AEROSPACE

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GETTING IT RIGHT

COLLABORATING FOR MISSION SUCCESS

VOLUME 10 | ISSUE 2 | DECEMBER 2019

Dr. Jamie Morin, The Aerospace Corporation, facilitates panel discussion "Achieving Enterprise Mission Success" with senior government leaders Dr. Neil Jacobs, NOAA; Lt Gen John Thompson, SMC; Maj Gen Michael Guetlein, NRO; and VADM Jon Hill, MDA (not pictured).

MAJORITY OF SATELLITES EXCEED DESIGN LIFE

By KRISTINE L. FERRONE
The Aerospace Corporation

The 2019 Satellite Lifetime Study surveyed design and actual life of U.S. military, civil, commercial, and foreign commercial satellites launched between 1980 and 2018. The scope was limited to free-flying, Earth-orbiting satellites with mass greater than 100 kg and design life greater than 1 month.

Design life is determined from requirements documents or published values. End of life is defined as the loss of the primary mission (primary payload failure, bus failure, out of operational orbit) or retirement. Actual life is defined as the time between successful launch and end of life and does not include secondary missions.

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U.S. Military/Civil satellites design life vs. actual life.

MISSION ASSURANCE SUMMIT

SPACE PROGRAM LEADERS ADDRESS THE FUTURE OF MISSION SUCCESS

By ALISON BAUERLEIN
The Aerospace Corporation

Leaders from every major U.S. space program gathered at The Aerospace Corporation's office in Chantilly, Virginia, in mid-November to discuss the challenges facing the future of space. The Mission Assurance Summit aimed to spark discussion of the new operational demands and security threats in space.

"What we've always called 'mission assurance' is no longer just about the success of an individual launch," said Steve Isakowitz, Aerospace president and CEO. "It's about creating resilient architectures and capabilities while also unfailingly delivering the individual space vehicles, ground functionality, and launches that build those architectures. I'm pleased that the space community came together to focus on how we can jointly keep ahead of emerging threats, innovate solutions that incorporate resilience, and allocate the resources needed to build a new space enterprise."

Participants included government executive leaders from Air Force Space Command, members of the Intelligence Community, the Missile Defense Agency, NASA, NOAA, the Space Development Agency, and the Air Force Space and Missile Systems Center.

"NOAA's satellites play an important role in helping protect lives and property," said Dr. Neil Jacobs, assistant secretary of commerce for environmental observation and prediction at the National Oceanic and Atmospheric Administration. "Given our reliance on space, it's more important than ever that the public and private sectors work together to assure the success of NOAA's mission. With that goal in mind, the Mission Assurance Summit was a great example of how the civil, military, intelligence, and commercial communities can work together to bring innovative approaches to mission assurance."

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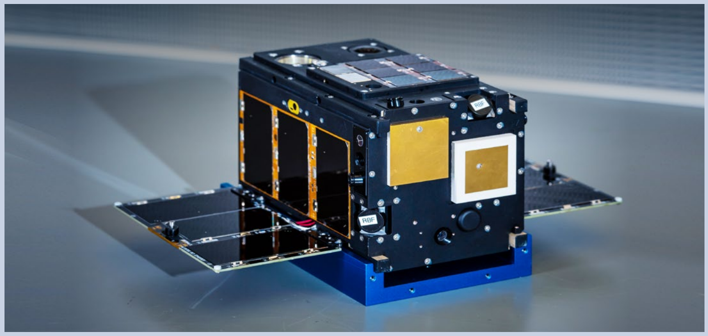
LESSONS LEARNED

FIRST AEROCUBES DEFINED USING MBSE—NOW ON ORBIT!

By ROB STEVENS
The Aerospace Corporation

AeroCube 10, a pair of 1.5U CubeSats, deployed from a 3U NanoRacks deployer aboard a Cygnus cargo spacecraft in August. These craft have started to perform several of the primary missions: engaging in proximity operations, demonstrating a new thruster, and deploying atmospheric probes.



AeroCube-10 being tested in the large area solar simulator in El Segundo.

To date, a vehicle has successfully deployed one of its 28 probes, while another has performed a thruster maneuver to start a slow approach toward its sister AeroCube.

