Defense Standardization Program

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Space Standards

Defense Standardization Program Journal

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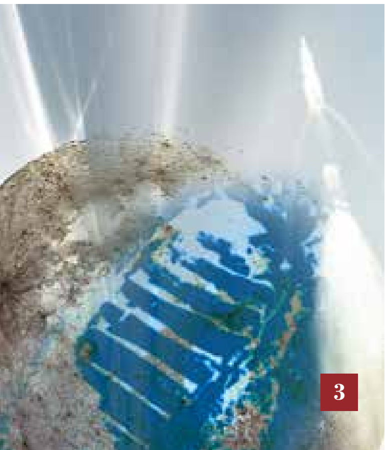

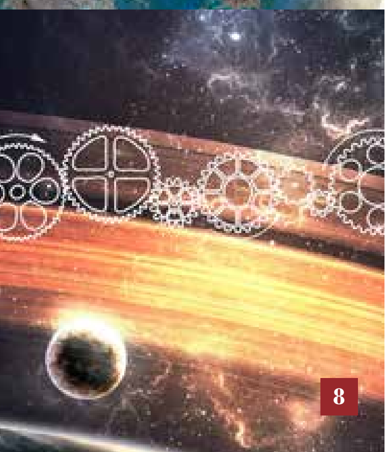

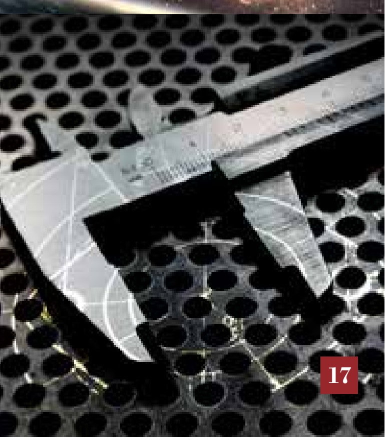

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Director's Forum

In the first 2 months of this year, two of the most experienced, knowledgeable, and capable people from the staff of the Defense Standardization Program Office retired—Joe Delorie and Steve Lowell.

For about the last 10 years, **Joe Delorie** has devoted the majority of his time to the development and simplification of ASSIST and its related tools. If you are not familiar with ASSIST, that may not seem such a big thing. If you are familiar with ASSIST, you'll recognize that it is one of the best standards access portals in the world. Some of the tools that Joe developed include one that builds a "Christmas Tree" of referenced documents, a "Referenced-By" tool that shows where a document is referenced in another document in order to ensure that changes are considered by all relevant users, and a tool that connects national stock numbers to military specifications to part numbers and to weapon systems. Called the Weapon System Impact Tool, it makes it easy to determine where military or nongovernment standards are called out in weapon systems, showing just how documents are being used. It also allows one to "turn the telescope around" and find for any given weapon system which specs are called out.

Joe is an outstanding teacher who has taught hundreds of people how to use the more advanced features of ASSIST and its companion tools and how to manipulate the finer intricacies to find exactly the answers that users are looking for.

As one of the most experienced folks on staff, Joe could be depended upon to provide historical context to questions and initiatives. As a techie guy, Joe was also one of the first to embrace the kinds of technological advancements that we could incorporate into our website, or ASSIST, or other DSP functions. As an excellent writer, Joe was someone I could always count on to develop the odd white paper, policy analysis, letter, response to constituent, or whatever was needed, knowing that it would be done well.

Joe has worked in numerous other areas of the Defense Standardization Program, helping to identify documents that could be moved to the private sector, guiding integrated product teams (IPTs) in the development of requirements for standardization documentation, doing standardization assessments, and helping drive the department toward the greater use of commercial products and processes.

Gregory E. Saunders
Director
Defense Standardization Program Office

Steve Lowell has been the deputy director of DSPO for the past 13 years. At the luncheon held in honor of Steve's retirement, I spoke about his accomplishments as a guest lecturer at several different universities, as well as the dozens of times he has spoken at conferences representing the Office of the Secretary of Defense. Recognized by his peers with numerous awards as well as rewarded by his superiors all the way to the vice president, Steve's unique knowledge of standardization, particularly in the defense sector, his willingness to help resolve difficult issues, and his talent for writing have made him a much-sought-after participant in meetings, IPTs, and conferences, as well as an encyclopedic resource for standardization policies, procedures, expertise, and history.

What Steve has been to me, to my bosses, and to his colleagues is a trusted advisor. While he has earned many well-deserved accolades for his own talent and work, he always seemed to be most pleased when he could help others look good. Whether that happened because he advised on how to address a problem or because he wrote a brilliant speech for them to deliver, he was accomplished at providing just the right advice or the right speech at the right time.

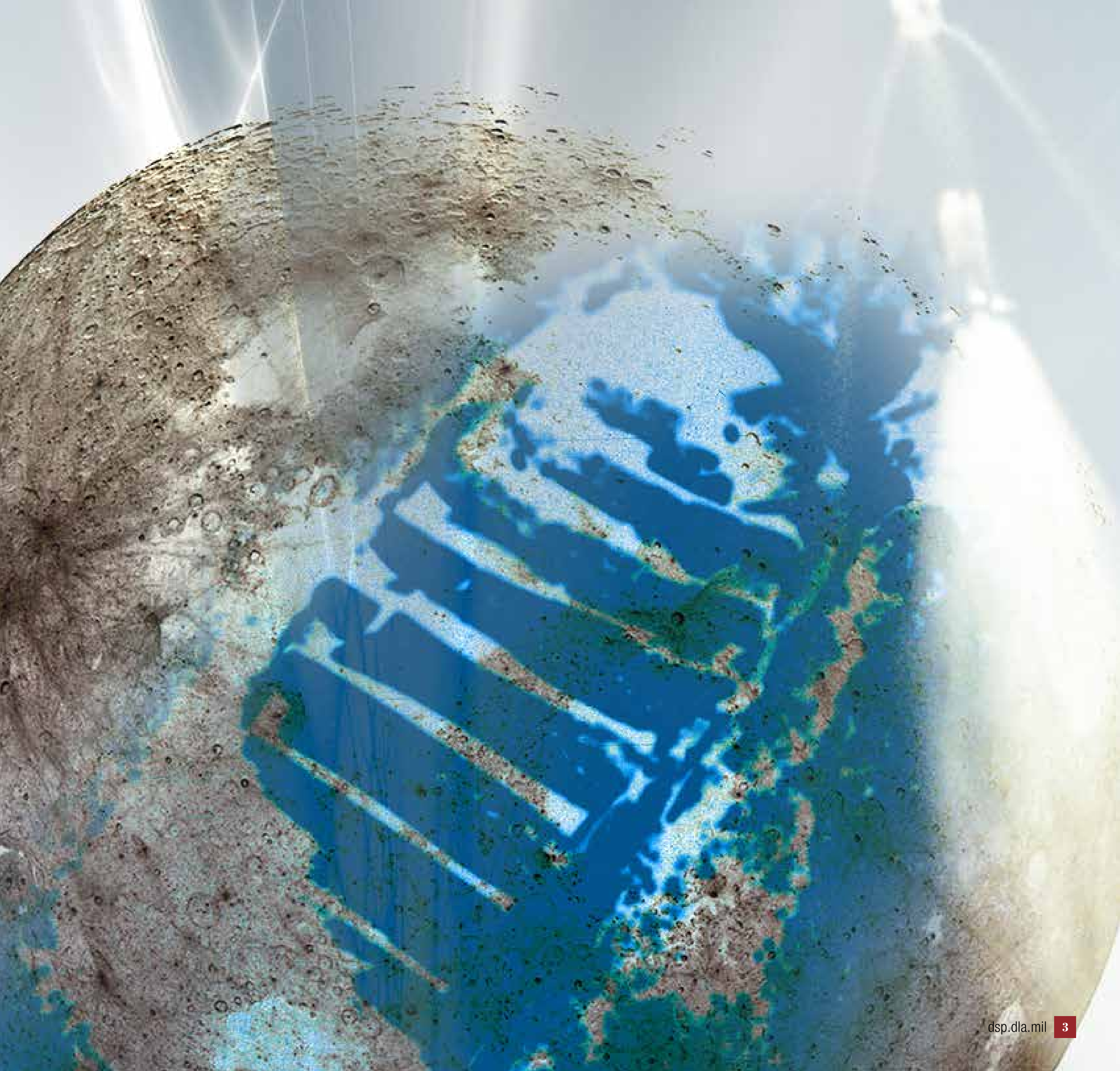
Both Steve and Joe have been extraordinarily effective "behind the scenes" people. Neither one particularly sought the spotlight during their careers, but their superior competence was reflected in the accomplishments of the Defense Standardization Program and in the work of those they helped. In an era where inflated rhetoric is all around us, where people get "participation" trophies just for showing up, and where, in order to stand out, we have been treated to "extreme" sports—as though regular sports were not sufficiently challenging—Steve and Joe were not people who just showed up, and use of the word "extreme" is not hyperbole.

Steve and Joe demonstrated extreme competence, extreme professionalism, extreme knowledge and skill, and extreme integrity and dedication.

And one last extreme—you guys will be extremely missed.

Standards in Space throughout NASA's History

By Paul Gill and Amber Wright



Since the foundation of the National Aeronautics and Space Administration (NASA) in 1958, engineers have used standards during its many missions for either defining mission requirements and documenting them formally or maintaining their respective lab or machine shop requirements informally for standardized procedures or parts.

The November 1967 launch of Apollo 4 marked a culmination of more than 7 years of developmental and standardization activities in design, fabrication, testing, and launch site preparation by tens of thousands of workers from government, industry, and universities to place the unmanned Apollo 4 126,000 kilograms into Earth's orbit.

On July 20, 1969, the Apollo 11 crew took "One Small Step for Man" and stepped foot on the lunar surface, pioneering and standardizing experimentation procedures on the lunar surface.

