AEROSPACE

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GETTING IT RIGHT

COLLABORATING FOR MISSION SUCCESS

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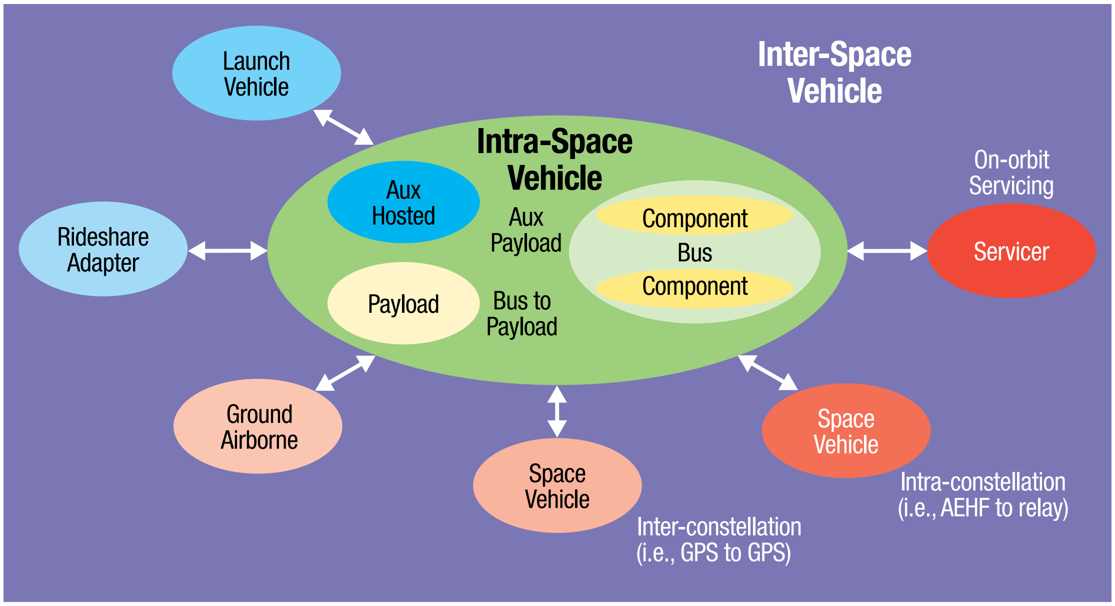
# SPACE VEHICLE INTERFACE SPECIFICATIONS




By JEFF B. JURANEK and
THANH T. TRAN
The Aerospace Corporation

This is a critical moment for the United States' involvement in space. Potential adversaries are developing and fielding antisatellite weapons and more effective military satellites. Meanwhile, the commercial market offers promising new possibilities for space, such as cheaper launch, large constellations, and miniaturization. But U.S. national security in modern times has traditionally relied on space systems developed over long timelines to provide extraordinary capabilities and avoid losing satellites to a

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# SPACE SYSTEM HIGH VOLUME PRODUCTION

By DAVE S. ECCLES,
SUSAN E. HASTINGS, and
JEFF B. JURANEK
The Aerospace Corporation

The space business is undergoing a disruptive transformation. Capital has been poured into space enterprises, supporting both satellite and launch vehicle production in larger numbers than previously seen. A few companies have constructed manufacturing facilities to produce satellites at faster rates—potentially producing several per day. In comparison with other industries, satellite production could benefit from methodologies employed for mass production of other complex systems (e.g., airplanes, automobiles) that must be reliable. As satellite quantities are scaled up, new methods and approaches will define high-volume production of space systems.

Designing and building satellites have historically been a low-volume endeavor characterized by craft production methods. Each satellite is essentially hand-built and the construction takes years to complete. Keeping manufacturing processes consistent is a challenge when constructing small numbers of hand-built satellites. Even so-called "clone" satellites, although similar, have an exclusive pedigree reflecting workmanship variations, engineering changes from lessons learned, and part changes due to obsolescence.