As the complexity of AeroCubes increases, so does the need for rigorous systems engineering practice. To help address this complexity, an AeroCube modeling team used a model-based systems engineering (MBSE) approach to capture key system definition attributes.

The requirements, concept of operations (aka CONOPS), verification activities, physical architecture, and system-level analyses were captured and interconnected in a system-definition model that serves as a "source of truth," which, unlike traditional document-based approaches, allows systems engineers to describe and trace these attributes consistently.

Within the systems engineering community, there are insufficient examples of MBSE being applied across a satellite lifecycle. The lessons learned from this MBSE application during development will help us advise other project leads as they integrate MBSE into their activities. Some of the key lessons learned include:

- Modeling helps avoid pitfalls. Rigorous system-definition modeling forces early conversations among engineers, scientists, and stakeholders about structure, behavior, and requirements, helping avoid surprises later in development (e.g., during the integration and test phase).
- Plan the SysML model structure. Create component libraries, functional packages, etc., at a general abstract level. Meta-modeling can be reused later for future projects.
- Make key SysML model artifacts accessible. Create a method of sharing model elements with the development team, reviewers, and other stakeholders. Provide an export of artifacts into a format that everyone knows how to use, such as spreadsheets.
- Introduce MBSE in parallel with the development process, at least initially. Although not a general rule for all situations, funding MBSE separately and gradually delegating a holistic system definition model as the source of truth are preferable to abruptly mandating a new approach to a successful, existing process.
- Create connections between model elements. One advantage of a descriptive digital model over separate static documents is the interconnections of all the system elements rather than separate standalone artifacts.

One example use of the MBSE implementation was that when a mission requirement was removed late during the detailed design phase, several actions were quickly performed and captured:

- Identified specific tests that were no longer required during integration and test phase

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HOW TO ADOPT ADDITIVELY MANUFACTURED (AM) STRUCTURES

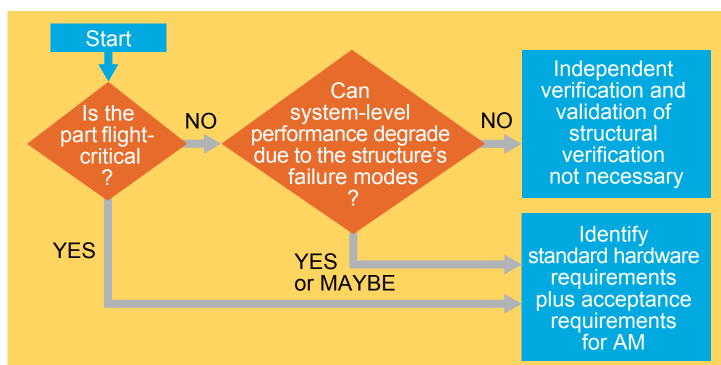
By BRETT E. SOLTZ
The Aerospace Corporation

AM structures are being used in a growing number of space system applications. Although AM can be attractive from design, schedule, and manufacturing perspectives, variability in material properties can be significant. This variability poses a concern that needs to be managed to ensure mission success.

A practical approach on how to adopt AM structures for national security space programs has been published. The degree of testing required is dependent on the type of hardware and is typically defined in existing standards. Verification may include performance, functional, vibration, shock, acoustic, thermal, pressure, and structural testing during qualification and acceptance. Verification requirements for AM hardware are no less than traditional hardware requirements, especially when new technology and manufacturing techniques are involved.

A flight-critical assessment provides insight into the consequences, including system failure, degraded performance, or instrumentation failure. System-level impacts could arise from contamination, impact damage, loss of conductivity, or loss of integrity or stiffness. Understanding how a part's failure modes can affect system-level performance is a key step in determining the extent of qualification and acceptance testing that is required for AM structures.

Similar to other process-sensitive hardware, proof testing of flight-critical AM structures is recommended to verify manufacturing and to ensure as-built hardware will survive a mission without failure or degradation. Less structural verification effort is required for nonflight-critical structures. The scope of structural verification activities should be based on the criticality of the AM part and the risk tolerance of the program.



Use of AM structures is dependent on flight criticality and required verification.