In May 1973, Skylab was launched as America's first space station and included a solar observatory, microgravity lab, medical lab, Earth-observing facility, and long-term crew accommodations. This mission involved development and standardization of technologies that propelled NASA into being able to support human life in outer space for extended periods of time, with the record-breaking spaceflight duration of 84 days.

First launched in April 1981, NASA's Space Shuttle flew more than 135 missions, traveling more than a half a billion miles. Throughout its many missions, shuttle crew members were able to standardize and document NASA's engineering processes, many of which are still used today.

Another watermark in NASA's history, NASA's International Space Station was launched into lower Earth orbit in November 1998 and serves the NASA community

Image courtesy of NASA.

as a microgravity and space environment research laboratory, helping to develop and standardize so many aspects of space exploration. This habitable satellite has even driven innovation and standardization in the solar industry, as its acre-sized solar array surface area acts as its long-standing power source.

Application of Standards

As a federal agency, NASA is required by Office of Management and Budget Circular A-119 to use voluntary consensus standards (VCS) unless their use would be inconsistent with applicable law or otherwise impractical, including where use of a VCS would not be as effective at meeting the agency's regulatory, procurement, or program needs. NASA develops its own technical standards when no VCS exists or can be adapted to meet NASA's engineering needs.

NASA-endorsed technical standards are proven technical standards that include NASA-developed standards, VCS, and other government standards; are identified and approved by NASA Headquarters offices for specific applications; and are considered first for use in developing technical requirements for current and future NASA programs and projects. The listing of endorsed standards includes multiple military standards (MIL-STDs). For example, MIL-STD-1472, "DoD Design Criteria Standard–Human Engineering," is a NASA-endorsed standard providing human engineering design criteria, principles, and practices to optimize system performance with full consideration of the inherent human capabilities and limitations as part of the total system design trade space. This more effectively integrates the human as part of the system, subsystems, equipment, and facilities to achieve mission success. Additionally, the U.S. Air Force has published MIL-STD-1541, "Electromagnetic Compatibility Requirements for Space Systems," another NASA-endorsed standard. This standard presents the electromagnetic compatibility requirements for space systems, including frequency management, and the related requirements for the electrical and electronic equipment used in space systems.

NASA Technical Standards System

The NASA Technical Standards System (NTSS) is a key element of the NASA Technical Standards Program, sponsored by the Office of the NASA Chief Engineer. This one-stop shop for NASA engineers provides single-point e-authorization access to standards, handbooks, specifications, and other standards-related information plus engineering tools, which reduces research time, streamlines workflow, and avoids unnecessary costs. Users can access the NTSS at https://standards.nasa.gov. It provides access to NASA, VCS, and other government standards, at no direct cost to the user, via electronic subscription delivery. These VCS are developed by standards development organizations, while the government standards are developed by the Department of Defense, Department of the Air Force, Department of Energy, Department of Transportation, and many other government entities.

NASA's programs and projects glean requirements from many sources, including previous mission documents, NASA's own standards, other government standards, and the many national and international industry standards. These documents are identified in program documentation as applicable documents.

For example, S. Eddie Davis of the Materials and Processes Laboratory at NASA's Marshall Space Flight Center in Huntsville, AL, leads a team that extensively uses the test methods defined in MIL-STD-2223, "Test Methods for Insulated Electric Wire." This MIL-STD ensures that electrical wires are not likely to ignite and/or burn in their use conditions in aircraft or in space vehicles. As Davis explains, NASA's spacecraft vehicle wiring, or more specifically, wire insulation materials, ignite more easily and burn more quickly than the same materials used for other wire insulation for one reason—wires carrying current heat up, sometimes at too high a temperature. Elevating the temperature to which a material is exposed makes most materials ignite more easily and burn more quickly. "These higher temperatures generated by the resistance in current-carrying wires make wire testing imperative," says Davis.

In the early 1990s, a phenomenon called arc propagation (also known as arc tracking and wire flashover) was discovered by the military on its aircraft that used polyimide-insulated wires. The military and NASA investigated the phenomenon, because NASA also used polyimide-insulated wires on its shuttle missions. Until this discovery, polyimide insulation seemed to be the perfect insulation in that it was lightweight and strong and provided good insulation. This arc propagation phenomenon occurred inside aircraft wings that were frequently folded or moved. Davis highlights that the effect was "the insulation would crack after frequent bending to expose the current-carrying conductor wire, and this current-carrying wire would then spark onto the insulation. This is normally not a big issue, but polyimide material had one surprising quality—it would burn and produce its own oxidizer, which allowed it to ignite easily and continue to burn in space vacuum, underwater, soaked in hydraulic fluids, and in every environment in which it was tested." NASA found this effect to be a risk, as the wire would burn in a space vacuum, so testing for this phenomenon became very important. Another result was that NASA moved away from using polyimide-only insulation as a precaution and changed to wire insulation of three thin layers: polytetrafluoroethylene, polyimide, and polytetrafluoroethylene, or TKT for short (Teflon™, Kapton®, Teflon).

Another example of NASA adopting military standards for use across multiple programs is the adoption of MIL-STD-1773, "Fiber Optics Mechanization of an Aircraft Internal Time Division Command/Response Multiplex Data Bus." NASA first began using MIL-STD-1773 for the data bus on board the Hubble Space Telescope in April 1990. The astronomical observatory has been flying and providing inflight data continuously for more than 26 years.

MIL-STD-1773 is the fiber optic equivalent of the all-electrical MIL-STD-1553, "Digital Time Division Command/Response Multiplex Data Bus." MIL-STD-1553 uses the same communication protocol but a different physical transmission medium, and it operates at a single data rate of 1 megabit per second (Mbps). NASA maintained the –1773 and –1553 logical protocol heritage but added greater bandwidth capability by introducing the 20 Mbps operation in addition to the 1 Mbps from the –1773 standard. Because of NASA's implementation of this standard, celestial images captured by NASA's Hubble telescope have been received from more than 3 billion miles of travel. These images have thrilled schoolchildren across the world in addition to aiding the international community to further refine our view of the universe and our place within it.

When the chill of November 2018 arrives, NASA is set to launch its Space Launch System (SLS) heavy-lift rocket. The SLS will be the largest rocket ever constructed, designed to send humans deeper into space than ever before, possibly to Mars sometime in the future. Its journey will be fueled by the many NASA, military, and other VCS standards used to drive its design, development, test, and operations.

Image courtesy of NASA.

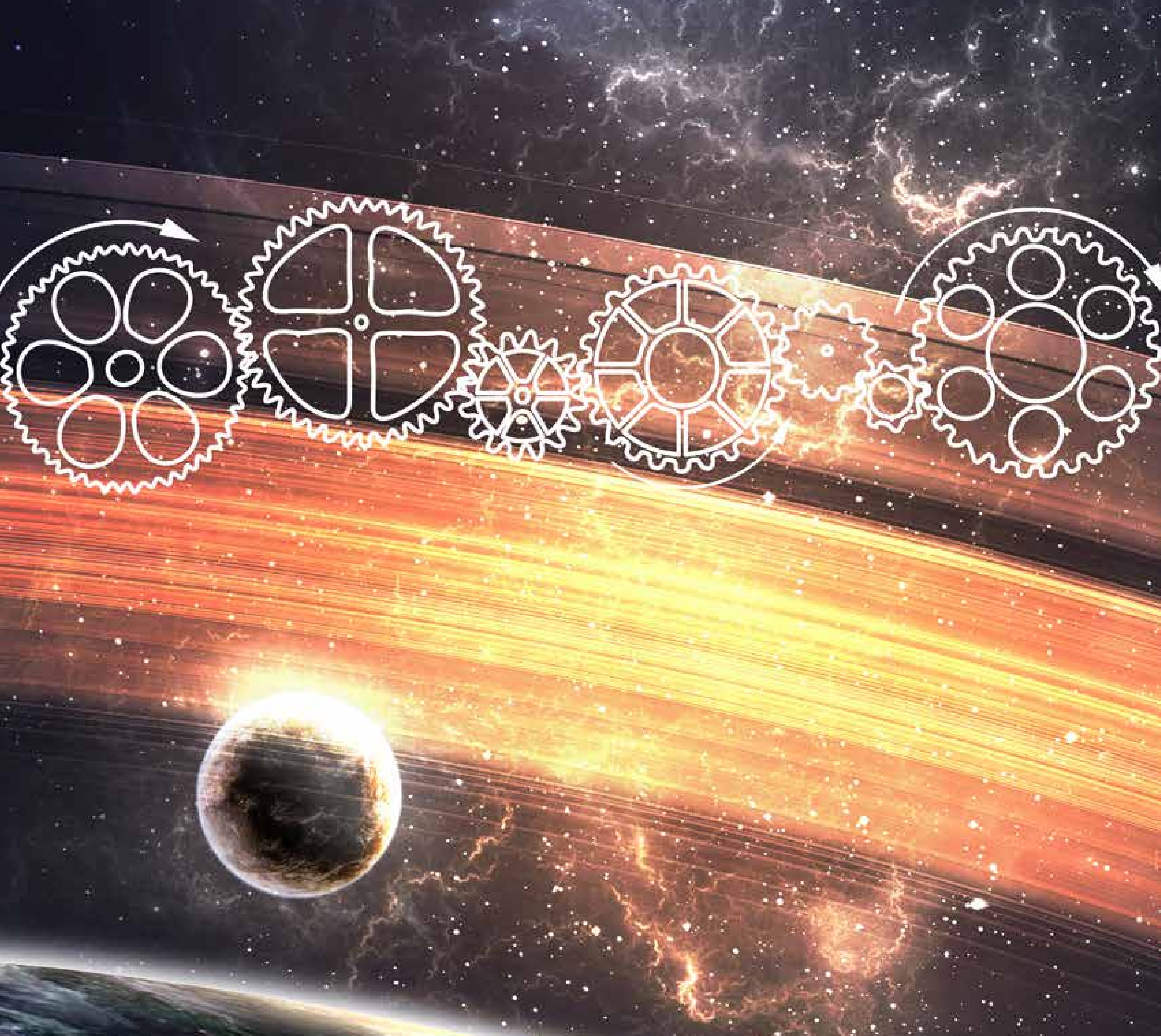
About the Authors

Paul Gill, NASA's technical standards program manager, plans, directs, and coordinates the agency's technical standards activities across the 10 NASA centers. He serves on technical committees of several national and international aerospace standards-developing organizations. Gill has received a number of prestigious NASA awards, including the NASA Exceptional Service Medal and the NASA Exceptional Achievement Medal.