One historical example of a high-volume, large, satellite constellation was Iridium, for which 98 communications satellites were built in the 1990s and, more

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**COMPARISON BETWEEN SATELLITE PRODUCTION METHODS**

| Traditional Satellites | Large Constellations |
|---|---|
| Low production volumes (≤100) | High production volumes (>100 to 1000s) |
| Built-in multiple locations using project or batch processing | Built in one location using flow processing |
| Low process yields due to high rework/retest | High process yields due to virtually no rework/retest |
| Craft methods—resulting in lots of process waste | Lean methods—with little process waste |
| Production line stops often—typically waiting on part deliveries or anomaly resolution | Production line only stops in rare instances—no late hardware deliveries |
| Satellite sites for large amounts of time before a value-added operation occurs | Satellite moves steadily, and value-added operations occur consistently |
| First flight satellite tested using protoqualification approach | Development satellites tested using a qualification approach and highly accelerated life testing |
| Manual testing and inspection verification | Automated testing and process validation |
| Build, inspect, rework, test—troubleshoot, retest, close paperwork, ship, reverify, launch | Build, verify, ship, launch |

## IN MEMORIAM: WILLIAM (BILL) TOSNEY (1953–2020)

It is with considerable sadness that we announce the passing of William (Bill) Tosney, who retired from The Aerospace Corporation in July 2017 after a distinguished 30 years of service.

Tosney became Aerospace's first Corporate Chief Engineer in 2008, where he focused on advancing systems engineering and mission assurance throughout the national security space enterprise, particularly by working with industry and government leadership to collaboratively develop technical best practices and lessons.

During his accomplished tenure at Aerospace, Tosney received the Director's Team Award from the NRO and David Packard Excellence in Acquisition Award from the Department of Defense. In 2005, he received an Aerospace President's Award for co-leading a study on national security space satellite development practices.

Bill was also the founding Editor-in-Chief of *Getting It Right*.

*"Bill made a difference not only because of his technical savvy and achievements, but because of his understanding of people—key to getting the job done. He led by example showing his dedication by being the first in the office and often the last to leave, but insisted on life balance. He always had time, made time, for the things that mattered most to include his friends that will toast him with a smile and a beer in hand."*

—Gail Johnson-Roth, Principal Director, CCEO

# MISSION SUCCESS FROM THE GROUND UP

By VERA L. SCHEIDLINGER, MATTHEW F. MARSHALL, and J. DENISE CASTRO-BRAN
The Aerospace Corporation

Every major space asset is built, tested, launched, and controlled by one or more ground-based facilities. Satellite processing facilities, environmental test chambers, test stands, mobile launchers, ground control stations, command and control centers, and data processing centers are integral parts of the space enterprise.

While many variables can affect the success of a facility or infrastructure project, one often overlooked element is the project delivery type. The approach or method used to organize all the components needed to design and build a facility can include management of contractors, architects, and consultants; sequencing of operations; and the actual execution of design and construction.

There are decisions that can affect the cost and schedule for successful development and delivery, as well as the efficiency of operations once the facility is complete. How much collaboration exists between the team that designs the facility and the team that builds it? Who is responsible for design issues—contractors, designers, or the government agency that owns the facility? Can construction begin while final designs are ongoing? How many contract efforts must the government agency manage?

Choosing the right project delivery type allows a space program's ground assets to deliver timely, cost-effective support for the operational life. Choosing the wrong project delivery type can undermine a program's efficacy and allow an overlooked detail on the ground to ultimately affect mission success.

The three major project delivery types are: Design-Bid-Build (DBB), Design-Build (DB), and Construction Manager at Risk (CMAR).

While DBB is the most common project delivery type, some state and federal agencies are beginning to more aggressively explore the potential benefits of DB and CMAR methods depending on the nature of the project. Each one results in variable outcomes in four areas:

- Number of contracts executed by the facility owner (i.e., the government agency)
- Roles and responsibilities of each participant in the facility project
- Point at which the contractor joins the project
- Ability to conduct design and construction activities simultaneously

Mission success is dependent on the success of the total system architecture.