As AM technology and process monitoring advance, AM hardware could become even more repeatable and robust compared to traditional manufacturing methods. If this future state is achieved, an update to test requirements would be warranted.

This study was published as TOR-2019-02060.

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CONSTRAINT-BASED MISSION ASSURANCE

By LEE JASPER
Space Dynamics Laboratory
Utah State University

In the space industry, missions are built with objectives driving all aspects, based on a requirements-driven model that considers technical, cost, schedule, and other resourcing.

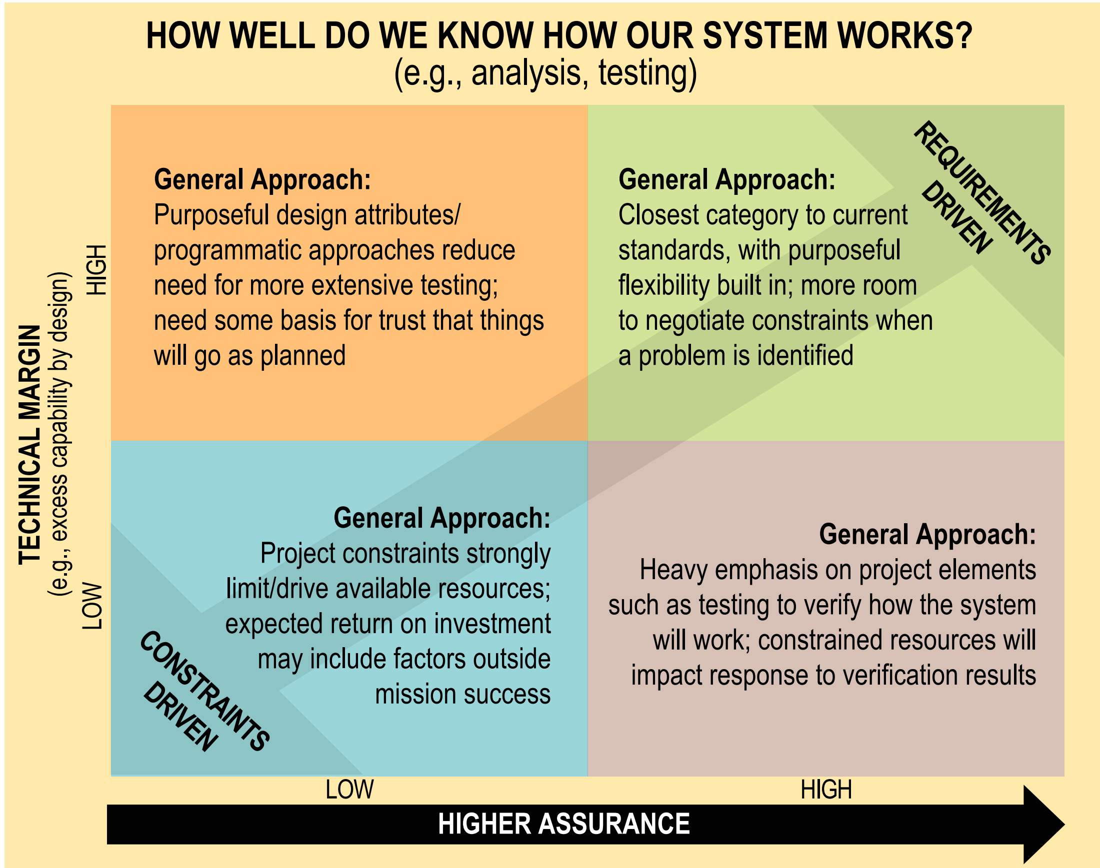
Conversely, small satellites are typically designed in a multiconstraint environment. Focus is placed on designing a concise outline of how small satellites and restricted missions are developed. A framework has been established that provides an alternative path from traditional requirements-driven development.

The framework develops a process in which scope and requirements are tradeable attributes. The methods for understanding the balance between scope and constraint, recognizing divergence from that balance, identifying methods to address alterations, and establishing a new balance are being researched.

The framework is based on agile software development concepts but is also derived from multiple programs and missions (big and small) that have gone through similar practices to achieve success.

Key design practices are starting to be adopted and described (e.g., "the spacecraft can survive a tumble," "full-system power resets periodically occur"), which help increase vehicle resiliency.