Amber Wright is the technical data manager for the NASA Technical Standards Program. She supports NASA in its agency-level technical standards activities. After 5 years working as a contractor for the Department of Defense, Wright came to work at NASA and received the Silver Achievement Award for supporting Space Launch System data management efforts in 2015, and an Innovation in Engineering award in 2016 for her leadership and inventive approach to the rejuvenation of the NASA Technical Standards System site.

The Broad Landscape of Civil Space Standards

By Mike Kearney



The broad landscape of space standards for civil programs has been developing for a long time, particularly as economic pressures have increasingly forced international civil space agencies into cooperative spaceflight ventures. Defense agencies, historically emphasizing standards infrastructure and approaches of their own, are now increasingly interested in capitalizing on the same benefits that the civil space agencies have seen. But the very features that make that landscape broad also make it difficult to navigate. Hopefully this overview of civil space standards will provide some context that makes it easier for defense organizations to enter the arena to adopt and even help develop civil space standards to meet the needs of defense systems of the future.

Following are the three primary standards development organizations (SDOs) developing standards uniquely for the space industry:

- The International Standards Organization (ISO) Technical Committee 20 Subcommittee 14, "Space Systems and Operations" (referred to as ISO TC20/SC14, or SC14, in this article)
- The American Institute of Aeronautics and Astronautics (AIAA)
- The Consultative Committee for Space Data Systems (CCSDS), also known as ISO TC20/SC13, "Space Data and Information Transfer Systems" (see the CCSDS article later in this issue for further explanation).

The combined publications of these three bodies, both published and in-work drafts, number just below 500 documents. And those are just the ones that are specific to space systems, not counting more general terrestrial standards from other organizations (Institute of Electrical and Electronics Engineers [IEEE], American National Standards Institute, etc.) that space missions may need to consider. So it is an intimidating field to wade into. But it becomes a bit less intimidating if you know the landscape, as you will see.

These are all voluntary consensus standards (VCS) standards-setting bodies. The adoption of their standards is voluntary because they do not carry the weight of international treaties such as regulatory standards under the International Telecommunication Union. NIST Circular A-119 cites, "A voluntary consensus standards body is defined by the following attributes: (i) Openness. (ii) Balance of interest. (iii) Due process. (vi) An appeals process. (v) Consensus."

Besides the "big three" listed above, some other SDOs produce standards that are usable or even essential for space programs. The Object Management Group Space Domain Task Force has published four space-specific standards, and it has plans for more standards in the future. The IEEE has a large library of electronic standards for general use with avionics that can be applicable to spaceflight. And the European Space Agency (ESA) has organized an international working group for SpaceWire/SpaceFibre standards. But for this overview of civil space standards, we will focus on the big three that account for the overwhelming majority of space standards: ISO TC20/SC14, AIAA, and CCSDS.

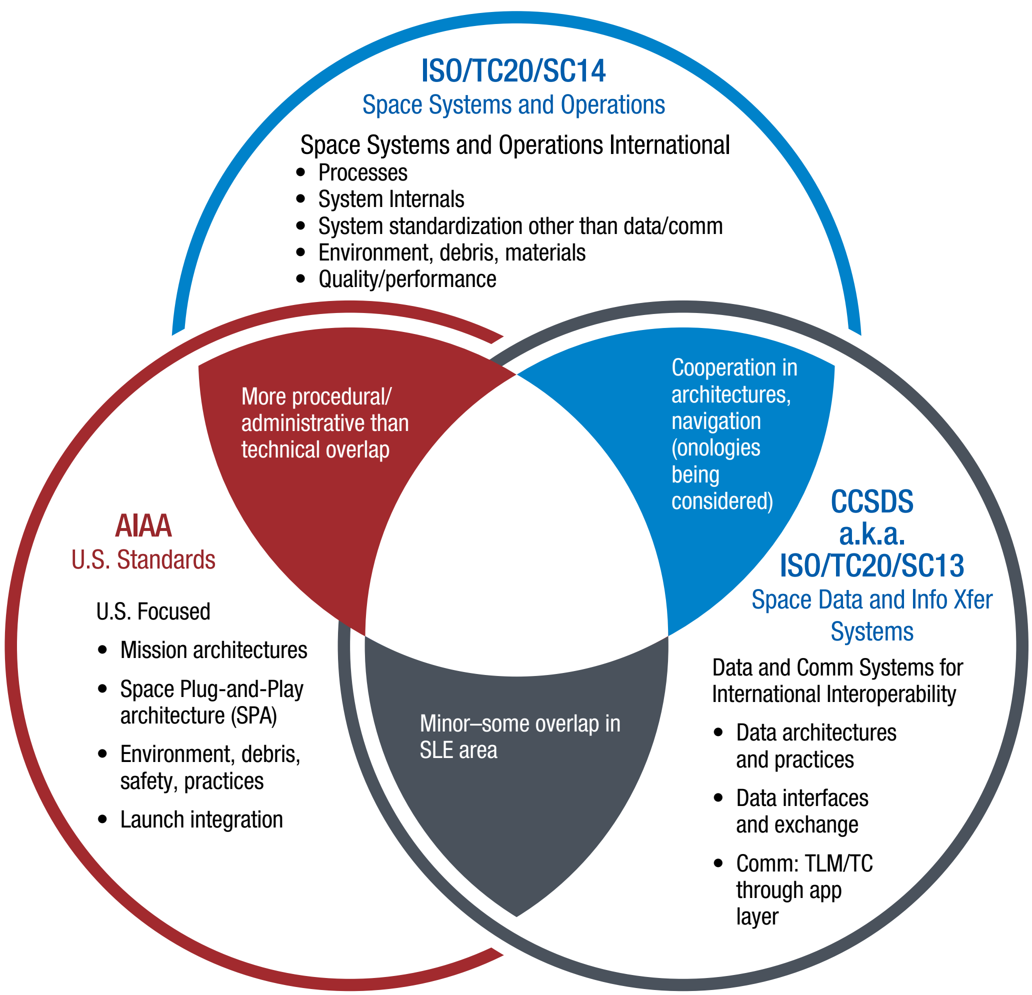
Where to Start?

When your mission, program, or project is reaching out to formulate a standards strategy or is seeking space-specific standards to adopt, the general breakdown for these three SDOs is as follows:

- For U.S. ***domestic*** space-specific standards in any of those areas, start with AIAA.
- For ***international*** standards for communications or data systems, start with CCSDS.
- For ***international*** standards for "anything else" besides communications and data systems, start with ISO TC20/SC14. "Anything else" includes testing, materials, space environment, orbital debris, design engineering, and program management and quality.

Figure 1 illustrates the relationship between the big three space SDOs. Note that there are some areas where they overlap, but it is generally a cooperative overlap, with coordination happening between the SDOs.

Figure 1. Relative Scope of Space Standards SDOs



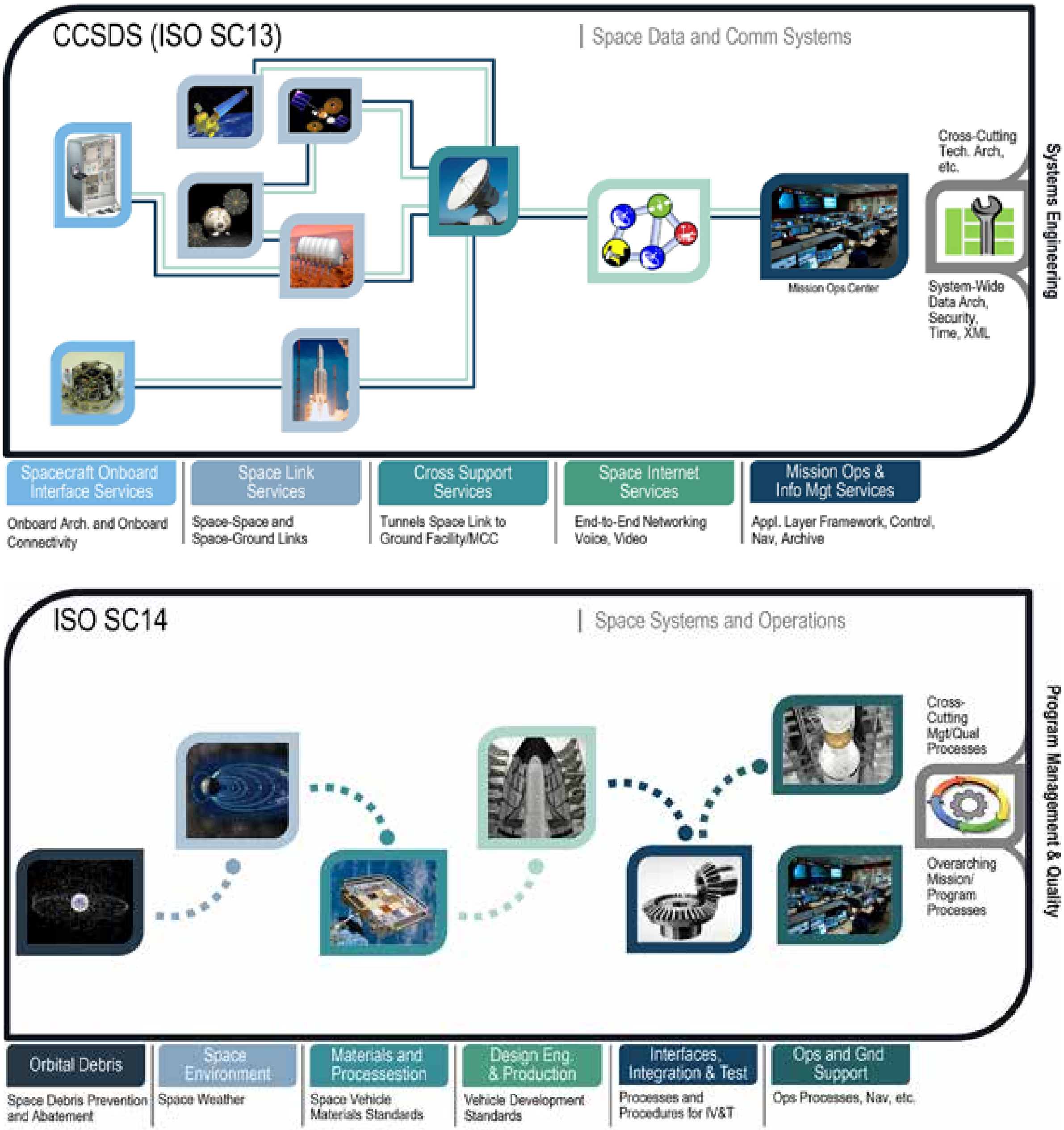
Source: Space Infrastructure Foundation, 2016; from Standards and Architecture class presentation.