**REFERENCE**

Aerospace report No. OTR20200619
https://aerospace.org/paper/ground-getting-space-right-construction-project-delivery-type

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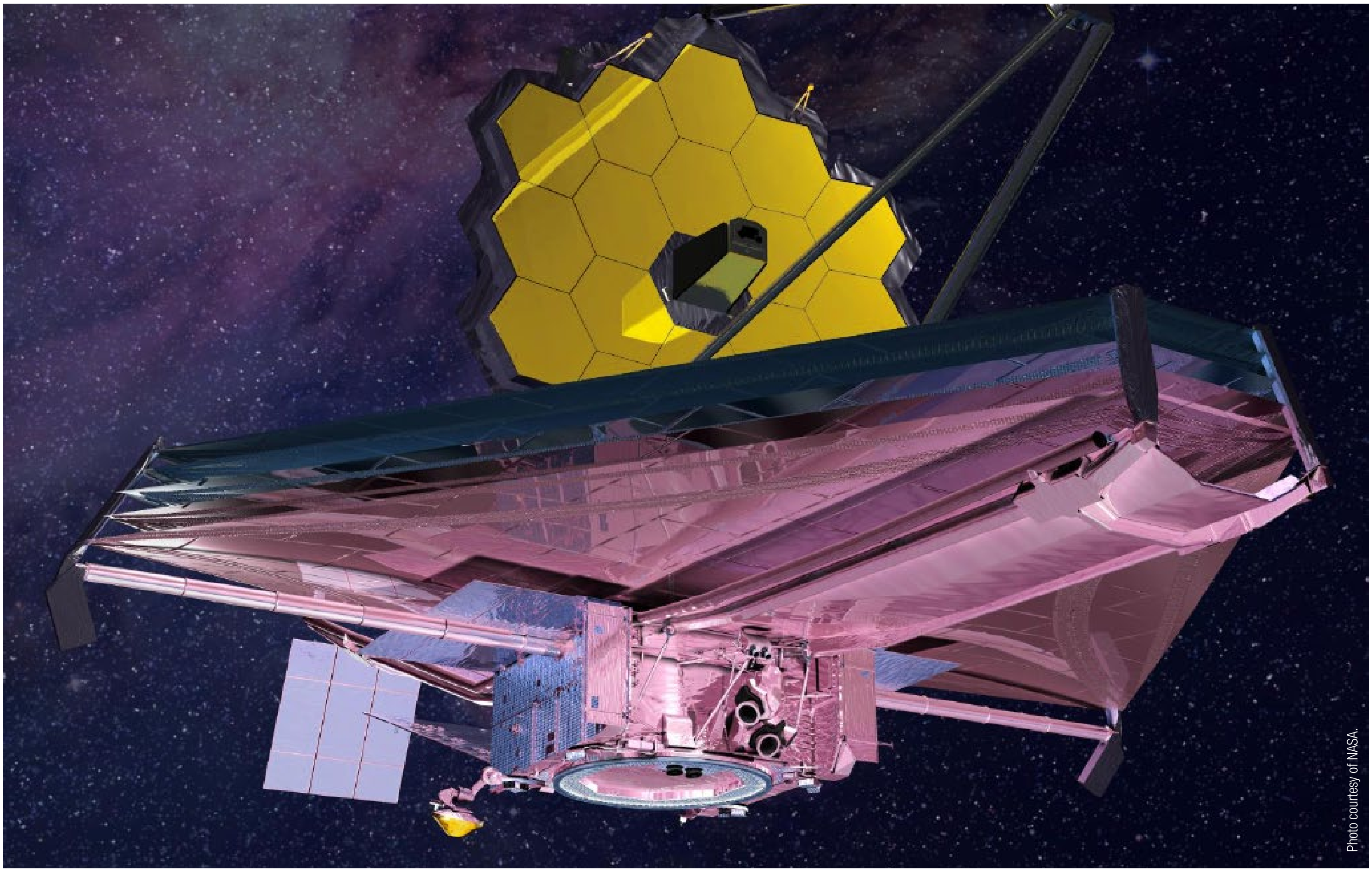
*PROJECT SUCCESS CRITERIA AND PROJECT DELIVERY TYPE*

