products.

Any standardization tool suite is operating in an environment characterized by geographically and politically distributed industry players. However, the industry has transcended geopolitical boundaries by managing standardization priorities using, among other tools, a tracking database. This database can inventory emerging standardization actions and trends in the industry, regardless of country or region. The collaborative management of the aerospace standardization is thus driven by the knowledge base of the industry's players. They benefit from the emerging OEM company role of integrator (developing and distributing product interface requirements) and prevalent e-business processes (**Figure 9**). The latter of these enable collaborative standards development; collaborative writing, editing and distribution; and the use of standards information as digital data.

Development Demands

The current environment for developing and using standards must seek shorter cycle times for each step of the development and approval process. This must be accomplished by both committee leadership and SDO support, utilizing tools that promote rapid consensus building and approaches enabling agile and rapid approval, reaffirmation and stabilization.

Technology SMEs working as PoCs in TCs must advocate shorter times to market (i.e., to the end user) and quick responses to technical writing proposals and ballot comments. This includes validating the need for a standard until the approved standard is available for use. The current system has built-in safeguards that tend to inhibit rapid responses to industry needs.

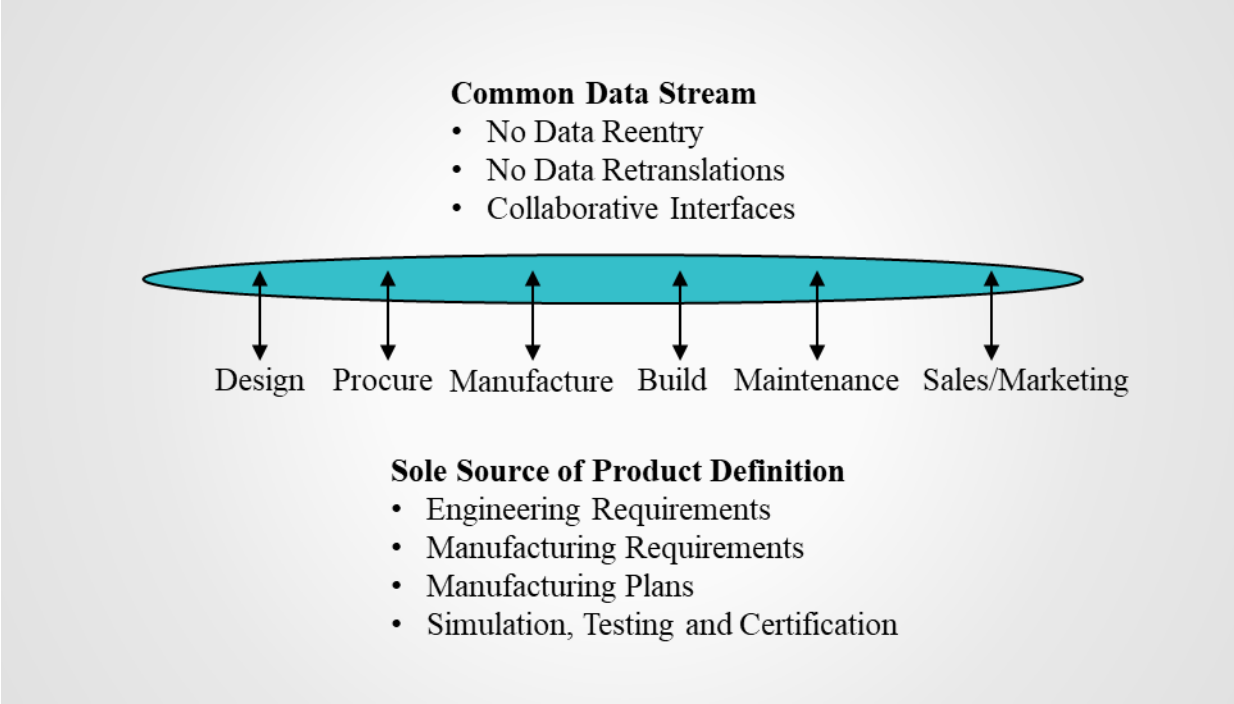


Figure 9. Standards Data Integration in the World of e-Business

Many existing aerospace standards systems continue to be paper based, using PDF files. However, most standards developers have embraced electronic development, the electronic establishment of consensus and electronic publication. In doing so, they generally have not re-engineered the processes, but have modified existing processes to make them suitable for automation.

There is increasing demand for the development of standards in formats that are electronically user-friendly. Examples include XML, HTML and platform-agnostic files, as well as files capable of being edited and commented on through built-in formatting tools. Demand is also rising for visibility into and access to standards projects throughout the development cycle, from the identification of a new standard through that standard's final balloting, approval and release. Also, meetings are continually being conducted with optional remote (i.e., electronic) attendance, facilitating global participation. Drafts are being coordinated, and consensus is being established for these, in real time online (i.e., electronically). Publications are rapidly becoming available in easy-to-use, nonrestrictive forms, and the configuration management of standards and standards data has become more robust. Ever-larger volumes of released data are becoming available throughout the life cycles of aerospace products, which are typically in excess of 50 years.

Authoring Tools

Major OEMs, government entities and SDOs have integrated tools based on standards. The predominant method currently used in the industry to create standards is document-format-based word processing. Fully interactive, web-enabled authoring enables technical content owners to edit and ballot a standard in near-real time. Authoring tools should take advantage of web formatting (HTML or XML) and web sharing, avoiding the markup-circulate-review-update document-based paradigm. Such tools should be platform independent and should easily accommodate the global

community. Standards need to be revised to be more machine readable, having functions like digital depictions, table look-ups, embedded links and so forth.

Across the aerospace industry, the strategic identification of standardization needs is fragmented. Some SDOs have a documented, robust process for managing the strategic direction of standardization. Some processes include approval and review systems based on business cases, and can capture and catalog both proposed and actual standardization work items – all while providing visibility to management. Other SDOs do not have a process like this for strategic standardization management. Instead, work items are proposed and initiated within these SDOs at the committee level, and are progressed as a result of discussions at the TC level. This leaves little or no opportunity for reviewing the draft standards and comparing them with the objectives of the organization. Also, in-progress work items are only informally tracked, if at all, and visibility at the SDO management level only appears at the draft standard's review and approval.

Practices across the industry appear to be widely distributed between these extremes. Often, an integrated industry position on a standardization policy, or on a set of standardization actions, is missed. Sharing best practices across the industry could benefit all. SDO alignment with industry needs can be achieved through the ANSI Company Member Forum (CMF) and Organizational Member Forum (OMF), with further coordination possible through the Government Member Forum (GMF). Greater participation there by aerospace companies is recommended.

Configuration Management Tools

The proper configuration management of technical data is critical to the aerospace industry. For standards, it means strictly managing the different versions of a document to ensure two outcomes: no data is ever lost, and an unbroken data trail exists between the first and the most recent version. The industry needs to have its major SDOs ensure that any changes made to a standard after its release as an approved voluntary-consensus standard must result in a change to the revision indicators. Also, no standard should have its numerical indicator (part of the title) changed without a clear reference back to the original standard number.

The aerospace industry needs to work with SDOs and standards distributors to develop a common understanding and use of terms related to active and inactive standards. Having different definitions for "cancelled," "obsolete," "inactive," "inactive for new design" and so forth is not only confusing; it can also cause costly errors through the misapplication of the standard. Moreover, because aerospace products can have life cycles of over 50 years, no standard should ever disappear from the inventories/indexes of standards developers or third-party standards resellers.

Delivery/Distribution Tools

It is not surprising to see universal alignment in the industry around the internet/World Wide Web as a distribution tool internally or externally. The predominant mode employed to flow information to suppliers and partners is now almost exclusively the encrypted electronic delivery of documents. This is often done through a version of a supplier's online portal (website). Delivery tools must enable new forms of electronic media in aerospace, especially in manufacturing, sustainment and operational environments. Delivery mechanisms need to consider all forms of viewable optimization in various electronic media.

Standards as Digital Data (or Smart Standards)

The most dramatic initiative regarding standards today concerns how data is used in the aerospace industry. Most standards data is still interpreted in document form, even though digital exchanges among customers, suppliers and partners are commonplace. Slow progress has been made in creating standards as digital data in a way that can be integrated with other functionally related data, regardless of source. Typically, this still requires some form of human interaction in capturing and recreating the data in a series of intermediate steps.

Data integration requires interactive data. Standards data needs to be considered, managed, delivered and stored as data sets instead of documents. Users create the view they need from a common data stream. Customized portals provide secure access to critical data. Standards stored as data elements can feed many other system applications, such as design tools, numerically controlled machines and additive manufacturing/3D printers, and can be accessed by human users.

To establish a collaborative infrastructure, a digital data exchange schema must itself be standardized in a way that is independent of infrastructure, lest it result in incompatible infrastructures. A package of digital standards information from any SDO must be in a consistent format so that users can acquire and use it via a single, consistent infrastructure within the enterprise. Systems suppliers must base their products on digital exchange standards, and must be active and influential in the appropriate committees to continue to develop the technologies surrounding digital exchanges.

Agreed-upon, platform-independent schema for the digital exchanging of standards data will enumerate what the data elements of the various standards types are, as well as the formats for each, the content for each, and so forth. The digital transformation of standards is essential and will result in efficient machine-to-machine transfers of data from NAS standards. The human element will be minimized, thereby creating efficiencies throughout a digital thread. This is what the standards of the future will become, and some SDOs are more advanced than others.

Standards Data Integration and Migration Down the Supply Chain

The digitalization ubiquitous in engineering and manufacturing offers opportunities for continued substantial improvements in the cost, quality and speed of design, development, production and sustainment processes. Large-scale enterprise integration and convergence is occurring in the aerospace industry through a digital transformation that facilitates data exchanges. The capability of the industry's IT systems to integrate all product data is now strategic and a key enabler. To fully realize these benefits, however, the development and enforced use of the next level of standardization is required.