When the U.S. aerospace community first conceives of the need for developing a new space standard, the normal procedure is to discuss it in a Technical Advisory Group special interest group organized by AIAA. If it is decided that international (vs. domestic) adoption is beneficial, then the U.S. community floats that proposal to the appropriate working group in either ISO TC20/SC14 or CCSDS. The Air Force exercised that process in 2010 when the United States Strategic Command (USSTRATCOM) proposed a new standard for the Conjunction Assessment Message. As a major capability for avoidance of spacecraft collisions, it was clearly beneficial as an international standard. So it quickly went to CCSDS and was published as a CCSDS standard in 2013 (and as an ISO standard in 2014). That process informs us on the scope and processes of those standards bodies, and what types of standards are best provided by each (Figure 1). And the USSTRATCOM use case validates that the defense community can easily participate in and use the process for civil space standards.

"By being an active participant in the SDOs that are developing standards your mission needs, not only will your mission have awareness of the schedule for the emerging standard that you hope to use in your project, you will also have greater confidence that the final standard will have the features and characteristics you need."

The SDO processes can also inform us of which body is most appropriate for mission/project teams to participate in, when seeking to encourage the development of a new standard in any given domain, so that it will have buy-in from the civil space agencies and commercial entities. Figure 2 shows the two international SDOs at the level of technical areas and working groups, and the relation to the mission architecture (in the case of CCSDS) and to program processes (in the case of ISO TC20/SC14).

Figure 2. The Breadth and Scope of the Two International Space SDOs



Source: Space Infrastructure Foundation, 2016; from Standards and Architecture class presentation.

The two main activities for programs and missions when addressing standards are (1) the ***adoption*** of standards that are already complete and published and (2) participation in the ***development*** of new standards, to fill a gap in the needs for future missions.

Adoption of Published Standards

When looking at the field of published standards, project managers and engineers will need to navigate the categories of standards and understand quickly what kind of document they are looking at. Each of the SDOs has some different nomenclature for their documents and products; it is important to know what kind of document you have before you decide to implement or place it on a contract. Table 1 has some guidance on that.

Table 1. Space SDOs' Document Nomenclature and Characteristics

Type of document	CCSDS	AIAA	ISO TC20/SC14
Normative and testable	Recommended standards (Blue books)	Standards	Standards
Normative but not testable	Recommended practices (Magenta books)	Standards and recommended practices	Standards
Informative (not normative)	Informational reports (Green books)	Guides	Guides and technical reports
Other types	Draft standards/ practices (Red books) and experimental specs (Orange books)	Special reports	Committee drafts, technical specifications, publically available specs, and international workshop agreements

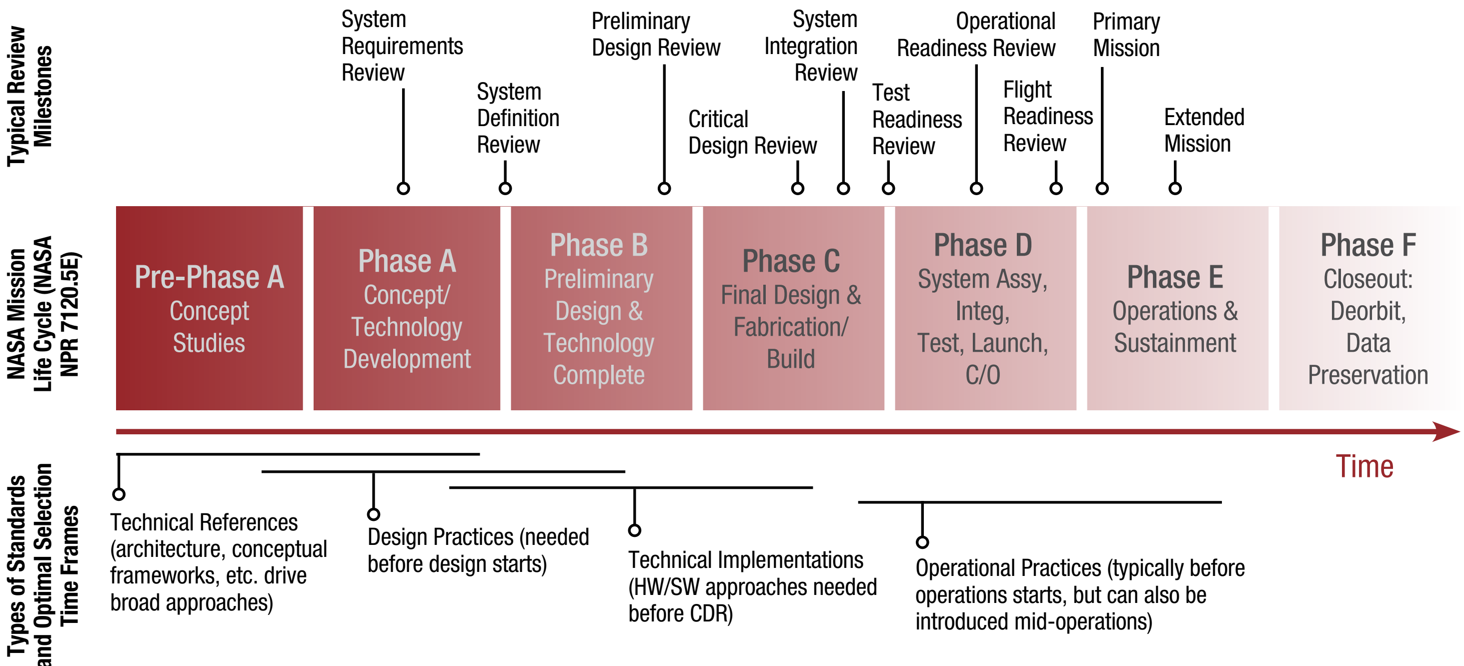
Source: Space Infrastructure Foundation, 2016; from Standards and Architecture class presentation.

The most important characteristic is, of course, whether the document is normative. Normative basically implies "shall" statements that can become verifiable requirements. Note that CCSDS further discriminates between merely normative and normative-and-testable. The CCSDS philosophy is that project managers should be able to easily tell which document is an implementable specification that can be verified by testing (CCSDS recommended standards, or "Blue books") and which ones may be normative, but not per se interoperably implementable or testable (CCSDS recommended practices or "Magenta books"). The latter may include, for example, normative reference architectures that can be verified by analysis, but not by testing. So it's clear when a program manager can place a CCSDS Blue book on a contract with confidence that the specification will be testable.

However, even though one may choose to use a normative, implementable, testable standard, that doesn't relieve the project of the need to perform due diligence with systems engineering. Even those specifications will often include options as part of the specification. All options may be implementable and testable, but the project still needs to down-select an option. This is often the unfortunate result of the standards body not being able to come to consensus on a parameter. Where interoperability between systems is at risk, the interoperating organizations will need to have agreement on that optional feature, and it will have to be documented in a "tailoring" specification of some kind, a contract or interface control document, or other.

In terms of when standardization decisions must be made, it's not necessarily the case they'll all be made at the beginning of the project. Some broadly applicable standards, technical references such as reference architectures and digital preservation, need to be made early in the mission life cycle. Standards for operational practices, however, can be made very late in the life cycle, and even adopted in the middle of the operations phase, during an ops concept revamp. Figure 3 illustrates the optimal selection time frames for the major categories of standards. This is mapped to the National Aeronautics and Space Administration (NASA) life cycle that most civil space agencies use, but the phase titles will inform one of the equivalent phases and milestones in the life cycle of defense acquisitions.

Figure 3. Mapping of Standards Selection Time Frames to Mission/Project Phases



Source: Space Infrastructure Foundation, 2016; from Standards and Architecture class presentation.

All of the major SDOs have online resources to access their published standards. Following are links to the lists of published standards for the "big three" space SDOs:

- AIAA: http://arc.aiaa.org/action/showPublications?pubType=standards
- ISO TC20/SC14: http://www.iso.org/iso/home/store/catalogue_tc/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=46614
- CCSDS: https://public.ccsds.org/Publications/AllPubs.aspx.

Most of those normative CCSDS standards are also available in ISO format (ISO TC20/SC13).

Adoption of Standards Still in Development

Most missions will choose to adopt only standards that are already approved and published. However, to take advantage of the latest technology, advanced missions may eye standards that are currently in development and monitor the SDO to see if a particularly interesting technology standard will be completed in time for the mission to use. In the case of VCS, this can be a risky approach, because the voluntary nature of support to SDOs can result in schedule slips when an SDO participant's management changes priorities. However, in terms of payoff, the mission can benefit greatly by being an early adopter of an advanced technology that comes with the added benefit of standardized interoperability with other organizations.