The trades between the margins presented in the system and the level of characterization allow for various approaches to help ensure the mission is successful. Ongoing research is exploring how this tradespace can expand outside of traditional practices.



Trades of technical margin and higher assurance in consideration of constraint-based missions.

This work was sponsored and performed in coordination with the Air Force Research Laboratory.

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SATELLITES EXCEED DESIGN LIFE

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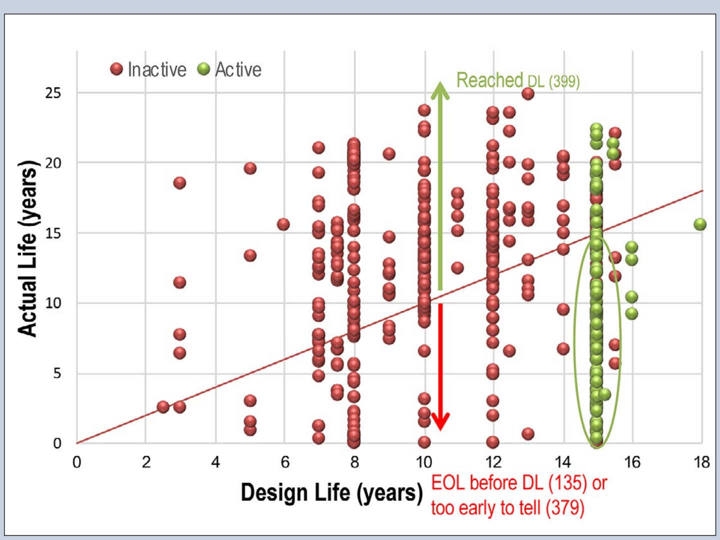
For the U.S. military and civil satellites, design life more than doubled for class A satellites while remaining constant for classes B and C satellites. In recent years, design life for U.S. military and civil satellites has clustered around long design life (>11 years) and the experimental range (1–3 years) with the overall trend of fewer satellite launches.

The design life for commercial satellites increased by greater than 50% for satellites with cost <$300M and remained flat for satellites with cost >$300M. The launch of high-cost satellites began only in 1994. For commercial satellites, large constellations, including Globalstar and Iridium, dominated the 5–8 year design life category in the 1995–1999 launch range.

With respect to actual life, ~87% of U.S. military and civil satellites and ~75% of commercial satellites met or exceeded their design life. There is a high number of "too early to tell" satellites: These were launched too recently to determine if they will reach their design life. Due to this large number (49 U.S. military and civil, 379 commercial), the percentage of satellites that reach or exceed design life could be altered significantly over time as they reach their end of life.



Commercial satellites design life vs. actual life.

U.S. military and civil satellites also experienced a higher mean actual life and greater success rate than commercial satellites of the same design life group.

The study will be published in a soon-to-be-released report titled "2019 Satellite Lifetime Study."

For more information, contact Kristine Ferrone, 281.283.6462, kristine.l.ferrone@aero.org.

Steve Isakowitz, president and CEO, The Aerospace Corporation, provides opening comments reflecting on the need to expand mission assurance to include resilient architecture and capabilities, while unfailingly delivering space vehicles, ground systems, and launches.

MISSION ASSURANCE SUMMIT

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This year's theme, "Achieving Enterprise Mission Success," focused on emerging mission assurance challenges that increasingly include complex integration across different domains and layers with a diversity of partners. The discussion covered a range of topics, including the need to build resilient space architectures and encourage production agility in order to address emerging threats to space systems.

"The U.S. is moving toward a new generation of space systems that is designed for a contested environment, can serve multiple missions, and can rapidly incorporate design, technology, and capability enhancements into production," said Derek Tournear, director of the Space Development Agency. "To deliver on every element of this undertaking, we will need to build interoperability and resiliency into the enterprise and make sure that our constellations and architectures work together to achieve the mission."

"This opportunity to come together as a space community allows us to explore the many areas where collaboration can reap rewards for the warfighter, the mission, and the nation," said Maj Gen Michael Guetlein, deputy director of the National Reconnaissance Office.