| PROJECT DELIVERY TYPE | DESIGN-BID-BUILD | DESIGN-BUILD | CONSTRUCTION MANAGER AT RISK |
|---|---|---|---|
| Risk and control | Govt. controls design process and construction; bears risk of incomplete or inadequate design | Design-build firm assumes risk for design, construction, and design documentation | Construction manager responsible for budget and schedule, advises govt. during the design |
| Cost estimation and control | Price determined after design, open competition for bids. Risk of higher cost due to change orders | Early commitment project price allows the govt. to budget; an incomplete design can create inaccuracy, bids may include more contingency dollars | Guaranteed max. price before completion of design, govt. can fix cost before construction is risk of design/construction compensation |
| Schedule estimation and control | Sequential process results in longer schedule durations | Fast-track with parallel design and construction phases | Fast-track: design and construction phases occur in parallel |
| Collaboration | Not collaborative, leading to possible change orders | Highly collaborative between contractor and designer with fewer change orders | Highly collaborative between construction manager and design with min. change orders |




*NASA's James Webb Space Telescope has hundreds of moving mechanical assemblies.*

# DESIGN AND TEST OF MOVING MECHANICAL ASSEMBLIES

By BRIAN W. GORE and
LEON GUREVICH
The Aerospace Corporation

The newly revised AIAA S-114A-2020, *Moving Mechanical Assemblies for Space and Launch Vehicles* specifies general requirements for the design, manufacture, quality control, testing, and storage of moving mechanical assemblies (MMAs) for use on space and launch vehicles.

The standard is applicable to the mechanical or electromechanical devices that control the movement of a mechanical part of a space or launch vehicle relative to another part. The requirements apply to the overall MMA as well as to integral mechanical components and instrumentation.

MMAs are designed to meet the following requirements:

- **Performance**—satisfactory operation during and/or after exposure to (proto-) qualification or acceptance environments to include launch, on-orbit, development, and handling environments
- **Physical**—clearances, alignments, interfaces, and mechanical/assembly tolerances
- **Electrical and Electronic**—cable and wiring harnesses, electrostatic discharge, and grounding
- **Structural**—stiffness, strength, and distortions
- **Reliability**—single-point failures, failure modes and effects, service life, and maintainability

Component designs such as fasteners and their locking devices, retention and release devices, pivots and hinges, cable systems, springs, dampers, stops, latches, bearings, gears, power/signal transfer components, and electric motors all have specific requirements to be evaluated and are subject to rigorous testing programs. Parts, materials, and process requirements are also outlined to ensure performance, reliability, and strength requirements are met as well.

Today's space industry is more diverse and entrepreneurial than ever before. The AIAA industry consensus process provides a forum for commercial, civil, and national security space to create and to collectively own the developed standard that establishes engineering and technical requirements.

Application of the MMA standard requirements as appropiate provides a greater confidence that mechanical moving equipment will operate successfully in space.

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## 2020 EVENTS

**August 20–21** *Space Warfighting Industry Forum, Virtual*

**August 27** *Space Policy Show: Public-Private Partnerships in the Space Sector, Virtual*

**August 31–September 3** *Humans to Mars Summit 2020, Virtual*

**September 1** *Space Traffic Management Workshop, Virtual*

**September 3–4** *Military Space Situational Awareness 2020, London, UK, Virtual*

**September 9–11** *2nd Summit for Space Sustainability, Virtual*

**September 22** *NASA Innovative Advanced Concepts (NIAC) Symposium 2020, Virtual*

**October 6–8** *Satellite Innovation 2020, Virtual*

**October 27–28** *Optical Communications Workshop, Virtual*

**November 16–18** *ASCENDxSummit: National Security Space, Virtual*

## SPACE SYSTEM HIGH VOLUME PRODUCTION

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recently, 81 satellites for Iridium NEXT. SpaceX, Telesat, and Amazon are planned to have hundreds or even thousands of satellites. Some of these have already started production using new methods. By July 2020 SpaceX's Starlink placed approximately 600 satellites in orbit.

The production scale and capital investment change as production increases from tens to hundreds to thousands of units. Satellites have never been produced in the thousands for a single constellation—different methods and infrastructure for high-volume production (HVP) are required.

HVP is not a new idea. Automobiles have been mass produced since the 1910s and 1920s. Commercial airplanes, automobiles, and consumer electronics all use production approaches that yield insights that can be adapted for use in the manufacture of large constellations of satellites. The table on the first page highlights key differences between traditional satellites versus large constellations.