Most SDOs do not have detailed projected schedules for their development efforts made public, but CCSDS does in a way that helps adopting missions plan their projects. From CWE.CCSDS.org, click on Management Framework and View Existing Projects. You can select individual standards efforts and view the detailed schedule for completion, and map it to your mission's need date for that standard.

Of course, the best way to manage risk in this situation is to have your mission's developers actually participate in the development of the standard and to be aware of any issues that might slip the schedule.

The Case for Participation in Standards Development

By being an active participant in the SDOs that are developing standards that your mission needs, not only will your mission have awareness of the schedule for the emerging standard that you hope to use in your project, you will also have greater confidence that the final standard will have the features and characteristics that your mission or project needs.

The standards of the future are deeply linked to off-the-shelf commercial capabilities as well as interoperability capabilities of the future. If you have capabilities in mind for future missions, you should be participating in these SDOs. If your programs or projects are directed to use off-the-shelf capabilities, then what these organizations are developing will be your tool sets for your future missions.

Another cost-effective argument for participation: When these teams are working, for example, a technical problem at an interface, it is likely a problem that your missions will have to solve anyway. Working it in these SDOs, you have many eyes on the problem that are funded by someone else's budget. Granted, it will probably take longer to reach consensus in a larger group. But the solutions found will have reduced risk and broader consideration of all possible issues and outcomes when worked in the diverse group of these SDOs.

The USSTRATCOM case mentioned earlier in this article is a great example. It was an obvious case where international interoperability was needed. That success illustrates that full participation of defense organizations is usually not a problem for these SDOs. Note that before a defense organization participates, advance coordination with the SDO's management is always a good idea. That usually should begin with the lead U.S. participants and secretariats in that organization: NASA for CCSDS, AIAA for the others. Another factor in sending participants to these meetings is that (depending on the task) the SDOs are usually looking for in-depth technical experts to help them with engineering tasks. Contributing organizations should make certain that they are contributing the right technical skills with cooperative mindsets, to better garner acceptance in the group.

Let's consider one more factor that should drive defense organizations to working with the civil space agencies' standardization efforts: the contingency scenario. If a mission is in trouble and needs unplanned last-minute support from a civil agency's assets, the rapid configuration of connectivity with the civil assets is only achievable if the mission has previously adopted the necessary standards. In the civil space agency world there are a few examples of this scenario: in 1995, NASA's Deep

Space Network (DSN) rescue of the United Kingdom's STRV vehicle; in 2008, NASA's DSN rescue of ESA's XMM-Newton (Figure 4) mission.

Figure 4. ESA's XMM-Newton

And there is a counter-scenario: NASA's and ESA's 2011 attempted rescue of the Russian Space Agency's Phobos-Grunt mission failed in part because the spacecraft did not accurately comply with the communications standards. So there are plenty of reasons for ***any*** spaceflight organization to participate in these SDOs that are working in the civil and commercial space standards arena.

Conclusions

So with an understanding of the civil space standards landscape, and the exciting technology areas that are developing in that environment, defense organizations should be well postured to make wise decisions on the adoption of standards and strategic choices on where to participate in the development of those standards.

OTHER RESOURCES

The non-profit Space Infrastructure Foundation provides a Standards and Architecture workshop that expands on much of the material in this article. The class is held at various space industry conferences, or it can be arranged at any location.

About the Author

Mike Kearney is a volunteer educator with the Space Infrastructure Foundation, the basis for his contribution to this publication. Based in Huntsville, AL, he is also an employee of the Aerospace Corporation and a consultant with Seabrook Solutions, LLC. He retired from NASA in 2015 after a 34-year career, primarily in ground systems development and operations. During Mr. Kearney's last 8 years with NASA, he served as chairman and general secretary of the international CCSDS committee and secretary of ISO's Technical Committee 20 Subcommittee 13.

SC14: International Space Standards

By Fred Slane

In the early 1990s, leadership in international space standards extended into the International Organization for Standardization (ISO) with the creation of a committee for space systems and operations. The Jet Propulsion Lab's Macgregor Reid—together with U.S. space industry giants such as Boeing and Hughes, Arianne Espace (France), Thales-Alenia (Italy), British Aerospace (UK; now part of Astrium), DLR (Germany), Roscosmos (Russian Federation), and others—chartered the Subcommittee for Space Systems and Operations (SC14) under the Technical Committee for Air and Space Systems (TC20) in ISO (referred to as ISO TC20/SC14 here).

Organization of the Work Program into Working Groups

The work program was originally organized into five working groups (WGs), with distributed chairs for the groups (WG1–Engineering, Japan; WG2–Interfaces, Integration and Test, U.S.; WG3–Ground Support and Operations, Germany; WG4–Space Environments, Russia; and WG5–Program Management, U.K.). All participating countries shared leadership at the subcommittee level and administration of the work program.

In the early 2000s, materials and processes became enough of a burden to the Engineering Working Group to be split off into WG6–Materials and Processes, France. A few years later, orbital debris work was separated from the Ground Support and Operations Working Group and WG7–Orbital Debris, U.K., was created. Soon Human Spaceflight (added to SC14 work under Russian leadership in 2007) will probably force the creation of a WG8.

A singular message here is that even with U.S. leadership in the fore, the evolution of voluntary consensus standards in the international environment is highly affected by different thinking, different culture, and different objectives from other countries. We ignore this message at our peril.

SC14 Strategic Vision

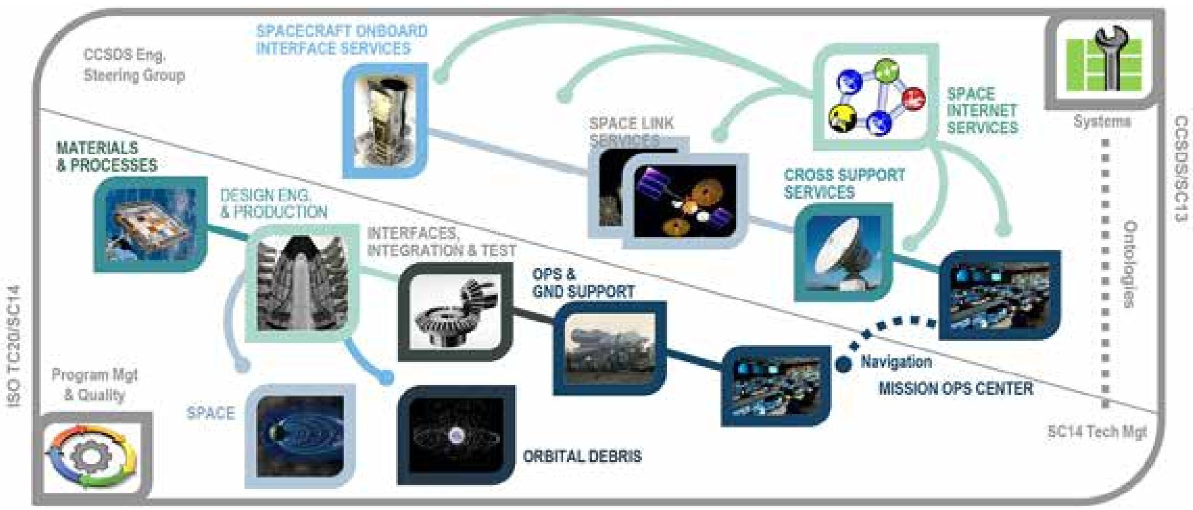
In 2008, work began on a strategic vision for SC14 at a side meeting with U.S. and U.K. members on Florida's Space Coast. Based on the published national objectives of all participating countries in SC14 (e.g., the U.S. National Standards Strategy), an implementation plan was created over about 5 years and finally was presented to all in Brazil.

Correspondence with Others

With a certain degree of understanding of strategy and organization inside SC14, it became clear that connection and harmonization with standards development organization (SDO) activity outside SC14 was desirable and achievable. The concept of "correspondence" becomes valuable here. Certain activities in SC14 "correspond" to activities in the Consultative Committee for Space Data Systems (CCSDS). Or similar degrees of activity may correspond between the two SDOs (e.g., ground operations and mission control may correspond to some degree). Sorting this out will require time, cultural awareness, technical savvy, and perseverance. Awareness of the ultimate objective of a cohesive, complete set of standards for the space industry is a very large concept for some actors.

Working with CCSDS, SC14 is considering interaction between the two groups as graphically depicted in Figure 1.