This new standardization will deal with the form, structure and substantive content of the data passed between/among computing processes during a product's design-build cycle with the assistance of technical standards. Such standardization allows for the use of common data for manufacturing planning, purchasing, tooling, inspections, configuration control and inventory control. It also allows for the development of numerical control data for machine tools, additive manufacturing/3D printing and robotic equipment, independent of where the data was generated. If one company offloads the manufacturing of a part to another, the receiving organization is now able to utilize the digital data without a tedious conversion.

Aerospace companies have turned to extremely complex and costly critical data systems. As a result, one of the most significant issues for the industry is the overarching goal of seamless data exchanges, including exchanges of standards data. Within the industry's largest, most technically advanced enterprises, manual data entry and re-packaging for transfers to other data systems must be minimized. Keeping this approach continues to make sacrifices in cost, quality and speed for the process of bringing a product to market and sustaining it.

IP Issues as Critical Showstoppers

To function optimally as enablers for business, standards need to be integrated with all the other sets of the digital data used. The safeguards and processes put in place by SDOs can make data integration difficult, if not impossible, and PoCs must provide influence to enhance this integration. Aerospace companies must be able to integrate data from an industry standard into their product definition data, and then flow requirements out through the supply chain.

The aerospace industry is not advocating the loss or violation of IP rights and protections. However, it needs to work with the standards developers to ensure that the resultant standards can be used and integrated in ways that support the aerospace industry, not inhibit it. Industry standards and national and international standards might become too difficult to integrate into the digital data of OEMs. If this happens, aerospace companies will be forced to write their own standards or turn to standards organizations willing to adopt new business models that allow for data integration. This issue is one of the largest challenges facing the future of the standards used by industry.

Goals for Standards Data

To operate in an environment with politically and geographically diverse players, standardization process' tools and information flow must be platform independent. In other words, the authoring, distribution and use processes must be decoupled from hardware and software, while still exploiting the best technology. Myriad smart tools or interfaces must be available to capture and interpret standards data as required by any application. This applies to both material requirements planning (MRP) and enterprise resource planning (ERP) systems with an interface requirements definition system or a digital design/engineering system. The digital data itself will have become the standard or specification. However, it will have the option of capturing that data in a particular way or view that enables machines and humans alike to interpret it.

Standardization tools of the future can certainly be expected to continue to evolve to exploit and further the strengths of today's standardization systems. The standardization tool set of the future must evolve to minimize the gaps in today's processes. What will ultimately drive these changes is the market, due to its drive for cost, quality and speed in any process used in product design, development, service, sustainment and disposal. Eventually, the best answer will surface and produce input from the aerospace industry for the necessary standards' technical changes.

Ontologies, taxonomies and tools, through the digital thread, must themselves be standardized across the SDOs, committees and standards. Although this is a complex issue that encompasses every aspect of systems engineering, this approach must be incorporated to ensure interoperability.

Conclusions

The aerospace industry needs to ensure that as new standards are developed, they are based on emerging technologies' needs and market relevance. The industry needs to develop processes and tools that allow stakeholders to identify existing or emerging standards activity, and that facilitate strategic standardization decisions.

The aerospace industry needs every relevant standards developer to maintain a robust standards development, coordination, approval, configuration management and promulgation system. This will ensure that standards data relevant to every step of the design-build-sustain life cycle is easily available. Such a system would be characterized by, among other things:

- Automated document preparation, coordination, commenting and balloting that is easily understood and flexible, and that engages the global community.
- Readily available and easily accessible standards development committee websites that meet the needs of the standards developer, the standards acquirer and the general information seeker.
- Tools that facilitate the faster, better and cheaper development and promulgation of standards that are technically accurate and current, market relevant, platform independent, and globally accepted and used.
- Tools that make it easy for the entire global aerospace industry to engage in the development and/or use of standards at any appropriate point in the process.
- Solutions for IP issues that prevent standards data from being easily integrated with other product data and migrated down the supply chain.

In this system, access must be provided not just to the standard as a document, but also to the digital technical information contained in the standard. This will enable users to access the standards data as they need it, in the forms in which they need it, and to easily integrate this data into product-definition data systems. Standards must move to being managed and controlled as a collection of data elements, rather than maintained as hard copies (i.e., printed documents). This will enable users (humans, machines and various applications) to integrate the standards data that best meets their needs.

Chapter 6
Standards and Civil Aviation

Recommendation No. 6: Policies and procedures for assessing the conformity of products and processes to standards are crucial. Qualification, certification and conformity assessments are major cost drivers, and they require improvement. The role ICAO plays in international standardization for the aerospace industry needs to be better recognized by the United States. Furthermore, the United States should use ICAO to provide leadership in advancing U.S. technology and initiating change where needed.

Although conformity assessments and standards are separate things, they are closely related. The certification of aerospace products by regulatory agencies, such as the FAA and European Aviation Safety Agency (EASA), is based on the use of and conformance to standards, including validation and verification. To the extent that the industry has harmonized standards and standards-related data, the certification process is greatly facilitated, and the associated costs are reduced. The IAQG utilizes one of the best strategies for global standardization. Established to help the aerospace industry implement the ISO 9000 Quality Management System, this IAQG-defined strategy is used for developing international standards. It has allowed the industry to rapidly drive globally harmonized quality requirements down through one of the largest and most complex supply chains of any industry.

The aerospace industry needs to implement a single industry approach to developing QPLs and their related qualified manufacturer/producer lists (QML), which accompany part and material standards. Established first for use with MIL-SPECs, QPLs and QMLs quickly became part of the data supporting civil aviation as the MIL-SPECs became de facto industry standards. A strategy should be developed to address when and how a standard should invoke requirements for qualification. This would offer guidance for inserting qualification requirements in specifications, taking into account the competition present in contracting. It would also consider any plans for addressing legacy QPL management in standards migrated from DoD to industry SDOs. An analogous approach with software standards qualification might also be necessary.

ICAO has long been developing international standards in aircraft operations, noise, emissions and other areas. The role ICAO plays in the development of standards needs to be supported by the industry and recognized by national, regional and local regulatory authorities. Standards developed by ICAO are consensus-based standards developed by national and industry aerospace representatives. As such, they constitute global aerospace standards. Their primacy over standards developed by other, non-aerospace international standards organizations needs to be asserted.

Conformity Assessments

Conformity assessments include assurance testing, often performed by both the manufacturer and a third party, that creates a qualified product, thereby reducing the need for aerospace companies' source inspection methods. Certainly, issues surrounding standards and conformity assessments

are equally important to all aspects – civil, defense and space – of aerospace. Some of these issues are addressed in the context of commercial aerospace, with the understanding that many of the same issues and conclusions apply to the entire industry.

> *"Quality measures consist of grade (or inherent value), fitness for use, and conformance to specifications."*
>
> *— Managing for World Class Competitiveness*

The phrase "conformity assessment" is the comprehensive term for measures taken by manufacturers and their customers, regulatory authorities, and independent third parties to assess conformity to standards.[18] Some consider this validation and verification, and it is often associated with the requisite testing. Conformity assessments for the aerospace industry depend on the existence of unambiguous standards. Customers, regulatory agencies, governments and military organizations assess products, processes and services against these standards to ensure that they actually conform to the standards as claimed. Aerospace regulatory agencies (e.g., the FAA, EASA) and government customers (e.g., DoD) require prior assurance of conformity to relevant standards before a product can be accepted and put into service.

The certification of aerospace products by regulatory agencies (e.g., the FAA, EASA) is based on the use of and conformance to standards. When the FAA issues a Type Certificate for a specific model of commercial aircraft, doing so constitutes a form of conformity assessment. The issuance is based on the determination that the design – including the standards defining the product – meets the requirements for a safe, reliable, producible, quality aircraft. Type Certificates vouch for type design data, which consists of the drawings and specifications necessary to define the configuration and the design features of the product.[19] The FAA's Production Certificate is based on the holder's demonstration of the ability to maintain a high-level quality system capable of continually producing aircraft that conform to the type design data, including the specifications.[20] Failing to comply with standards, or using outdated standards, results in corrective action on the part of regulatory agencies, along with the potential withdrawal of either certificate.

IAQG: A Standards Success Story

The IAQG defined a new strategy for developing international standards that allowed the aerospace industry to harmonize global quality requirements throughout its large and highly complex supply chain. The group's successes in civil aviation are presented in this chapter, but the IAQG is not confined to the commercial sector; it supports the entire aerospace industry. In fact, DoD and NASA are some of the biggest users of the suite of IAQG quality standards.

The challenge overcome by the IAQG entailed creating standards that met the needs of the aerospace industry. In the process, however, the group also had to create a new standards system

[18] National Research Council, "Standards, Conformity Assessment, and Trade into the 21st Century" (1995).
[19] 14 CFR Subpart 21.31, Type design, https://www.govinfo.gov/app/details/CFR-2002-title14-vol1/CFR-2002-title14-vol1-sec21-31.
[20] 14 CFR Subpart 21.139, Location of or change to manufacturing facilities, https://www.govinfo.gov/app/details/CFR-2012-title14-vol1/CFR-2012-title14-vol1-sec21-139.

with which to develop, promote and implement these new quality standards. Industry leaders had very specific requirements for the standards system needed to support an internationally accepted aerospace quality system. It needed to be international in both scope and membership. Industry wanted direct participation, and wanted to include aerospace regulatory agencies and customers. Also, it was critical that the system had a fast, responsive standards development cycle, and that – most importantly – the results were a single, globally used and recognized standard.

The aerospace industry was reluctant to create a new SDO, but there was no existing venue that met all the above requirements. Therefore, the industry went to three of the major aerospace standards developers and requested a special alliance to support an entirely new standardization model. The result was the IAQG. As **Figure 10** shows, the IAQG is a composite organization of the global aerospace industry. It is not a legal entity, but rather a dynamic cooperative based on trust among international aerospace companies.