Leaders representing government and industry presented on the need for innovative and responsive architectures and a radical departure from traditional paradigms in order to prepare the national security space to continuously outpace threats.

"The summit provided a much-needed chance for the national security space community to re-examine what mission assurance means," said Lt Gen David "DT" Thompson, vice commander of Air Force Space Command. "The focus of mission assurance must shift from systems to warfighters. What matters most is if the soldiers, sailors, airmen, and Marines in the field can rely on the space capabilities they need to execute their missions."

The two-day conference opened with technical presentation sessions on progress in agility, resilience, and innovation to include advancements with enabling tools (i.e., model-based engineering) and strategies (i.e., defensive cyber operations). The following day focused on an executive session that challenged our most senior government and industry leaders to provide insights into the priorities for ensuring that programs meet the needs of national security space.

"Mission assurance requires us to not only deliver capability that works in the space environment, but to deliver critical and timely capability that works under the stress of warfighting," said Lt Gen John "JT" Thompson, commander of the Space and Missile Systems Center. "We've got to change our legacy paradigms of mission assurance—and get faster at it—across the space enterprise."

For more information, contact Gail Johnson-Roth, 310.336.0030, gail.a.johnson-roth@aero.org.

FIRST AEROCUBES DEFINED USING MBSE

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- Modified the CONOPS
- Reran the system power analyses based on the new CONOPS to ensure adequate power
- Updated lower-level requirements that derived from the removed requirement
- Identified the subsystems, software, and components that would be affected so that all the members of the team would have the same understanding of the expected system behavior

This fast-paced AeroCube project provided an ideal pathfinder for MBSE implementation.

A report containing the lessons learned from the pilot MBSE project is released under OTR 2019-01065.

For more information, contact Rob Stevens, 310.336.8786, robert.e.stevens@aero.org.

RECENT GUIDANCE AND RELATED MEDIA

Adaptive Mission Assurance Strategy for Pre-Acquisition: Phase 1 by A.B. Taylor et al.; TOR-2019-01781; USGC

MBSE Training & Learning Opportunity Catalog by A. Chang et al.; TOR-2019-02715; USG

Schedule Integration by R.B. Crombie et al.; TOR-2019-02048; USGC

Small and Cube Satellite Functionality Trends by M. Nguyen; TOR-2019-02711; USGC

2019 Systems Engineering Forum—Leveraging Model-Based Systems Engineering (MBSE) Across the Enterprise by A. Hoheb et al.; ATR-2019-01156; USGC

Space and Launch Requirements Addendum to AS9100D Quality Management Systems by R.L. Morehead et al.; TR-RS-2018-00028; PR

Tailoring for ANSI/AIAA S-120A-2015 Mass Property Control for Space Systems: Space Vehicles by Y.C. Tam et al.; TR-2018-01203; PR

How to Adopt Additively Manufactured Structures on NSS Programs by Brett E. Soltz et al.; TOR-2019-02060; USGC

PR	=	Approved for public release
USGC	=	Approved for release to U.S. government agencies and their contractors
USG	=	Approved for release to U.S. government agencies

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2020 EVENTS

January 6–10 *AIAA Science and Technology Forum, Orlando, FL*

January 27–30 *Reliability and Maintainability Symposium, Palm Springs, CA*

February 4–6 *Microelectronics Reliability and Qualification Workshop, El Segundo, CA*

March 2–5 *Ground System Architectures Workshop, Los Angeles, CA*

March 7–14 *2020 IEEE Aerospace Conference, Big Sky, MT*

March 24–26 *Spacecraft Thermal Control Workshop, Torrance, CA*

March 31–April 2 *32nd Aerospace Testing Seminar, Los Angeles, CA*

April 20–23 *Space Power Workshop, Torrance, CA*

May 5–6 *Space Parts Working Group, Torrance, CA*

May 5–7 *Systems Engineering Forum: Applying MBSE across the Enterprise, Chantilly, VA*

May 13–15 *45th Aerospace Mechanisms Symposium, Houston, TX*

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Getting It Right is published every three months by the Corporate Chief Engineer's Office within the Office of the Executive Vice President of The Aerospace Corporation. Direct questions and comments to gettingitright@aero.org.

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Cleared for public release 2019CC0630
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