Figure 1. Depiction of Interaction between CCSDS and SC14



OTHER RESOURCES

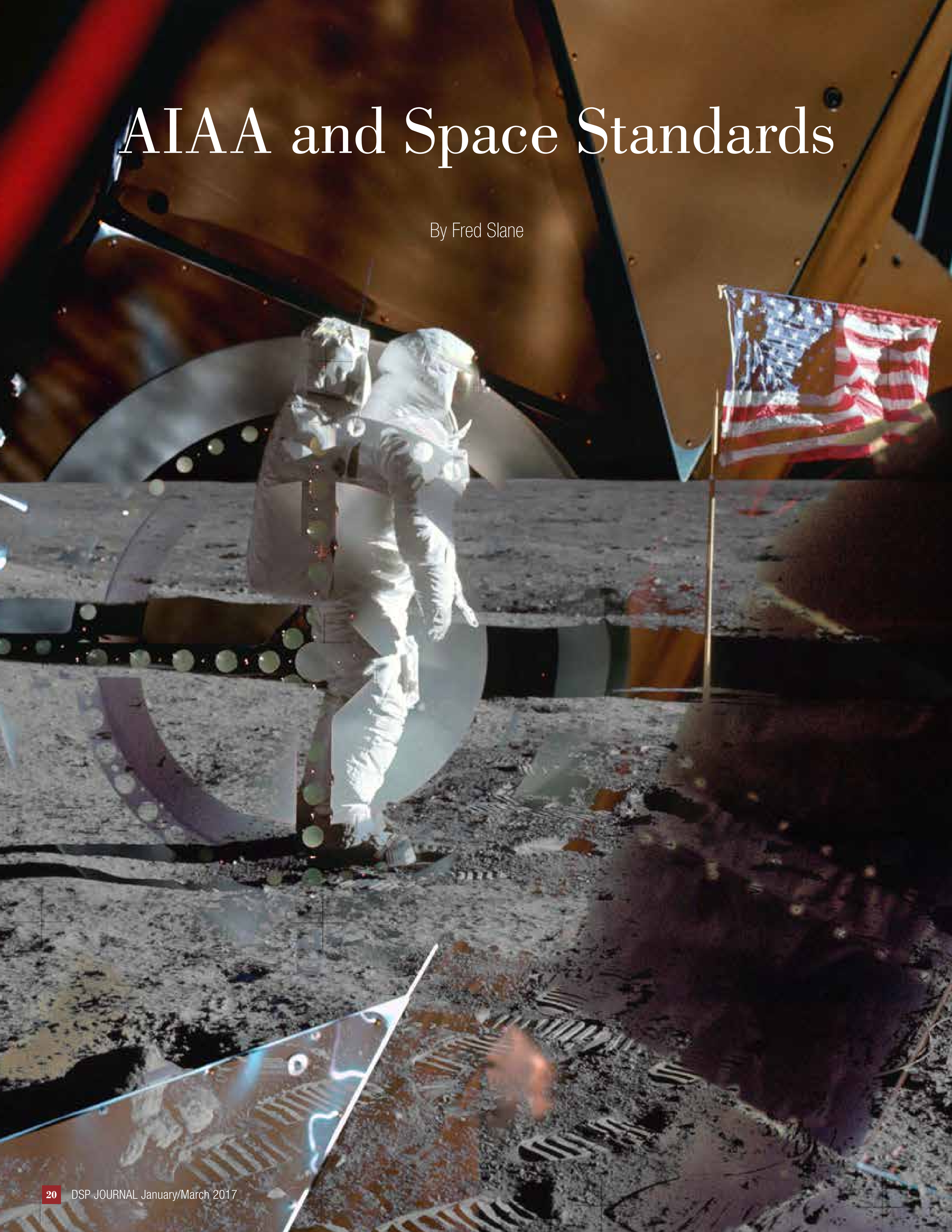
The non-profit Space Infrastructure Foundation provides a Standards and Architecture class that expands on much of the material in this article. The class is held at various space industry conferences, or it can be arranged at any location.

About the Author

Fred Slane is a founder and executive director of the Space Infrastructure Foundation, a 501(c)(3) non-profit organization. Working almost entirely in space systems for over 30 years, he retired from the U.S. Air Force in 2001 after a 20-year career and completed another 8 years in the Air Force Reserve. Serving with the AIAA Standards Executive Council and ISO’s Technical Committee 20 Subcommittee 14 since 1999, Mr. Slane is the current chair of the TC20/SC14 U.S. Technical Advisory Group and is based in Colorado Springs, CO.

AIAA and Space Standards

By Fred Slane



As the space industry approaches the 60th anniversary of spaceflight, a reflection on the role of open standards is an appropriate measure of the maturity of the industry, its actors, and markets. Generally, the role of open standards is described by the American National Standards Institute (ANSI; https://standardsboostbusiness.org). The advent of a strong international, commercial space market is an impetus for the U.S. defense and civil sectors to leverage open space standards as a best practice.

The American Institute for Aeronautics and Astronautics (AIAA) has been producing space standards since 1990, with the publication of ANSI/AIAA G-003-1990, “Guide to Reference and Standards Atmosheric Models.” Under the administrative control of the AIAA Standards Executive Council (SEC), committees on standards are established for the specific purpose of writing one or more designated standards. Unlike most other AIAA bodies, membership in standards committees is not restricted to AIAA members only but is open to any qualified subject matter experts (SMEs). This is necessary for AIAA standards to qualify as “open” standards.

In the late 1990s, the AIAA, working with the National Aeronautics and Space Administration (NASA), the Department of Defense (DoD), and the major space companies, attempted to provide a general guide to open space standards, the Collection of Preferred Space Related Standards (CPSRS). Standard topic areas catalogued more than 2,000 space-related documents into 10 topic areas: Documentation and Configuration Management, Program Management; Systems Engineering and Integration, Aerospace Environments, Celestial Mechanics, Mass Properties; Computer Systems, Software, Networking; Human Rating, Factors, and Health; Electrical Systems, Electronics, Avionics/Control Systems, Optics; Structures/Mechanical Systems, Fluid, Thermal, Propulsion, Aerodynamics; Materials and Processes, Parts; System Test, Analysis, Modeling, Evaluation; Safety, Quality, Reliability, Maintainability; and Operations, Command, Control, Telemetry/Data Systems, Communications. After about 2 years of work, this effort was abandoned when DoD and Hughes withdrew support following changes in International Traffic in Arms Regulations implementation procedures.

Past Production of Standards

A complete view of AIAA standards is online (http://arc.aiaa.org/page/standards). The following is a limited sample:

- Standard Atmosphere, including a 2016 update of the original 1990 AIAA G-003 document.
- Pressure Vessels, with project leadership from the Aerospace Corporation. These standards were migrated to international standards in the International Organization for Standardization (ISO) through the Subcommittee for Space Systems and Operations (SC14).
- Space Plug-and-Play Architecture, sponsored by the Air Force Research Laboratory in Albuquerque. Standards in this set on ontology and electronic data sheets were strategically migrated to CCSDS in the SOIS group.

- Mission Assurance, a set of 39 standards in three categories: management, engineering, and testing. Under the label of Safety, Dependability, and Produce Assurance, the principles of the AIAA Mission Assurance standards are now present in international standards in SC14.

Another significant contribution the AIAA has made to standards development is administrative support to the international space standards committees. The largest international standards organization is the ISO, and the U.S. member body to ISO is the American National Standards Institute. ANSI has designated the AIAA as administrative lead for the space standards (as related to ISO). Historically, the AIAA has been the only place in the United States where a comprehensive view of voluntary consensus standards is possible.

Working to Establish a Better Forward Vision

In the 2010 time frame, about a decade after the demise of the CPSRS effort, AIAA leadership on the SEC again looked at approaches for advancement of open standards development. Looking primarily inward with a view to both aviation and space, efforts were made for the following:

- **To increase the engagement of the AIAA technical committees (TCs) in standards development**. While there were existing pockets of standards work in the TC community, an effort was made to expand the role of the TCs to directly sponsor new standards development activities and to foster closer technical ties with existing committees on standards. This was seen as a way to bring not only fresh ideas to the standards efforts, but also more resources and expertise as the TCs enjoy both a larger membership pool and greater support from the institute.
- **To establish domains for standards development rather than simply waiting for standard topics to be suggested in the hitherto rather haphazard manner**. The establishment of domains was intended to target standards development strategically.

Results of That Engagement and Other Things

In the past 2 or 3 years, the SEC strategic leadership has shown promising results, including the following examples:

- ANSI/AIAA S-119-2011(2016), "Flight Dynamics Model Exchange Standard." This effort was sponsored by the Guidance, Navigation, and Control Technical Committee. This standard deals with aviation systems and is one of the first standards produced by a committee on standards spawned from a technical committee.
- AIAA S-117A-2016, "Space Systems Verification Program and Management Process." The committee on standards membership for this effort is from the Systems Engineering Technical Committee. This standard provides a broader definition of space systems verification methods than the limited test methods employed for conventional spacecraft.

- The International Standards Advisory Board. This was established to develop and recommend to the AIAA Board of Directors related policies and procedures and to provide oversight of the administration of international standards secretariats and ISO U.S. technical advisory groups assigned by the American National Standards Institute to the institute.

Almost predictably, foresight of the opportunities for a standards development organization (SDO) in the space industry has not been unique to the AIAA. The Aerospace Industries Association has assumed support for the Consultative Committee for Space Data Systems (CCSDS) from the AIAA (the AIAA retains support for the U.S. advisory committee here). The American Society for Testing and Materials acts as the primary SDO supporting the Federal Aviation Administration and U.S. industry in their collaborative efforts in the United States for commercial manned spaceflight. For space systems standards to advance in some coherent fashion, it has become necessary for these SDOs to establish some means of strategic collaboration.

AIAA Constitutional Change Impacts (2016–17)

AIAA Standards Executive Council restructuring of the AIAA standards work has been in discussion for several years. Institute membership approval of constitutional changes in 2016 has created a needed degree of flexibility and strategic thinking to the institute governance model that should also positively affect AIAA standards, including open standards efforts. Undertaking a more aggressive leadership role is one objective of the SEC within the institute and may extend to related NASA, CCSDS, and SC14 standards work. The use of domains (consistent with CPSRS and 2010 visions) may be extended.

Conclusions

What we see looking forward for the AIAA standards program, based on the history and position today of AIAA standards work, are engagement and interaction. SMEs need to be engaged from within the institute membership and outside. Effective interaction and planning with other U.S.-based SDOs is necessary for U.S. industry to prevail in the global space marketplace.

OTHER RESOURCES

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About the Author

Fred Slane is a founder and executive director of the Space Infrastructure Foundation, a 501(c)(3) non-profit organization. Working almost entirely in space systems for over 30 years, he retired from the U.S. Air Force in 2001 after a 20-year career and completed another 8 years in the Air Force Reserve. Serving with the AIAA Standards Executive Council and ISO's Technical Committee 20 Subcommittee 14 since 1999, Mr. Slane is the current chair of the TC20/SC14 U.S. Technical Advisory Group and is based in Colorado Springs, CO.

CCSDS: Advancing with Technology

By Mike Kearney

Considering the origins of the Consultative Committee for Space Data Systems (CCSDS), it should be no surprise that the committee's standards are often linked to technology advancements. CCSDS grew out of late 1970s work by the National Aeronautics and Space Administration (NASA) Jet Propulsion Labs' Adrian Hooke and his colleagues, pioneering packet telemetry approaches.