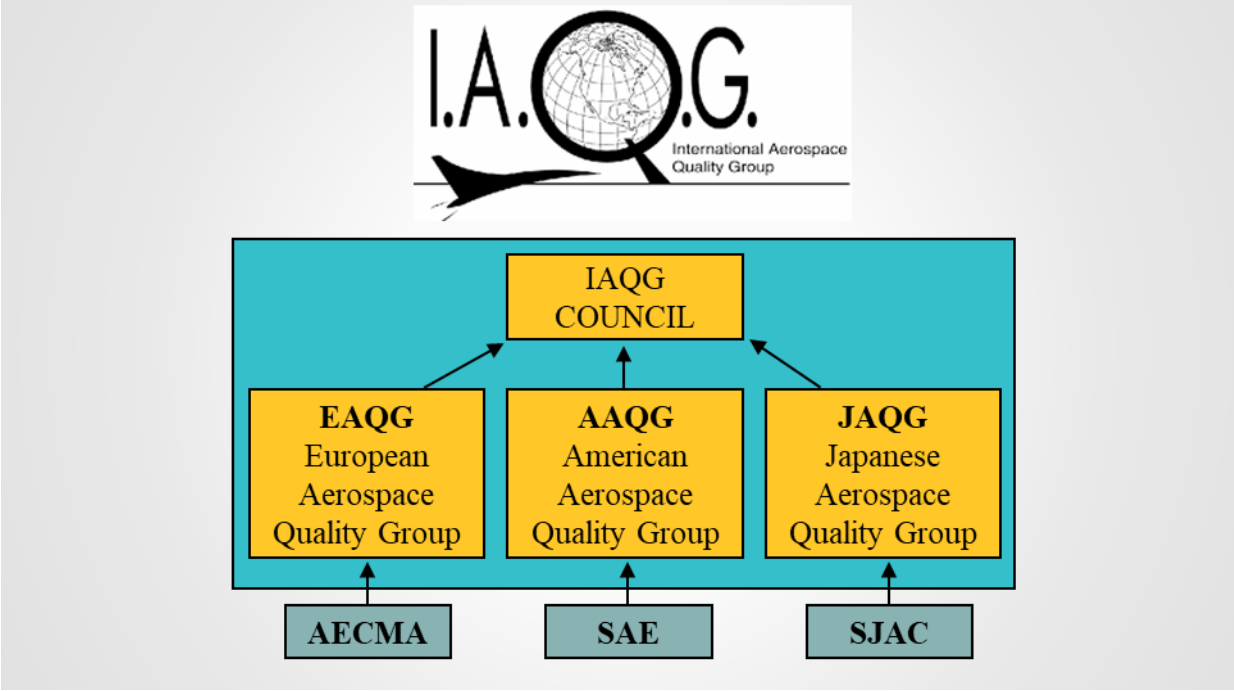


Figure 10. International Aerospace Quality Group (IAQG) Composition

The IAQG exists for the purpose of establishing and maintaining standards and initiatives to make significant improvements in quality performance and reductions in cost throughout the aerospace value stream. To facilitate its work, and to take advantage of existing infrastructures, the group is divided into three region-focused sectors: Europe, the Americas and Asia. Respectively, it is sponsored by three region-focused aerospace SDOs: the European Association of Aerospace Industries (AECMA), SAE International and the Society of Japanese Aerospace Companies (SJAC). Additionally, the group has a close liaison with AIA. The three regional sectors coordinate requirements for quality-related standards, and the results are then harmonized by the IAQG. The globally harmonized standard is then published simultaneously by each of the three sponsoring organizations.

Developing a single aerospace quality system and follow-on quality standards in months was quite an achievement. The *real* power of the IAQG, however, comes from the commitments of its member companies. There is an agreement of intent to implement the resultant IAQG standards, signed by the leadership of all involved companies prior to the development of the standard. Since a standard only has value if it is used, the commitment to implement it from the highest levels of the companies involved is key to its success. This was the first time in the history of the aerospace industry that signed commitments from leadership had been required prior to their participation in the development of international standards.

The success of the IAQG as a global industry standards development model is one that should be seriously looked at for other standards types and other standardization initiatives. The IAEG has followed the IAQG's example, but it coordinates standards development through IPC International and its affiliated Association Connecting Electronics Industries. Notwithstanding, the IAEG has implemented a powerful strategy. It brings together an entire community, forges alliances among standards developers, and solicits corporate commitments to implement standards to improve business.

Significant Room for QPL Improvement

QPLs and their related QMLs have not been as successful as the IAQG has. In these lists, the parts and materials used to design, manufacture, assemble and test aerospace products are defined by standards. Consequently, DoD and industry standards have become mandated by the commercial and DoD regulatory agencies as part of the type, design and production certification processes. Parts defined by these standards can make up a significant portion of product bills of materials at most aerospace companies.

The concept of qualifying and listing producers and distributors of parts defined by standards was brought to maturity by DoD and its management of suppliers for DoD procurements. These QPLs have been used on MIL-SPECs since the 1950s. QPLs were once managed as part of the MIL-SPEC system, and many aerospace company standards systems have adopted the same practice. DoD performed or oversaw the qualification testing and inspection, and maintained the lists of approved parts and suppliers, along with the base standard. The whole aerospace community used these QPLs not only for defense products but also for commercial aircraft.

In the mid-1990s, as part of acquisition reform championed by AIA, DoD cancelled or migrated over 6,000 MIL-SPECs/MIL-STDs to industry SDOs, such as SAE International, AIA and ASTM International. This move took advantage of best commercial practices and allowed industry to share in the development and maintenance of these documents. It was hoped that this would also result in more timely and technically current documents.

However, the migration of DoD standards and associated QPLs to a select few industry standards developers had a major flaw. It left no central qualifying agency in place to manage and update the qualification requirements for these technical standards. The aerospace industry did not have the infrastructures in place to continue the maintenance of the QPLs; nor did it have organizations to conduct the qualification testing and inspections. Also, the standards organizations receiving

the cancelled MIL-SPECs as part of MIL-SPEC reform lacked the processes or mechanisms needed to incorporate QPLs into their standards systems.

Some SDOs, responding to industry, have realized the need for third-party qualification, and have developed or collaborated with affiliated organizations. For example, SAE International works with the Performance Review Institute (PRI), and AECMA established a European equivalent, AECMA-CERT. Not all SDOs have set up processes for dealing with qualification requirements. AIA, which received over 500 MIL-SPECs to maintain, does not have a standards process to allow for QPLs. Even when industry decides to develop a common QPL through an organization like PRI, there still remain questions regarding maintenance, funding and liability issues surrounding the QPL.

The transition of thousands of MIL-SPECs and accompanying QPLs to industry was further complicated by inconsistency in DoD's processes. The rules were unclear for cancelling a MIL-SPEC and its accompanying QPL upon transferring it to an industry organization. The same was true of the rules for indicating supersession. Processes addressing transfers and supersession were not always well understood by the aerospace community, and were not consistently applied by DoD. Consequently, there are cancelled MIL-SPECs with active DoD QPLs; transferred standards with orphaned QPLs (because the industry organization that picked up the base standard did not pick up the QPL); and confusing text regarding supersession directions. In response, AIA established the Early Warning Project Group (EWPG) to help with the transition of MIL-SPECs to industry organizations. This group notes that 809 of the 6,351 documents used by aerospace have (or had) QPLs. Of these, 110 were superseded by industry standards.

The AIA SGB recommends that the aerospace industry address the costly issues arising from the confusing and inconsistent processes surrounding QPLs. An industry forum should be established to develop a strategy for managing QPLs to make the process transparent to the ultimate end user (e.g., manufacturing associates). The strategy should address when and how a standard should invoke requirements for qualification. It should provide guidance for inserting qualification requirements in specifications, taking into account competition in contracting. It should also consider any plans for addressing legacy QPL management for standards migrated from DoD to industry SDOs.

ICAO: Setting Standards and Specifications for Worldwide Operations

ICAO is a specialized agency of the United Nations (UN) whose mandate is to ensure the safe, efficient and orderly evolution of international civil aviation. Its headquarters is in Montreal, Canada, and it has seven regional offices throughout the world. The organization is funded and directed by 193 national governments to support their diplomacy and cooperation in air transport as signatory states to the 1944 Chicago Convention.[21] The organization's role is explained well in its explanation of why standards are necessary:

> "Civil aviation is a powerful force for progress in our modern global society. A healthy and growing air transport system creates and supports millions of jobs worldwide. It forms

[21] International Civil Aviation Organization, "About ICAO," https://www.icao.int/about-icao/Pages/default.aspx.

> part of the economic lifeline of many countries. It is a catalyst for travel and tourism, the world's largest industry. Beyond economics, air transport enriches the social and cultural fabric of society and contributes to the attainment of peace and prosperity throughout the world.
>
> "Twenty four hours a day, 365 days of the year, an aeroplane takes off or lands every few seconds somewhere on the face of the earth. Every one of these flights is handled in the same, uniform manner, whether by air traffic control, airport authorities or pilots at the controls of their aircraft. Behind the scenes are millions of employees involved in manufacturing, maintenance and monitoring of the products and services required in the never-ending cycle of flights. In fact, modern aviation is one of the most complex systems of interaction between human beings and machines ever created.
>
> "This clock-work precision in procedures and systems is made possible by the existence of universally accepted standards known as Standards and Recommended Practices, or SARPs. SARPs cover all technical and operational aspects of international civil aviation, such as safety, personnel licensing, operation of aircraft, aerodromes, air traffic services, accident investigation and the environment. Without SARPs, our aviation system would be at best chaotic and at worst unsafe."[22]

ICAO's role is particularly significant for the worldwide aerospace industry because it is a prime example of cooperation, consensus, compliance and commitment (dubbed the Four C's). The cooperation and consensus aspects are particularly powerful in that member nation and industry representatives voluntarily participate. They develop wide-ranging standards, via the consensus of the technically based stakeholders, for the clear common good. Aircraft noise and emissions standards are examples of this. These were developed and are managed by member nation participants, and they reflect a continued imperative to advance technology. By creating these, stakeholders have also reaped commercial benefits.

