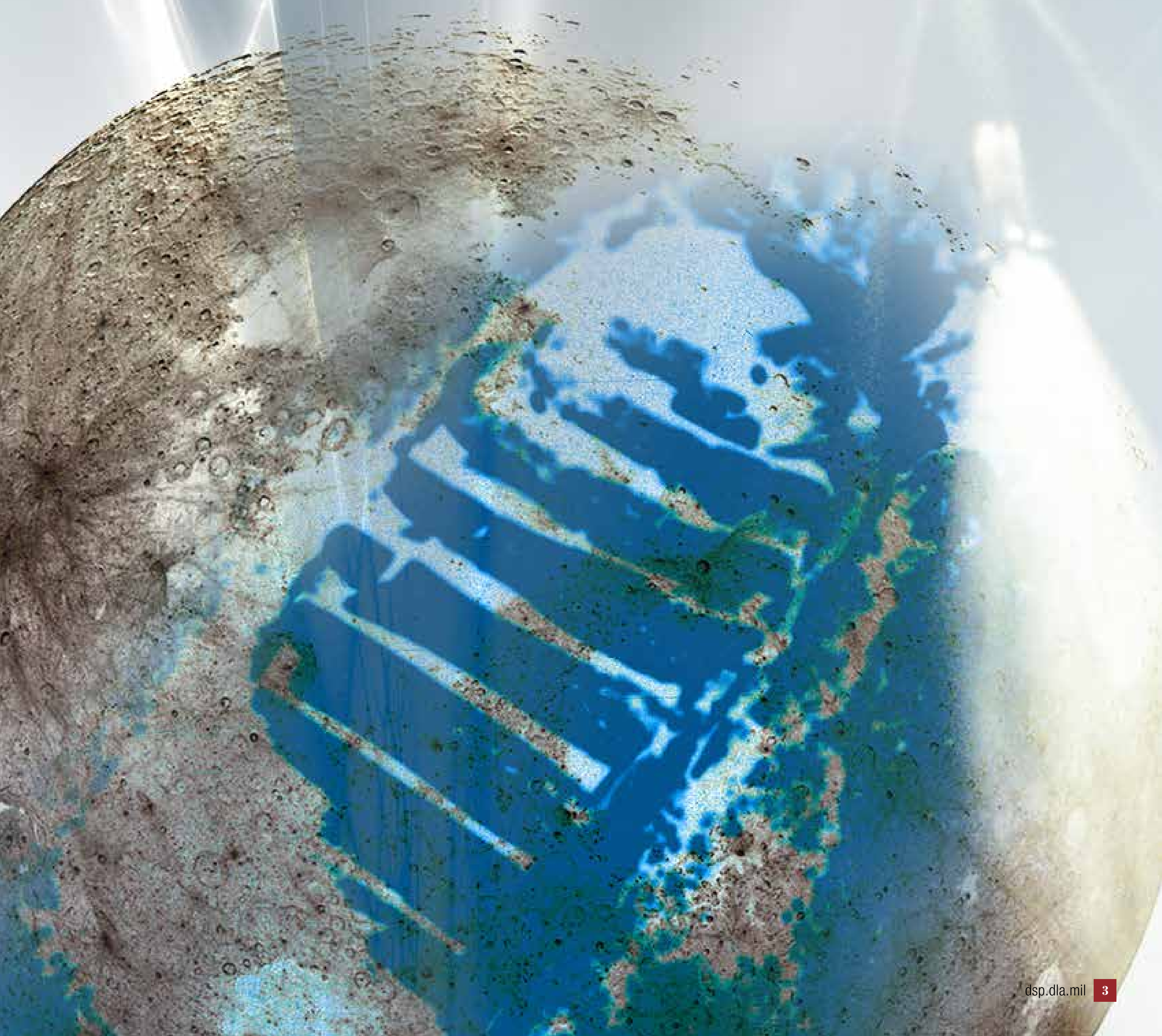
Standards in Space throughout NASA's History

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.


Image courtesy of NASA.

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 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.