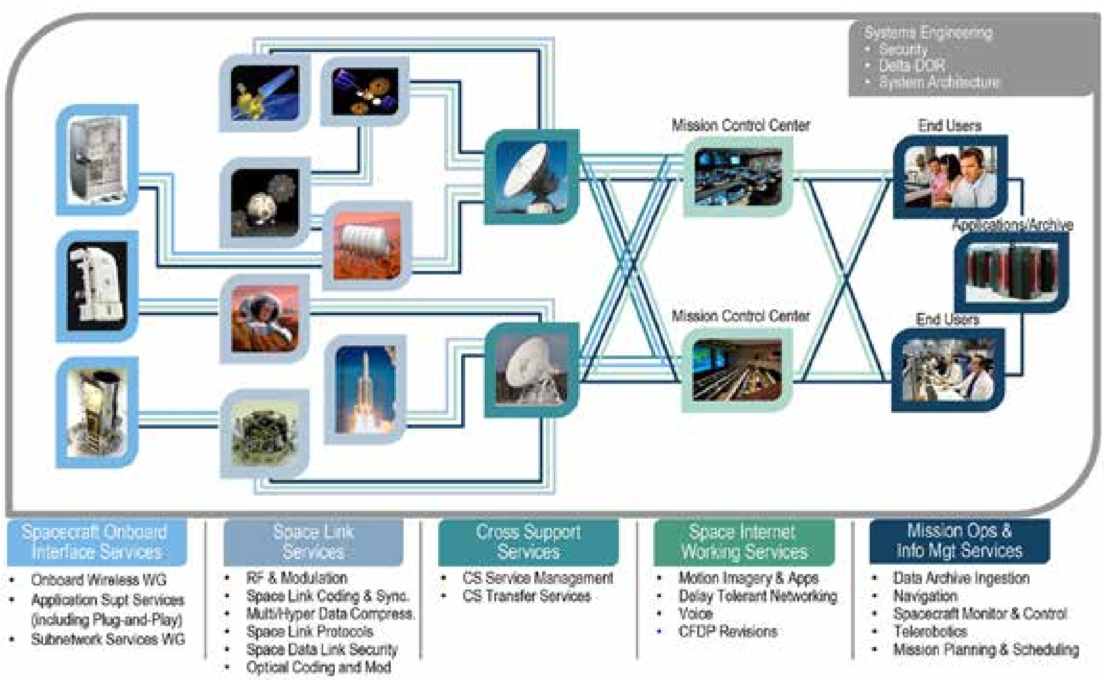
In the early 1980s, Mr. Hooke used his contacts in the European Space Agency (ESA) to organize a NASA-ESA bilateral activity to use the technology for international space cooperation. This quickly grew into the fully international CCSDS. As Mr. Hooke provided leadership of the CCSDS over the next three decades, CCSDS addressed such breaking communications technologies as advanced coding and sysncronization methods, data compression methods, space internet-working, and optical communications. While the organization does not per se have a charter to develop advanced technologies, it quickly recognizes when emerging technologies are important to international interoperability, and it advances them directly toward standardization.

The civil space standards overview in this issue provides the overall landscape that CCSDS fits into, and the business case for participating in standards development. This article provides specifics for CCSDS and some sound bytes on the development work where CCSDS is standardizing important technologies in the communications and data domain.

CCSDS has two roles in the standards domain: besides publishing its standards under CCSDS cover, most of its normative standards are also forwarded to the International Standards Organization (ISO) for approval where the CCSDS organization is recognized as ISO TC20/SC13 (the sister organization to SC14). This dual-certification (CCSDS and ISO) improves acceptance in the international arena. SC13 standards are the same content with an ISO cover, but while CCSDS distributes its standards for free, ISO standards must be purchased for a fee.

As of this writing, CCSDS has 160 published and currently active documents, and it is currently working on 86 approved document projects. These projects span virtually all technical areas associated with any spaceflight mission, as illustrated in the CCSDS architecture overview in Figure 1.

Figure 1. The CCSDS End-to-End Architecture



Note: Technical areas are color coded, and the working group titles are listed for each area.
Source: CCSDS, used with permission.

A Sampling of Exciting Ongoing Development Efforts

Some representative topics are being developed in CCSDS that should be of interest to all organizations with a future stake in spaceflight missions. If you are in one of those organizations and have a technical background in that area, consider contacting the CCSDS working group chair in these teams (see links) and signing up to participate. Participation can be electronic (e-mail discussions and document reviews) or in person at CCSDS meetings. Of course, in this international civil space arena, all the responsibilities for export and International Traffic in Arms Regulations compliance apply to the participants.

In the Space Link Protocols Working Group, a new space link protocol is being developed to eventually supplant the long-standing CCSDS TM/TC/AOS (Telemetry, Telecommand, and Advanced Orbital Systems) protocols. It is the Unified Space Link Protocol. The Informative (Green) book is due in 2017 and the Normative (Blue) book is due in 2018. This is a very foundational and important effort for future spacecraft command and control.

In the Delay Tolerant Networking (DTN) Working Group, internet protocols are being adapted for the demands of spaceflight, including disruption and delay tolerance. DTN provides a dramatic improvement in bandwidth and latency for disrupted environments. While the solution to "Delay" issues draws the attention of deep space missions, DTN also greatly improves LEO mission resilience and efficiency by automating the recovery from communications gaps. This effort is in response to agreement by 14 civil space agencies in the Interagency Operations Advisory Group that envision a "Solar System Internet" for future space communications architectures. NASA has fully engaged this initiative by implementing DTN on the International Space Station; this is already showing real on-orbit benefits. Currently, the working group has completed the basic protocols and network management and is now working on routing and security for the DTN environment. This is done in close coordination with the Internet Engineering Task Force to maintain compatibility with the terrestrial Internet. DTN capabilities will have a dramatic impact on missions in the long-range future.

The Space Data Link Security Working Group is standardizing security features at the link layer for CCSDS protocols. The Informative (Green) book is due in 2017 and the Normative (Blue) book is due in 2018.

The Spacecraft Onboard Interface Services area's Application Support Services Working Group has developed innovative standards for onboard electronic data sheets to streamline configuration and control of onboard spacecraft data systems. This is an XML-based method to fully describe access protocols and virtualization of common onboard sensor/actuator devices and onboard software components, including the standardization of classes. Both the Informative (Green) and the Normative Recommended Practice (Magenta) books are due in 2017, while the Normative Recommended Standard (Blue) book is due in 2018.

“CCSDS has 160 published and currently active documents, and it is currently working on 86 approved document projects. These projects span virtually all technical areas associated with any spaceflight mission.”

The Onboard Wireless Working Group (WWG) efforts are for (1) asset tracking and management; (2) intra-vehicle communications; and (3) assembly, integration, and test (AIT) activities. Asset tracking is basically RFID-based logistics control, for example, for onboard habitats or flight support ground systems. Intra-vehicle communications supports not only WiFi-based communications for habitats and spacesuits, but also payload-to-launch-vehicle WiFi that will help reduce launch weight and improve rapid payload integration. The AIT focus is to improve launch facility ground support equipment configuration and connectivity for test scenarios. Because of efficiency improvements and rapid configuration in all these scenarios, this work has dramatic implications for both launch and on orbit systems. The WWG has completed several RFID books, and it is working on its final Normative (Blue) book for RFID; it has started work on the wireless network communications Informative (Green) book.

The Optical Communications Working Group is establishing practices and standards so missions can use the much greater bandwidth and performance by using laser-based space communications systems. Because optical communications systems are susceptible to weather interference at the ground stations, missions will need to have alternative ground station support from other agencies, hence driving the need for interoperability. There are some difficult issues with standardization choices, so this group recently resolved to issue some experimental specifications first, currently scheduled for 2019. Besides those documents on physical layer functions and coding/synchronization, they are also developing agreements on atmospheric/weather practices and processes. Figure 2 depicts NASA's Laser Communications Relay Demonstration, which will perform optical communications in the gigabit range.

Figure 2. NASA's Laser Communications Relay Demonstration

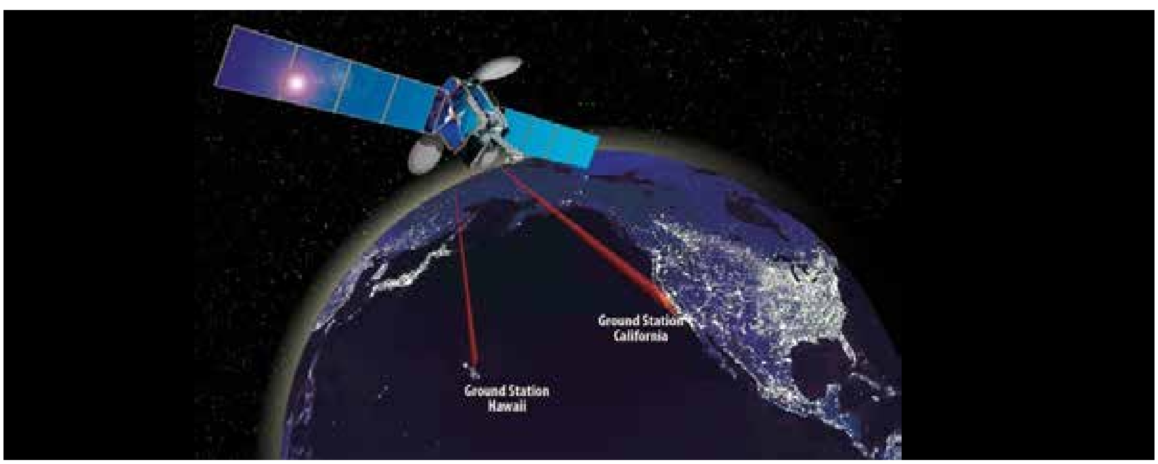


Image courtesy of NASA.