In effect, these voluntary noise and emissions standards represent consensus-based conformity assurance standards. Consider the chaos that might result if, for example, noise standards or runway lighting standards were specific to the locality, or even if the language of operations were locally specific. ICAO provides an invaluable forum for harmonizing various standards for operations, and has proven effective worldwide. Industry needs to utilize bodies like the International Coordinating Council of Aerospace Industries Associations (ICCAIA) to promote incorporating industry requirements into ICAO standards.

ICAO is primarily aviation-operations based. In recent history, conformity assessment has fallen to national airworthiness agencies, and there has recently been some consolidation across national boundaries. That said, there is still a critical need for additional international harmonization among agencies. For example, the FAA and EASA should harmonize their standards, considering that North Atlantic traffic involves air vehicles traversing several nations' boundaries hundreds of times a day. There is no question that conformity assessment in aviation is a trans-national issue. Ongoing harmonization efforts must continue.

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[22] International Civil Aviation Organization, "Making an ICAO Standard," https://www.icao.int/safety/airnavigation/pages/standard.aspx.

Within these airworthiness agencies, the value of consensus-based international standards development is recognized. Standards provided by ICAO and specific industry organizations like IATA are emerging as a valid path to conformity assessment for aviation-type certification, production certification and airworthiness certification – not for rule making. This is primarily because the airworthiness agencies have begun to recognize that the path to consensus and collaboration is much easier. Moreover, it is often already completed by the time a standard is published. Restated, international-participant, consensus-based organizations like ICAO and IATA are essential to future conformity assessment processes and international standardization.

Worldwide Safety Improvements

Governments and industry in the United States and Europe have taken significant steps to improve the work of safety regulatory authorities around the world. As a result, all ICAO members are overseeing safety in accordance with international standards. ICAO has audited all safety regulatory authorities and does not conduct safety assessments for airports and other infrastructures needed to meet international standards and public expectations.

The U.S. and European governments, in strong coordination with ICAO, should take steps to ensure that all activity aimed at promoting adherence to international safety standards is coordinated. This will ensure that there is a common set of priorities and no duplication of effort. The U.S. aerospace industry should promote the use of ICAO as the venue for the development of both national and global security standards.

Conclusions

The aerospace industry needs to better articulate and understand the essential relationship between standards and conformity assessments. Also, it needs to harmonize the standards that form the basis for regulations and certifications, and to develop globally accepted conformity assessment schemes that are mutually recognized and cost effective. The models for global standards development established by the IAQG and the IAEG have proven to be successful methods for achieving globally harmonized standards. The aerospace industry should seriously consider adapting or adopting this model for more standardization efforts.

The process for identifying qualified products and producers through the standards system can be optimized. The industry needs to establish a special task force to deal with QPLs. This task force will ensure that the processes surrounding the lists' invocation, development, configuration management, distribution and use are clearly understood and uniformly applied throughout the industry by all applicable standards developers.

ICAO has been functioning as an international standards developer for the aerospace industry. The industry should work with governments and regulatory agencies to ensure that ICAO standards are recognized as international standards. Furthermore, it should ensure that it maintains the right to utilize ICAO over the ISO as an aerospace-specific international SDO.

Chapter 7
Standards for Defense

Recommendation No. 7: Senior DoD and aerospace industry leadership must recognize the extent to which the commercial aviation and space industries, as well as the defense industry, depend upon MIL-SPECs and MIL STDs. This refers to both the library of technical knowledge and the discipline of configuration control embodied in the system of MIL-SPECs and MIL-STDs. DoD needs to proactively support and participate in the development of industry standards, and must utilize industry standards to the greatest extent practicable.

MIL-SPECs/MIL-STDs have been fundamental to the aerospace industry for the past 70 years. These documents support all military platforms, and because of the close relationships between civil and military designs, they form a large part of the standards used by commercial aviation. MIL-SPECs are in effect de facto industry standards. Although it was the aerospace industry that called for MIL-SPEC/MIL-STD reform in the 1990s, the results showed that MIL-SPECs are critical in both the military and commercial aviation sectors.

The cancellation of thousands of MIL-SPECs, as well as their transfers to industry SDOs for maintenance, placed a strain on the industry's standards infrastructures. The government (especially DoD) recognized that using industry standards requires participating in standards development and management. The development and use of global industry standards is critical to the international sale of defense products and their global interoperability. To ensure the existence of suitable standards for defense products, there needs to be mutual recognition of the interdependence between industry and government standards.

MIL-SPECs Fundamental to Aerospace

MIL-SPECs/MIL-STDs are utilized with all of the aerospace industry's design, build, operate, sustain and disposal cycles. The defense and civil aerospace industries largely matured in parallel. They have shared many technological advancements, the same need for safety and reliability, and even the same airspace and pilots. Early civil pilots made themselves available to meet military needs, and retired military pilots have filled the needs for skilled civil aviators.

The engineering descriptions of parts, manufacturing processes, quality control procedures and designs have always been contained in a suite of specifications/standards produced by the military and various industry associations. Among the latter are AIA, SAE International, ASTM International, IEEE and many others. A symbiotic civil-military balance has emerged over the years as an undocumented division of labor among the various major standards players. Each

depends on the other to fulfill its responsibilities, and each undertakes the necessary standards development, upkeep and publication. This ensures that both the civil and military aerospace industries are technically supported.

MIL-SPEC Reform: A DoD Initiative, A Response to an Industry Request

With the end of the Cold War in the late 1980s, the United States was eager to reap the promised "peace dividend" from no longer needing to support such a large and robust military establishment. In the early 1990s, as defense budgets plummeted, DoD began to upset the balance of labor for maintaining the nation's – and indeed the world's – needs regarding aerospace standards. DoD looked to meet its needs through dual-use technologies, dual-use products and dual-use standards.

At the urging of senior leaders from the aerospace industry, then-Secretary of Defense William J. Perry, in 1994, announced a policy that would dramatically increase DoD's reliance on standards produced by the private sector. The initiative, called MIL-SPEC Reform (MSR), called on DoD to review roughly 29,000 military documents and eliminate those it no longer used; inactivate for new design those that had been retained only to support legacy systems; and transfer to the private sector those that were still needed but described commercial products or practices. In theory, this made perfect sense; in practice, it had been the policy for years without great success.

Secretary Perry established integrated process teams, an oversight council and a waiver process for MIL-SPECs/MIL-STDs, and allocated millions of dollars to expedite reform. MSR resulted in the inactivation of 8,100 MIL-SPECs and MIL-STDs, and the cancellation of 9,600 documents – 3,500 of which were replaced by industry standards. It also saw the transformation of thousands of the remaining specifications from detailed prescriptive specifications to performance-based specifications. Although there was much good that came from MSR, many in industry perceived some of the reform negatively. They interpreted it as DoD unilaterally walking away from the balance of labor in developing and maintaining the documents needed by the aerospace industry both in the United States and internationally.

The aerospace industry also identified conversions to industry specifications with which its engineers did not agree. Similarly, it identified the cancellation of documents it had designed into airframes for both military and civil aviation fleets. The aerospace and defense industries asked DoD to slow the process. However, since DoD no longer had the resources to keep up the standards, it continued with the conversion process. As a result, thousands of specifications were cancelled or converted within only a few years. The decision made by the executive council in charge was that it was better to force immediate consideration than to prolong the illusion of maintaining technical documents that were obsolete and technically inadequate.

The aerospace industry was unprepared for the rapid rate of cancellations and conversions. To alleviate this burden, the EWPG was charged with reviewing the documents being cancelled and converted in order to assess the impact. The EWPG reviewed aerospace companies' use of the documents slated for cancellation or conversion, and monitored and ultimately managed much of the conversion process. It established procedures to make identical or nearly identical voluntary, nongovernmental standards to replace MIL-SPECs/MIL-STDs, and transferred the documents'

custody to the two principal private sector standards developers, SAE International and AIA. Both developers have done much over the years to meet that challenge.

Through the Defense Standardization Program Office (DSPO) and the aerospace industry, DoD has continued to work in partnership to address standardization issues. However, many committees find themselves with too few participants from aerospace and defense due to industry downsizing coincident with the expanded need. Coupled with the other demands placed on aerospace standardization (continued globalization, lack of clear standardization leadership, uncertain economic conditions, increased international competition), this demands taking measures to meet the industry's needs.

Rethinking of the Role of MIL-SPECs

The aerospace industry, along with many other industries, called for a move away from design or prescriptive standards toward standards that define requirements in terms of desired performance. In some instances, as MIL-SPECs were converted into performance-based specifications, essential requirements were lost or were written in such a way that the contractor's execution of the requirements was unverifiable.

The industry was also unprepared to take over the piece-part qualification of hundreds of parts that had been previously covered by MIL-SPECs/MIL-STDs and qualified by military qualifying activities. Qualification generally applies to products whose use can have safety implications, and whose verification testing takes a long time, is very expensive or requires special equipment that is not readily available. Qualification is accomplished independent of instant acquisition in order not to hold procurement for the long testing. The defense industry has relied on DoD qualification to meet needs for weapon systems at the prime contractor and multi-tier subcontract levels. To a lesser but still significant degree, industry has relied on this qualification for the production of civil aircraft as well.