Design for production (DFP) is an approach that considers the product design, process design, and production planning for a product using a concurrent engineering or "collaborate approach." DFP basic principles include:

- **Ease of manufacturing:** Product designs and processes that meet engineering and quality requirements in the easiest way possible—that favor simplicity and standardization
- **Efficiency:** Processes that minimize time and processing steps through the reduction/elimination of waste using lean production methods
- **Economical production:** Mature designs and capable processes that allow for high repeatability and value-added processing

Design qualification for objects flown in space has always required rigorous environmental testing to stress the hardware at different test profiles for either qualification, protoqualification, or acceptance levels—which is defined in the environmental testing standard TR-RS-2014-00016. Highly accelerated life testing is an alternate and complementary test strategy that combines environmental and operational stresses to quickly identify failure modes and accelerate testing.

Once a satellite design is qualified, large constellation builders have taken the additional step of flying prototype spacecraft and assessing their on-orbit performance before finalizing their designs and scaling up production. Process verification is applied to the production system (factory, production line, etc.) to ensure it is ready to start high-rate production. In-process controls and measurements provide confidence in product manufacturing consistency.

HVP requires a mission assurance strategy that qualifies the design and the manufacturing process to ensure no learning curve from one unit to the next on the assembly line.

**REFERENCE**

Aerospace Report No. OTR-2020-00640

*For more information, contact Dave Eccles, 703.812.0673, david.s.eccles@aero.org; Susan Hastings, 571.304.3871, susan.e.hastings@aero.org; or Jeff Juranek, 310.336.3190, jeff.b.juranek@aero.org.*

## SPACE VEHICLE INTERFACE SPECIFICATIONS

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hostile environment, with little room for error.

The United States can rise to the challenge to outpace the threat with a system architecture that is both resilient and agile. As government and industry evaluate ways to satisfy this need, numerous approaches have been proposed, one of these being common interface specifications.

Over 70 current and past interface documents were surveyed and cataloged that include both government and commercial interfaces. These were characterized and evaluated against a set of criteria directly supporting outpacing the threat, focusing on resiliency and enterprise agility. The interface documents fell into two categories: intra- and inter-space vehicle.

A Quality Function Deployment (QFD) matrix was used to evaluate a subset of the interface documents using weighted acquisition criteria: nonproprietary interfaces, common data interfaces, open/modular architecture, rapid technology insertion, etc. There were two key findings from the QFD assessment:

- No all-encompassing solution existed that is relevant to the defined acquisition criteria, as the interface documents evaluated range from both general approaches to detailed requirements in one or a few focused areas
- The QFD matrix provided a valuable reference for identifying future solutions for defined needs in specific, cross-cutting interface standards

Mission success is not only dependent on meeting technical and functional requirements but also on providing a timely solution that meets potential adversarial threats.

**REFERENCE**

Aerospace Report No. TOR-2020-00935
*Space Vehicle Interface Study*

*For more information contact Jeff Juranek, 310.648.2020, jeff.b.juranek@aero.org or Thanh Tran, 310.469.2873, thanh.t.tran@aero.org.*

### RECENT GUIDANCE AND RELATED MEDIA

**Small Satellite Supply Chain Study** by C.C. Venturini; TOR-2020-01501; USGC

**Common Payload Interface Standard—Command and Data Handling** by C.V. Sather; TOR-2020-00918; USGC

**Aerospace Mission and Antenna Control System Software** by M.T. Presley; TOR-2020-01650; USGC

**Automotive Industry High Volume Production (HVP) Benchmarking** by J.B. Juranek; ATR-2020-01711; USGC

**Stakeholder Review: Tailoring of SMC-S-016 (2014), Test Requirements for Launch, Upper-Stage and Space Vehicles** by J.W. Welch; TOR-2020-00566-Rev A; USGC

**Data Driven Space Supply Chain Analysis Under COVID-19 Environment** by J. Chang; TOR-2020-01299-Rev A; USG

**Tailoring for AIAA S-121A-2017, Electromagnetic Compatibility Requirements for Space Equipment and Systems** by R.M. Putnam; TR-RS-2020-00029; PR

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