Digital preservation is an application that is often mistakenly not considered until the mission is over. It needs to start with a standard process adopted early in the development cycle. The CCSDS Data Archive Ingest (DAI) Working Group has developed the Open Archival Information System (OAIS) as a process to guide that practice, and it has been overwhelmingly adopted even in organizations outside of the space industry. The OAIS document is currently in its 5-year review and the DAI working group is soliciting comments. Moving from processes to protocols, the DAI working group has a notional plan for a future architecture for interoperable interfaces for archives, and participants with an interest in having their mission's data accessible in the truly long term are welcome to engage.

There are many other topics at work in CCSDS as well, and all 86 (as of this writing) current standards documents that are in development are described in the list of projects on the CCSDS Management Framework. Clicking on the working group name will take you to its charter, and clicking on the document name will take you to its description and schedule.

Conclusions

In the field of data and communications, CCSDS is a great resource for organizations with a stake in the future of spaceflight to identify the technologies that are on the horizon for standardization and to get involved in influencing the ways that technology can be effectively used. Standardization of technology features such as interoperable interfaces will drive industry trends and the accessibility of that technology. Your future missions will use some of these standards, and your opportunity to shape them is happening now.

OTHER RESOURCES

The CCSDS website at www.ccsds.org is your starting point for more resources like the links in this article. It includes prototype software implementations, lists of vendors for CCSDS-compliant systems, and contacts for each working group and agency. Besides a workshop course from the Space Infrastructure Foundation, there is also a training class on CCSDS protocols that is often available at the Ground Systems Architecture Workshop held in the Los Angeles area in March.

About the Author

Mike Kearney is a volunteer educator with the Space Infrastructure Foundation, the basis for his contribution to this publication. Based in Huntsville, AL, he is also an employee of the Aerospace Corporation and a consultant with Seabrook Solutions, LLC. He retired from NASA in 2015 after a 34-year career, primarily in ground systems development and operations. During Mr. Kearney's last 8 years with NASA, he served as chairman and general secretary of the international CCSDS committee and secretary of ISO's Technical Committee 20 Subcommittee 13.

Program News

Topical Information on Standardization Programs

DSPO's Stephen Lowell Retires

As of January 3, 2017, Stephen C. Lowell has officially retired with 40 years of dedicated federal service. Throughout his career, he has made significant contributions to agency-wide operations and the Department of Defense's readiness.

(From left) Greg Saunders and Steve Lowell at Mr. Lowell's retirement luncheon at the Fort Belvoir Officers' Club.

Mr. Lowell began his career as specification coordinator with the Navy, which significantly contributed to the foundation of his expert knowledge of the Defense Standardization Program. He served as the deputy director of the Defense Standardization Program Office for the last 13 years of his career.

A luncheon was held in honor of Mr. Lowell's retirement on February 8, 2017, at the Fort Belvoir Officers' Club.

Events

Upcoming Events and Information

March 14–15, 2017, Knoxville, TN

SAE 2017 Additive Manufacturing Symposium

Get the latest information on innovations, technical advances, products, applications, and market issues. Deepen your knowledge of the challenges and solutions associated with the advancement of additive manufacturing (AM) technologies and processes. Network with the diverse community working on AM and with the manufacturers that implement and use AM. Identify new applications and potential new product design opportunities, and gain an understanding about designing products for AM. For more information, go to http://www.sae.org/events/ams/.

April 25–27, 2017, Washington, DC, Area

PSMC Spring 2017 Meeting

The Parts Standardization and Management Committee (PSMC) will hold its spring 2017 meeting at LMI in Tysons, VA. Presentations and subcommittee breakout discussions will address these primary topic areas: parts management procedures, guidance, and implementation; standardization; obsolescence mitigation; counterfeit parts and risk mitigation; and parts management tools and data. If you work in a parts management related area and are interested in becoming a PSMC participant, please contact Donna McMurry at Donna.McMurry@dla.mil or 703-767-6874.

June 5–9, 2017, Denver, CO

AIAA Aviation Forum

The AIAA Aviation and Aeronautics Forum and Exposition is the only aviation event that covers the entire integrated spectrum of aviation business and technology. Twelve technical conferences and a new demand for an unmanned UAS symposium in one location make this a must-attend event in 2017! Industry, academia, and government leaders will share their perspectives on the new challenges, future opportunities, and emerging trends in the global aviation industry. Plenary sessions examine some of the most critical issues in aviation today. The Forum 360 panel discussions build on the themes and discussions of each day's opening plenary session, adding a layer of content and context that enhances the value of your forum experience. An innovative and extensive technical program provides the latest in innovative research and developments that will drive advancements in aviation. For more information, go to http://www.aiaa-aviation.org/program/.

People

People in the Standardization Community

Welcome

On February 1, 2017, **Katharine "Kathie" Morgan** began serving as president of ASTM International, one of the world's largest standards development organizations. She succeeds Jim Thomas, who served in the role for 25 years. Ms. Morgan is a 33-year veteran of ASTM International. She served as executive vice president for the past 2 years. She also previously served as vice president of Technical Committee Operations in which she led a 50-member team that supported the volunteer work of ASTM International's 30,000 members worldwide.

Farewell

Joseph Delorie's 3-year tour as a rehired annuitant with the Defense Standardization Program Office ended on February 6, 2017. For more than 20 years of his career, he served as a senior analyst at DSPO and developed DSP policy and procedures in a number of areas, particularly with a focus on developing and maintaining automated tools that support the mission of DSP. He also dedicated a major amount of his time to the development and simplification of ASSIST and its related tools. Mr. Delorie officially retired on January 2, 2014, with 41 years of federal service.

Upcoming Issues
Call for Contributors

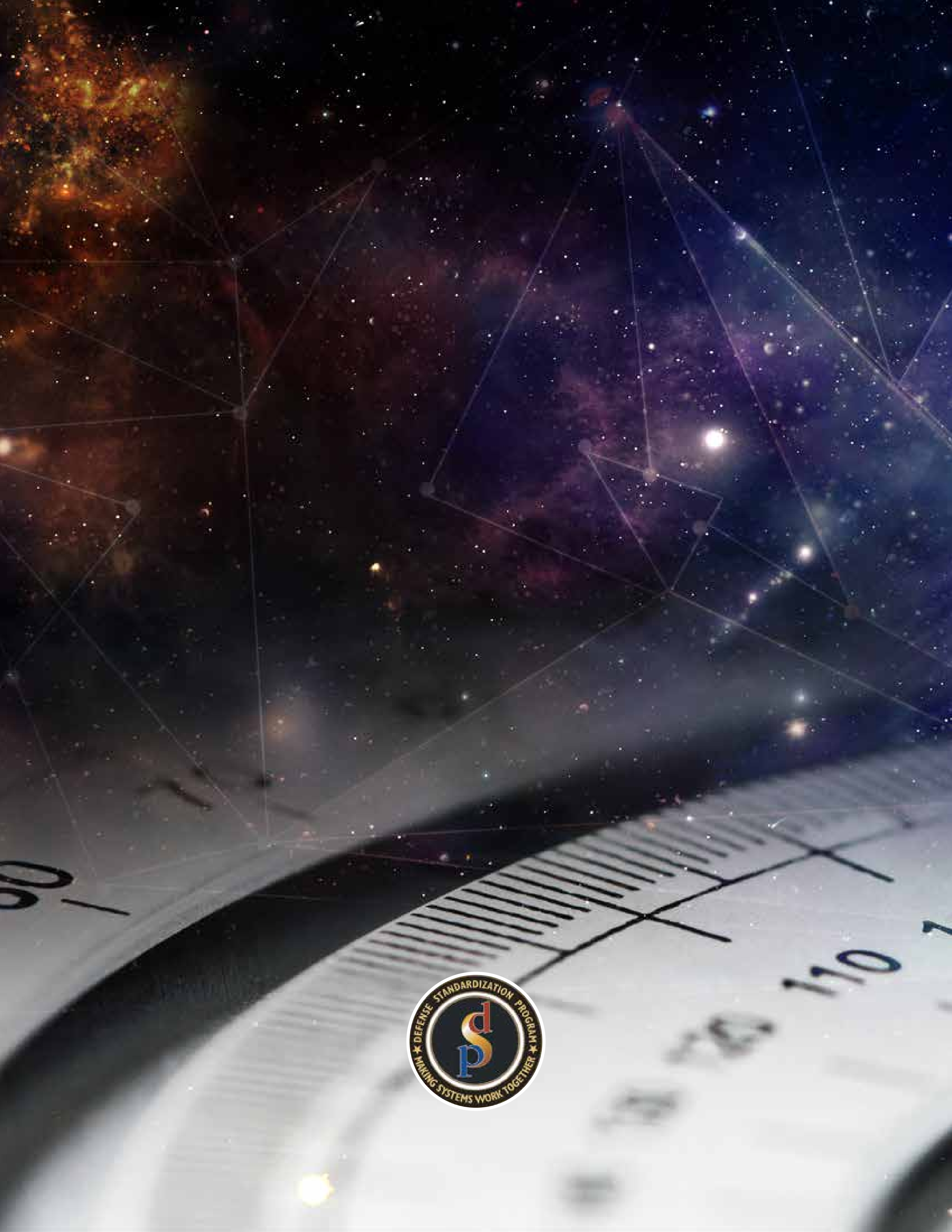
We are always seeking articles that relate to our themes or other standardization topics. We invite anyone involved in standardization—government employees, military personnel, industry leaders, members of academia, and others—to submit proposed articles for use in the *DSP Journal*. Please let us know if you would like to contribute.

Following are our themes for upcoming issues:

Issue	Theme
April/June 2017	Standardization Stars
July/September 2017	Warfighter Support

If you have ideas for articles or want more information, contact Nicole Dumm, Editor, *DSP Journal*, Defense Standardization Program Office, 8725 John J. Kingman Road, STOP 5100, Fort Belvoir, VA 22060-6220 or e-mail DSP-Editor@dla.mil.

Our office reserves the right to modify or reject any submission as deemed appropriate. We will be glad to send out our editorial guidelines and work with any author to get his or her material shaped into an article.


DEFENSE STANDARDIZATION PROGRAM
MAKING SYSTEMS WORK TOGETHER