Prior to MSR, the aerospace and defense industries had begun to develop an industry-run and -supported independent qualification capability. At the time of MSR, comparatively few items were being qualified through this capability, and widespread reliance on it had not developed. With MSR, DoD cancelled – or converted into nongovernmental standards – any specifications that called for qualification.

Trustworthiness, counterfeit parts, unqualified parts and removed parts' reuse remain issues for the aerospace industry. This is true for both hardware and software. Initiatives like Trusted Supply Chain Traceability through the Global Semiconductor Alliance are assisting aerospace companies in assuring traceability. There are also chemicals traceability requirements, and aerospace companies must be able to follow the supply chain back to the original source of supply. Fortunately, with new tagging identification systems, methods and protocols identified by standards, the industry has implemented – and will continue to implement – strategic measures.

Aerospace Industry Standards Requiring DoD Input

As stated in (now-cancelled) MIL-STD-970: "The DoD is committed to increased defense contractor productivity and improved acquisition efficiency. Standardization documents play an important role in this context and must be selected and properly applied with this objective in mind. They provide the framework by which requirements are defined."[23] These words regarding the importance of standards – contained in DoD's historic documentation for the use of standards – commits the government to using standards for acquisition. To demonstrate that DoD is committed to using industry standards to support the acquisition of new platforms and programs, assistance is needed to ensure that DoD requirements are contained in and met by these standards. The move to use industry standards does not mean that DoD no longer has to concern itself with the management and maintenance of these documents.

Key to DoD's acquisition policy is the use of commercial best practices and industry standards. The National Technology Transfer and Advancement Act of 1995, Public Law 104-113, requires federal agencies and departments to use technical standards that have been developed or adopted by voluntary-consensus standards bodies as long as those standards meet the government's needs.[24] Government agencies and DoD recognize the huge cost and time savings through the dual use of technology – technology defined by standards. Office of Management and Budget (OMB) Circular No. A-119, Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities, as revised in Volume 81 of the Federal Register (FR) in 2016,[25] has resulted in reduced government costs.

DoD efforts to replace MIL-SPECs/MIL-STDs with commercial item specifications saved procurement funds and reduced the need for suppliers to maintain separate military and commercial production capabilities.[26] For the aerospace industry, working closely with DoD has been key to creating standards that add value in both military and commercial applications, and that allow each industry to take advantage of the best practices developed by the other. To ensure that DoD requirements are contained in industry standards, DoD technical experts need to participate fully in the development and maintenance of industry standards. One of the greatest threats to aerospace standardization efforts is the lack of suitable standards for logistics support and sustainment. Also detrimental is the under-funding and under-representation of DoD interests in industry standardization activities.

The development and use of global industry standards is critical to the international sale of defense products and their interoperability. Interoperability, facilitated by standards, is vital to any successful joint military effort, such as those of the North Atlantic Treaty Organization (NATO) or UN peacekeeping efforts. Programs like Future Combat Systems, 21st Century Warfare, Joint

[23] MIL-STD-970, Standards and Specifications, Order of Preference for the Selection of (October 1987). This standard was cancelled without replacement in 1994.
[24] National Technology Transfer and Advancement Act of 1995, Public Law 104-113, https://www.govinfo.gov/content/pkg/PLAW-104publ113/html/PLAW-104publ113.htm.
[25] 81 FR 4673, Revision of OMB Circular No. A-119, "Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities," https://www.govinfo.gov/app/details/FR-2016-01-27/2016-01606.
[26] Jordan W. Cassell and Robert L. Crosslin, "Benefits of the Defense Standardization Program" (September 1991), https://apps.dtic.mil/sti/pdfs/ADA242585.pdf.

All-Domain Operations (JADO) and Integrated Battlespace Management depend on industry standards to define how each platform will integrate and operate in the larger system of systems. This reinforces the notion that DoD must support these standards activities.

The AIA SGB now works closely with DoD standardization executives and the DSPO. This ensures continued, close alignment with industry and DoD standards development and maintenance activities. This must be expanded to also have a closer alignment with NIST and the critical technologies being worked there.

MIL-SPECs: Created for Defense, Used by Everyone

DoD must recognize the value of industry standards to the development, procurement, operation and sustainment of defense platforms. However, it must also understand the key role government standards play in commercial aerospace. Commercial aviation has a strong foundation in military products, and dual use is ubiquitous in aircraft design. Also, U.S. standards for aviation are not limited to aircraft made in the United States; aircraft manufacturers throughout the world incorporate U.S. MIL-SPECs into their product definitions. This is because the parts, materials and processes they define have a high degree of acceptance and are used worldwide. Thus, it is to DoD's advantage to have commercial aerospace using MIL-SPECs, as the more widely a standard is used, the more suppliers there may be – and this can lower costs.

Because of the high dependence of commercial aviation on MIL-SPECs/MIL-STDs, the commercial industry is greatly impacted by any changes to this critical library of technical data. Senior DoD leadership needs to understand and acknowledge the commercial aviation industry's dependence on MIL-SPECs. Members of the commercial side of the aerospace industry, as well as defense contractors, need to be involved in any changes made to the MIL-SPEC infrastructure. There remains a need for education and guidance on the use of cancelled specifications, the implication of supersession notices, and part markings based on converted MIL-SPECs.

Conclusions

Senior DoD leadership must always recognize the critical role government standards play in the commercial aerospace industry. In response, DoD leaders should involve aerospace industry stakeholders in any major standardization initiatives. This will ensure that the key technical data contained in MIL-SPECs and MIL-STDs is available to support dual-use products and platforms, and to ensure a strong supply chain for DoD parts and materials.

In recognition of the global role that MIL-SPECs play in the aerospace industry, DoD is urged to establish more effective mechanisms for communicating with the industry on standardization issues. These must include discussions regarding standardization actions that impact both DoD and industry. They would involve industry stakeholders, and would help to define standardization issues and develop solutions that are mutually beneficial.

A multidisciplinary government-industry forum would develop recommendations for how standardization could best support logistics reform, interoperability, evolutionary acquisition, technology insertion and reductions in total ownership costs. Also, it would address such issues as

business strategies that promote civil-military integration for the acquisition of defense products and platforms; configuration management policies and practices; technology insertion; logistics support; sustainment; and commercial parts management.

Senior DoD leadership can contribute to ensuring that industry standards are suitable for DoD use and both meet and contain DoD requirements. However, this requires acknowledging that government SMEs must participate in the industry committees that develop and maintain these standards. Also, sufficient funding must be made available; otherwise, DoD risks having neither internal nor external standards available for designing, manufacturing and sustaining military products. A closer relationship with NIST is essential, also.

Chapter 8
Space's Imperative for International Standardization

Recommendation No. 8: The aerospace industry, DoD, NASA, NIST and the FAA need to work together. Collaboratively, they can ensure the development of globally recognized standards that support both government and commercial space interests. The development and use of industry standards that support United States-based technology must be key strategic components of the aerospace industry's standardization strategy.

The space industry has moved rapidly from military, single-product efforts to commercial-production products. As a result, the need for standards and the use of industry-developed documents are essential. Many new, nontraditional space vehicle companies (e.g., SpaceX, Virgin Galactic, Blue Origin) have entered this market, and many countries are now planning and executing spaceflight for both commercial and defense purposes. Also, the number of satellites has grown enormously, and the new U.S. Space Force is a major player representing space defense interests.

Many aspects of space standardization are common with commercial aviation and electronics. Standard fasteners, materials, electronic performance specifications and other such things are used extensively. Through its SDOs, the aerospace industry must establish the infrastructures needed to develop standards for space industry-unique needs for propulsion components, vehicle interfaces, payload vehicle interfaces, ground support equipment and other such items. Europe has the European Space Agency (ESA) and European Cooperation for Space Standardization (ECSS). These agencies have taken the lead in developing standards for space activities (project management, product assurance, engineering, etc.) for the entire European space community. Without a clear strategy and support from industry and government space agencies, the United States will be ceding the development of standards for the commercial space industry to venues outside of its influence.

State of the Space Industry

Space technology was developed and deployed extensively throughout the last half of the 20th century. There were the first suborbital flights, extended orbital flights, landings on the moon, and deployments of satellites enabling worldwide, low-cost communication. There were also many more milestones, collectively encompassing a record of technological advancements and achievements unmatched in history. This record is significant because of the prima facie achievements, but more so because of the less noticeable achievements with the related technologies that were required to enable the space flights.

These "secondary" achievements were very significant enablers of success in the Cold War, and they have facilitated many other accomplishments and derived technologies that make modern life

what it is. For that reason, the United States must examine and reevaluate its perspective on space as an economic and strategic frontier – one where U.S. leadership must be maintained well into the 21st century. There is significant emerging competition among nations.

The extent of standardization in any industry sector is influenced by the maturity and economic health of the sector, and so it is with space, both commercially and politically. The space industry, whose major components are commercial and government launch services, vehicles, propulsion, and payload manufacturing and integration, did not exist until the end of the 20th century. It must be conceded that launch vehicles are developed in response to national security concerns, not solely in response to market demands.

Standardization in the Space Industry: Domestic and International

To a large extent, standardization in the space industry has always had much in common with terrestrial aviation and electronics. Standard fasteners, materials, electronic performance specifications and other such things are used extensively. This is not surprising in as much as the technology is closely derived from existing specification libraries used in these industries. There are few standards for the unique aspects of space, such as propulsion, vehicle interfaces, payload vehicle interfaces and ground support equipment. The space industry must increase its recognition of the benefits of standardization in these areas.

Space standardization today is focused primarily on range safety and launch site safety – specifically, launch corridors, destruct protocols and the environmental impact of launches, reentry licensing and so forth. The FAA space operations rules, found in 49 U.S.C. 701, Subtitle IX, Commercial Space Transportation,[27] are examples of these. In addition, there is emphasis on the insurance-driven conformity assessment of vehicles and loads. This is driven primarily by relevant MIL-SPECs and specifications issued by the NATO Advisory Group for Aerospace Research and Development (AGARD). Among many other organizations, ASME and AIAA are engaged in the areas of systems integration and vehicle interfaces. However, the space-related regulatory agency is predominantly either the government or an agency customer.

It is difficult to integrate standardization, and to develop and standardize common and consistent interfaces between propulsion systems and vehicles, and between payloads and vehicles. This is because of the differing flight environments and access requirements, which are primarily instance-specific. Advances have been made in vehicle-systems integration, such as DoD's Evolved Expendable Launch Vehicle program, which uses standard specifications for payloads using a common mechanical and electrical interface to the vehicle. In addition, the booster core of the launch vehicle has been standardized. These standards are intended to reduce manufacturing, assembly, payload integration and launch operation process costs.

Internationally, space standardization appears to be more evolved. In the EU, for example, the ECSS initiative aims to promote the use of existing standards and adopt commonly used international standards. It also aims to ensure coordination among, and liaisons with, standardization organizations, European governmental agencies and industry.

[27] 49 U.S.C. 701, Commercial Space Launch Activities, https://www.govinfo.gov/app/details/USCODE-2009-title49/USCODE-2009-title49-subtitleIX-chap701.

Observations Relative to the Space Standardization Landscape

The landscape of United States-based space industry standardization can be seen as closely paralleling that of its mother industry, aviation. The level of space industry integration does not approach that of the EU, as the level of standardization is minimal. This is partially due to the flat market demand for commercial services, and partially due to lagging industry maturity. However, as disruptive technologies in propulsion and power, among other things, are now taking hold in vehicle design, these are rapidly expanding the range of market options.

There are many implications of increasing competitiveness in the space industry. Emerging companies dominate the commercial space standardization and launch arena. Without a collaborative approach to standardization among the world's governments and manufacturers, companies in the United States might ultimately have to conform to standards developed outside the United States; alternatively, they might be held to international standards created without much U.S. input.

An integrated approach to U.S. space standardization is needed, executable through existing international committees. Without this, it is difficult for U.S. space commerce interests to create cohesive, efficient supply chains and products that are globally standardized. U.S. space industry interests seeking business opportunities outside the United States might be forced to conform to standards being developed without active participation. Most likely, this will result in a competitive disadvantage. Notably, the EU and China are participating aggressively in the international standardization landscape.

In the United States-based space industry, there is no forum where major industry drivers (NASA and commercial vehicle and payload producers) convene to develop and integrate approaches to space standardization. There is also no significant standardization within the space industry or within a joint industry-NASA collaboration. NASA participates in some international forums, such as the Consultative Committee for Space Data Systems, but there exists no independent space agency-based organization to address space data-handling needs.

Space standards are promulgated in ISO TC 20 Aircraft and Space Vehicles, SC 13 Space Data and SC 14 Space Systems and Operations. There is little U.S. involvement there though, even in the U.S. TAG, although NASA holds the secretariat position.

Conclusions

The commercial space industry has emerged significantly in the 21st century and includes new commercial companies. This progress has to be aligned with the new U.S. Space Force and defense interests. The benefits of industry standardization are critical to cost, quality and repeatability. Industry and government need to work together to ensure that globally relevant standards exist to meet technical needs in space. Also, their collaboration can ensure that the U.S. space industry does not continue to cede strategic standards and associated technical strength to regional (e.g., Europe) and/or international interests.

Chapter 9
Essential Standards for Rotorcraft/UASs/UAVs/Drones

Recommendation No. 9: Industry, NASA, DoD, NIST and the FAA need to work together. Collaboratively, they can ensure the development of globally recognized standards that support government, defense and commercial rotorcraft/UAS/UAV/drone interests. The development and use of industry standards that support United States-based technology must be key strategic components of the aerospace industry's standardization strategy.

Rotorcraft-specific standards are few, and the ecosystem/landscape is worthy of further study. The Vertical Flight Society, founded in 1943 as the American Helicopter Society, Inc., is the world's only international technical society for engineers, scientists and others working to advance vertical flight technology.[28] However, the society does not develop standards. Rather, it addresses industry, government and academic challenges specific to vertical flight, and technologies pertaining to:

- Aerodynamics.
- Avionics.
- Dynamics.
- Electrification.
- Health and usage monitoring.
- Noise and acoustics.
- Product support.
- Propulsion.
- Safety.
- Systems engineering.
- Test and evaluation.
- Unmanned operations for rotorcraft and drones.

In September 2017, ANSI created the ANSI UAS Standardization Collaborative (UASSC), which has co-chairs from both government and industry. An ANSI standardization collaborative is a mechanism for advancing cross-sector coordination in the development and compatibility of the standards and conformance programs needed to support emerging technologies and national/global priorities. The mission of the UASSC is to coordinate and accelerate the development of standards and conformity assessment programs. Its focus is on the programs needed to facilitate the safe integration of UASs into the U.S. national airspace system, supported by international coordination and adaptability.

The UASSC provides a standardization roadmap for UASs, complete with a summary that it provides to industry to preempt duplications of standardization activities and drive coordination.

[28] The Vertical Flight Society, "Why Join the Vertical Flight Society?," https://vtol.org/.

The collaborative offers recommendations for harmonizing UAS integration efforts emerging from SDOs' roadmaps and FAA rules, guidance, policies and certifications/approvals. In its reports, it specifies concerns about overlaps of, and gaps between, the technologies related to UASs/UAVs.

ANSI was helpful by taking the lead on providing oversight and outreach on standards activities related to new technological developments and new product classifications. Additional support for UAS/UAV standards is coming from ISO TC 20 Aircraft and Space Vehicles, SC 16 UAS. There is little U.S. involvement there, even though the U.S. TAG is administered by SAE International.

In addition to UASs/UAVs, the concept of air taxis continues to gain traction worldwide. There are four leading startup companies in the electric vertical takeoff and landing (eVTOL) air system arena: Joby Aviation, Archer Aviation, Lilium Jet and Vertical Aerospace. These companies anticipate producing thousands of eVTOL air taxis in 2027.

Conclusions

UAS/UAV/drone technology has emerged rapidly, and the benefits of industry standardization in this area are critical to cost, quality and repeatability. They are especially critical to public safety, as these vehicles often operate at very low altitudes. Pilotless manned air vehicles add another significant level of concern.

Commercial and defense interests could have overlapping and competing technical needs that must be addressed by standards and regulation. Consequently, industry and government need to work together to ensure that globally relevant standards exist to meet UAS/UAV technical needs.

Chapter 10
Aggressive Alignment with Emerging Technologies

Recommendation No. 10: Leadership in TCs and governing boards must act quickly on proposals to create or expand TCs to address emerging technology standards development. Aerospace companies must be involved and seek leadership positions in these organizations – considered external outreach by some aerospace companies – to effect influence. ANSI standards development principles are most advantageous here for addressing gaps and eliminating overlap. Aerospace companies must be proactive and place their best technical representatives in the emerging technologies and TCs early in the process. Aerospace interests must be represented more aggressively in these emerging technologies, and education at all levels is essential.

The U.S. aerospace industry must become much more aggressive in assessing and engaging in emerging technical activity related to standards. This concept, along with informed and deliberate internal company management, has been known for many years as Strategic Standardization Management. Consideration must be given to the technology and standards development infrastructure, ecosystem and environment, as well as all types of organizations: industry associations, SDOs and consortia with purviews over emerging technologies.

Technologies relevant to aerospace interests continue to rapidly evolve, and they must be addressed holistically and across SDOs. Thus, it is imperative for U.S. aerospace companies and SDOs to quickly align and create working groups and TCs to address these technologies at the earliest stages of their technological development. Early alignment ensures that U.S. aerospace is in a leadership position. It also ensures that U.S. aerospace companies are included in discussions about what may be standardized and what may be maintained as company secrets and IP.

Also essential is keeping a close watch on emerging public policies related to these technologies. Increasingly, technical standards are being developed by multiple providers. The best approach for the aerospace industry is to first develop voluntary industry standards. Then, industry can work to have standards incorporated by regulation, in contracts, or in jurisdictions where aerospace companies' sources reside or sell their products.

All efforts must be made to assess gaps and address the potential for overlapping standards development. A gap assessment flowchart might be warranted for specific technologies, and all SDOs and industry associations and consortia, worldwide, should be considered for their potential standards interests relative to the specific emerging technology. This process might need to be repeated over time as technological development and technical maturity occurs and events warrant.

The need for aerospace-specific derivatives of more generic industry standards must be evaluated for the value they might add as well. In most emerging technical domains, aerospace interests are in the minority. There are many significant aerospace-relevant emerging technologies, and many

technologies that are rapidly advancing in areas where aerospace interests must be represented more aggressively, relative to standards development. These include technologies in the fields of:

- Additive manufacturing and 3D printing.
- Advanced and additive materials/material science.
- Advanced communications and telecommunications.
- Advanced electronics and microelectronics.
- Agile and Development Security Operations (DevSecOps).
- Alternative fuels and propulsion systems.
- Artificial intelligence, machine learning, and resilient and responsive designs.
- Augmented reality.
- Automated and connected infrastructure.
- Autonomy.
- Avionics.
- Biotechnology.
- Blockchain and distributed ledger technology.
- Cloud computing.
- Cybersecurity.
- Data analytics and analysis.
- Digital design, engineering, product definition and exchange.
- Digital displays.
- Digital qualification and verification.
- Digital transformation.
- Digital twins.
- Directed energy.
- Distributed computing.
- Energy technologies.
- Engineered biology and biotechnology.
- Hypersonics.
- Internet of Things (IoT).
- Model-based engineering.
- Multidomain operations.
- Nanotechnology, miniaturization and micro-miniaturization.
- Object management.
- Open sources and open applications.
- Open system architectures.
- Operational test and evaluation.
- Privacy.
- Quantum information science.
- Quantum physics.
- Robotics.
- Software and enterprise architecture/systems architecture.
- Software factory and software testing.
- Space.

- Survivability.
- Sustainability and the continued elimination of restricted substances/chemicals/materials of concern throughout life cycles, including end of life.
- Sustainment/logistics/product support and predictive maintenance.
- Systems engineering and integration (continued enhancement).
- Systems Modeling Language.
- Traceability.
- UAVs/UASs.
- Wearables.

The aerospace industry must also watch closely the emerging management systems standards (MSS) and international guidance documents outside the technical domain. In the past 25 years, MSS have evolved from covering solely quality and environmental processes to covering numerous business processes.

Additionally, education, briefings, papers and conferences about standards and standardization are essential to the aerospace industry. This applies at many levels, from senior leaders to emerging professionals, as there are many who are uninformed.

Conclusions

Technologies relevant to aerospace interests continue to rapidly evolve. It is imperative for U.S. aerospace companies and SDOs to quickly align and create working groups and TCs to address these technologies at the earliest stages of technological development. Early alignment will ensure that U.S. aerospace is in a leadership position. As part of this, U.S. aerospace companies will participate in discussions about what can be standardized and what must be maintained as company secrets and IP.

Ever more consortia are being developed with purviews over emerging technologies. In response, all efforts must be made to assess gaps and address the potential for overlapping standards development. Technologies must be addressed holistically across SDOs, industry associations and consortia, as technical standards are increasingly being developed by multiple providers. Also, the need for aerospace-specific derivatives of more generic industry standards must be evaluated for the value they can add. In most emerging technical domains, aerospace interests are in the minority.

Appendix A

Glossary of Terms Used in This Report

Standard – A technical specification or other document available to the public, drawn up with the cooperation and consensus or general approval of all parties affected by it, based upon the consolidated results of science, technology and experience, aimed at promoting optimum community benefits and approved by a standardization body (e.g., the International Organization for Standardization). Standards are individual documents for generally agreed-upon business product and component definition, processes, practices, products, procedures or policies. Standards can be developed internally within an organization (internal standards) or externally through various standards-developing organization committees (external standards). Standards are the means by which technical and business decisions are documented and communicated. For the purpose of this report, specifications are considered to be standards.

Standards-Developing Organization (SDO) – A voluntary, cooperative, non-profit association formed to further technology in a particular area of expertise. Often formed by individuals interested in furthering a particular profession, SDOs form committees, subcommittees, technical advisory groups and other such bodies to address particular areas of interest. For the purpose of this paper, the term's abbreviated form, "SDO," is extended to consortia, trade organizations and U.S. organizations accredited by the American National Standards Institute (ANSI).

Standardization Organizations and Definitions

Standardization – Process of establishing and using, by common agreement, the engineering criteria, terms, principles, practices, materials, items, processes, equipment, parts, subassemblies and assemblies appropriate to achieving the greatest practicable uniformity of products and engineering practices.

Strategic Standardization – The utilization and integration of standards in an interactive, systemic sense to achieve greater business competitive advantages through subsystems to facilitate the implementation of a complete system. The strategy is to exert influence within SDO committees to create or modify external standards that represent the best competitive interests of the organization at the national and/or international level(s). Strategic standardization leverages human capital resources.

Strategic Standardization Management – A macro process and management leadership discipline that investigates, defines, recommends and implements standardization strategies and policies by which an organization can gain a competitive advantage. It is a process by which key managers judge the organization's best influence in SDO committees by organizational representatives to initiate or modify standards that reflect the optimum business, technology and product plans for the organization. It is the strategy of an open-system plan for product components or interfaces with equipment or products produced by other organizations. This is achieved through continual processes of gaining information, benchmarking, assigning metrics to key processes and

managing goals, for which progress is charted toward end-of-period goals. A management discipline, it organizes an entity's standardization resources. Due to manufacturing necessity, industry agreement or national or international policy, the need to operate according to standards is essential to organizations in a wide array of industries.

International Standardization – Standardization in which involvement is open to relevant bodies from all countries.

Regional Standardization – Standardization in which involvement is open to relevant bodies from countries from only one geographical, political or economic area of the world.

National Standardization – Standardization that takes place at the level of one specific country.

Company Standardization – Standardization that takes place within a corporation or company.

Types of Standards and Definitions

Standard – A document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of an optimum degree of order in a given context.

International Standard – A standard that is adopted or developed by an SDO whose processes involve voting and consensus building by countries (i.e., one country, one vote). Examples are the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC).

Global Standard – A standard that is recognized, accepted and used by the global marketplace, regardless of the processes and organizations used to develop the standard.

Regional Standard – A standard that is developed or adopted by a regional SDO and made available to the public.

National Standard – A standard that is developed or adopted by a national standards body and made available to the public.

Harmonized Standard – Standards on the same subject, approved by different standardization bodies, that establish the interchangeability of products, processes and services, or that establish a mutual understanding of the test results or information provided according to these standards.

Voluntary Standards – Standards that are established generally by private sector bodies, and that are available for use by any person or organization, private or governmental. These standards are generally developed in a consensus process characterized by openness to all materially affected parties, direct participation by technical experts, due process for arbitration of conflicting views, and an appeals process for reviewing procedural anomalies. Sometimes these standards can become mandatory when a government body stipulates them in legislation or regulation.

Quasi-Mandatory Standard – A standard with which there is no legal obligation to comply, but that is required in practice or under certain conditions, such as a purchasing requirement or for compatibility with other products.

Mandatory Standard – A standard with which there is an obligation to comply by virtue of an action by government or by an authority endowed with the necessary legal power; called a code, regulation, or rule. In addition to specifying *how* a product must conform, a mandatory standard usually prescribes *who* must implement the standard; to *what* products the standard applies, and under what conditions; and *when* conformance is required. It could also prescribe how conformance is to be established, define exemptions and deviation procedures, and impose penalties for nonconformance.

De Facto Standard – A standard that has not been promulgated and adopted, but that has come into use by general acceptance, custom or convention; could be described in a published document.

Performance Standard – A standard that prescribes the acceptable functional or operational characteristics of a material, product or system related to the circumstances of use to which the performance applies; includes or references the test methods by which these characteristics are measured.

Design Standard or Prescriptive Standard – A standard that describes how the required performance can be achieved by prescribing the physical or dimensional characteristics of a product or system and its manufacture, construction or fabrication; can describe a product that has been determined by a product test to be in conformance with a prescribed set of performance standards.

Industry Standard – A standard developed and promulgated by representatives of an industry for materials, products and processes related to that industry. An industry standard generally represents a consensus of the industry regarding the nomenclature, identification, standard sizing, and material, design or performance specifications for materials and products of that industry.

Company Standard – A standard applicable to the design, manufacture, quality control, testing, installation or servicing of the products and services of a particular organization.

Proprietary Standard – A standard developed by a common interest group and not generally promoted for use by the public. Company standards and some industry standards are generally considered to be proprietary standards.

Government Standard – A standard developed, adopted or promulgated by a federal, state or local government agency. A government standard is generally mandatory as applied to government procurements or when adopted as a code, regulation or rule by a regulatory authority.

Federal Standard – A standard promulgated by the Federal Supply Service, General Services Administration, pursuant to a Federal Property Management Regulation. Federal standards provide standard data and test methods for reference in federal specifications, and identify standard items for use in the Federal Supply Service.

Federal Information Processing Standard – A standard developed by the National Institute of Standards and Technology, adopted and promulgated by the Department of Commerce under the provisions of Public Law 89-306. Federal information processing standards are applicable to federal information processing installations and government procurements of information-processing equipment. They are generally mandatory in nature.

Military Standard (MIL-STD) or Military Specification (MIL-SPEC) – A standard developed and issued by the Department of Defense, used predominantly for military activities. They are generally mandatory in nature.

Management Systems Standard (MSS) – The highest-level description of a discipline (management or technical) that defines the discipline's organization and management, and that requires a system of internal organizational procedures to reflect the discipline's requirements as differing from those of a technical standard. This document reflects the consensus approach to the elements of a particular technology (e.g., ISO 9000 or ISO 14000).

Regulatory Standard – A standard that has some form of statutory enforcement behind it.

Appendix B
Significant Industry Associations, Consortia and Standards-Developing Organizations in U.S. Aerospace

Industry Associations

- AAAI – Association for the Advancement of Artificial Intelligence
- AAAS – American Association for the Advancement of Science
- AACC – American Automatic Control Council
- AAEES – American Academy of Environmental Engineers & Scientists
- AAS – American Astronautical Society
- ABMA – American Bearing Manufacturers Association
- ACDM – Association for Configuration and Data Management
- ACerS – American Ceramic Society
- ACES – Applied Computational Electromagnetics Society
- ACM – Association for Computing Machinery
- ACS – American Chemical Society
- ACT-IAC – American Council for Technology-Industry Advisory Council
- ADIAG – Airworthiness Defense Industry Advisory Group
- AEE – Association of Energy Engineers
- AFCEA International
- Agile Alliance
- AGMA – American Gear Manufacturers Association
- AGU – American Geophysical Union
- AIA – Aerospace Industries Association
- AIChE – American Institute of Chemical Engineers
- AIM Photonics
- AITP – Association of Information Technology Professionals
- America Makes - National Additive Manufacturing Innovation Institute
- AMS – American Meteorological Society
- AMTA – Antenna Measurement Techniques Association
- ANS – American Nuclear Society
- ANSI – American National Standards Institute
- AOC – Association of Old Crows
- APS Physics – American Physical Society
- ARM – Advanced Robotics for Manufacturing
- ARSAG – Aerial Refueling Systems Advisory Group
- ASA – Acoustical Society of America
- ASCE – American Society of Civil Engineers
- ASD – AeroSpace and Defence Industries Association of Europe
- ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers
- ASM International (formerly the American Society for Metals)
- ASME – American Society of Mechanical Engineers

- ASNT – American Society for Nondestructive Testing
- ASPE – American Society for Precision Engineering
- ASPRS – Imaging & Geospatial Information Society
- ASQ – American Society for Quality
- ASSP – American Society of Safety Professionals (formerly ASSE – American Society of Safety Engineers)
- ATMAE – Association of Technology, Management, and Applied Engineering
- AUVSI – Association for Unmanned Vehicle Systems International
- AVSI – Aerospace Vehicle Systems Institute
- BCSP – Board of Certified Safety Professionals
- CCSDS – Consultative Committee for Space Data Systems
- CEF – Corporate Eco Forum
- CLEP – Council of Logistics Engineering Professionals
- CSA – Cloud Security Alliance
- CSRA – Cyber Security Research Alliance
- DAMA International
- DMDII – Digital Manufacturing and Design Innovation Institute
- ECCMA – Electronic Commerce Code Management Association
- ECI – Ethics & Compliance Initiative
- ECIA – Electronic Components Industry Association
- EEI – Edison Electric Institute
- GAMA – General Aviation Manufacturers Association
- GSA – Global Semiconductor Alliance (formerly Global Semiconductor Industry)
- HFES – Human Factors and Ergonomics Society
- IACMI – Institute for Advanced Composites Manufacturing Innovation
- IAI – International Aluminum Institute
- IAPMO – International Association of Plumbing & Mechanical Officials
- Iasa Global
- ICCAIA – International Coordinating Council of Aerospace Industries Associations
- ICCP – Institute for the Certification of Computing Professionals
- IEEC – Integrated Electronics Engineering Center
- IEST – Institute of Environmental Sciences and Technology
- IET – Institution of Engineering and Technology
- IISE – Institute of Industrial and Systems Engineers
- IMAPS – International Microelectronics Assembly & Packaging Society
- INCE – Institute of Noise Control Engineering
- INCOSE – International Council on Systems Engineering
- INFORMS – Institute for Operations Research and the Management Sciences
- IOF – Industrial Ontologies Foundry
- IOM3 – Institute of Materials, Minerals & Mining
- ION – Institute of Navigation
- IOP – Institute of Physics
- IPv6 Forum
- IRI – Innovation Research Interchange (formerly the Industrial Research Institute)

- ISA – International Society of Automation
- ISA – Internet Security Alliance
- ISACA (formerly Information Systems Audit & Control Association)
- ISASI – International Society of Air Safety Investigators
- ISPRS – International Society for Photogrammetry and Remote Sensing
- ISSA – Information Systems Security Association
- ISSS – International System Safety Society
- ISTVS – International Society for Terrain-Vehicle Systems
- ITEA – International Test and Evaluation Association
- ITS America – Intelligent Transportation Society of America
- LIFT (of ALMMII – American Lightweight Materials Manufacturing Innovation Institute)
- MCFA – MultiCore for Avionics
- MLC – Manufacturing Leadership Council
- MMPDS – Metallic Material Properties Development and Standardization
- MRS – Materials Research Society
- MTConnect Institute
- MTS – Marine Technology Society
- MxD (formerly DMDII – Digital Manufacturing and Design Innovation Institute)
- NACE International
- NAE – National Academy of Engineering
- NAEM – National Association for EHS&S Management
- NAEP – National Association of Environmental Professionals
- NCMS – National Center for Manufacturing Sciences
- NCMS – Society of Industrial Security Professionals
- NDIA – National Defense Industrial Association
- NEMA – National Electrical Manufacturers Association
- NFPA – National Fire Prevention Association
- NIBS – National Institute of Building Sciences
- NIRPS – National Institute for Rocket Propulsion Systems
- NSPE – National Society of Professional Engineers
- NTSA – National Training & Simulation Association
- OASIS – Organization for the Advancement of Structured Information Standards
- OSA – Optical Society (formerly Optical Society of America)
- PIER – Progress in Electromagnetics Research
- PowerAmerica (Next Generation Power Electronics Manufacturing Innovation Institute)
- PRI – Performance Review Institute
- PSM – Practical Software and Systems Measurement
- PSMA – Power Sources Manufacturers Association
- RAES – Royal Aeronautical Society
- RIN – Royal Institute of Navigation
- SAFe – Scaled Agile Framework
- SAMPE – Society for the Advancement of Material and Process Engineering
- SAWE – Society of Allied Weight Engineers
- SCC – Standards Council of Canada

- Scrum Alliance
- SCS – Society for Modeling and Simulation International
- SEA – Supplier Excellence Alliance
- SEI – Software Engineering Institute (Carnegie Mellon University)
- SERC – Systems Engineering Research Center
- Service Architecture
- SES – Society for Standards Professionals (formerly Standards Engineering Society)
- SFTE – Society of Flight Test Engineers
- SIA – Semiconductor Industry Association
- SIAM – Society for Industrial and Applied Mathematics
- SISO – Simulation Interoperability Standards Organization
- SME (formerly Society of Manufacturing Engineers)
- SMTA – Surface Mount Technology Association
- SOLE – International Society of Logistics
- SPIE (International Society for Optics and Photonics)
- SRA – Society for Risk Analysis
- SSPC – Society for Protective Coatings (formerly Steel Structures Painting Council)
- STC – Society for Technical Communication
- TCSP – Transglobal Secure Collaborative Program
- TIA – Telecommunications Industry Association
- TMS – The Minerals, Metals & Materials Society
- UEFIF – Unified Extensible Firmware Interface Forum
- UPA – Usability Professionals Association
- USENIX (Advanced Computing Systems Association)
- USGIF – United States Geospatial Intelligence Foundation
- USTLC – US Technology Leadership Council
- Vertical Flight Society (formerly AHS International, Inc.)

SDOs and Laboratories

- AIA – Aerospace Industries Association
- AIAA – American Institute of Aeronautics and Astronautics
- AIAG – Automotive Industry Action Group
- ACMA – Air Movement and Control Association International
- API – American Petroleum Institute
- ASD-STAN – Aerospace and Defense Industries Association of Europe - Standardization
- ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers
- ASME – American Society of Mechanical Engineers
- ASSP – American Society of Safety Professionals
- ASTM International
- ATIS – Alliance for Telecommunications Industry Solutions
- AWS – American Welding Society
- B11 Machinery Safety (ANSI standards)

- CSA Group
- DSPO – Defense Standardization Program Office (U.S. Department of Defense)
- ECIA – Electronic Components Industry Association
- ISACA's CMMI® Maturity Models
- ICC – International Code Council
- IEC – International Electrotechnical Commission
- IEEE – Institute of Electrical and Electronics Engineers
- IIW – International Institute of Welding
- INCITS – InterNational Committee for Information Technology Standards
- IPC International, Inc. – (formerly Institute of Printed Circuits)
- ISO – International Organization for Standardization
- ISO/IEC Joint Technical Committee (JTC) 1 Information Technology
- ITU – International Telecommunication Union
- MMPDS – Metallic Materials Properties Development and Standardization
- MORS – Military Operations Research Society
- NCSL International (formerly National Conference of Standards Laboratories)
- NFPA – National Fire Prevention Association
- NISO – National Information Standards Organization
- NIST – National Institute of Standards and Technology
- NSF International (formerly National Sanitation Foundation)
- OAGi – Open Applications Group Inc.
- OASIS – Organization for the Advancement of Structured Information Standards
- OASIS Open (formerly SGML Open)
- OEOSC – Optics and Electro-Optics Standards Council
- OMG – Object Management Group
- OPC Foundation
- ORC HSE (formerly Organization Resources Counselors, Inc.)
- OSLC – Open Services for Lifecycle Collaboration
- PICMG – PCI Industrial Computer Manufacturers Group
- PRI – Performance Review Institute
- QIF – Quality Information Framework
- RTCA (formerly Radio Technical Commission for Aeronautics)
- SAE International (formerly the Society of Automotive Engineers)
- Secure Technology Alliance
- SEMI Worldwide
- SES – Society for Standards Professionals (formerly Standards Engineering Society)
- S-Series
- SWISS – Standard for Digital Transformation (XSB)
- SX000i – International Specification for Integrated Product Support (IPS) S-Series
- The Open Group
- UL, LLC – Underwriters Laboratories
- VITA
- X12

Consortia

- 3D PDF Consortium (merged with PDES, Inc.)
- CALCE – Center for Advanced Life Cycle Engineering
- CAM-I – Consortium for Advanced Management-International
- CHREC – Center for High-Performance Reconfigurable Computing (National Science Foundation)
- DMSC – Digital Metrology Standards Consortium
- DSC – Defense Sustainment Consortium
- EMBC – Embedded Microprocessor Benchmark Consortium
- EMCC – Electromagnetic Code Consortium
- FACE – Future Airborne Capability Environment
- IAEG – International Aerospace Environmental Group
- IAQG – International Aerospace Quality Group
- ICES – International Cooperation on Education about Standardization
- $(ICS)^2$ – International Information System Security Certification Consortium
- IFAN – International Federation of Standards Users
- NCOIC – Network Centric Operations Industry Consortium
- NextFlex
- OGC – Open Geospatial Consortium
- PDES, Inc.
- RTC – Robotics Technology Consortium
- SOSA – Sensor Open Systems Architecture
- W3C – World Wide Web Consortium

U.S. Government Entities

- DoD – Department of Defense
- DSPO – Defense Standardization Program Office
- NIST – National Institute of Standards and Technology
- OSD – Office of the Secretary of Defense
- U.S. Army
- U.S. Navy
- USCG – U.S. Coast Guard
- USMC – U.S. Marine Corps

Notes:
1. Several organizations are both industry associations and SDOs.
2. This list is not meant to be exhaustive, and the author welcomes additions and corrections.