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SPACE COLLABORATION COUNCIL BEGINS NEW ERA OF GOVERNMENT–INDUSTRY COOPERATION

By WAYNE GOODMAN, Ph.D.
Executive Vice President
The Aerospace Corporation

The space industry is changing rapidly, and stronger collaboration between government and industry is necessary to effectively address emerging challenges.

The prospect of a war in space, the emergence of new entrants, and the use of secondary payloads have disrupted the status quo, and we must change how we work together to adapt effectively to this changing world.

It was the challenges posed by a string of launch failures in the late 1990s that originally prompted Aerospace to establish a collaborative forum known as the Space Quality Improvement Council (SQIC), where senior quality and mission assurance professionals from the contractor community could come together to tackle industrywide mission assurance challenges. Over the years, other forums such as the Mission Assurance Improvement Workshop (MAIW) were established to expand this collaboration across a wider group of executive leadership in industry and government.

These forums primarily focused on industry quality concerns and informational outbriefs to government leadership to share industry perspectives, discuss issues, and offer recommendations. These activities had a positive effect, as evidenced by the string of launch successes and the influence of the groups' products on industry best practices.

John Kowalchik (Lockheed Martin), Wayne Goodman (Aerospace), and Tom Fitzgerald (USAF/SMC) discuss industry concerns at the first Space Collaboration Council meeting.

While these forums provided a way for industry to raise government awareness of key issues or concerns, they did not provide a direct seat at the table with the government to discuss issues and work them out together.

To address this shortcoming and recognize that it is increasingly important to view space systems as an integrated enterprise, The

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MISSION ASSURANCE CONSIDERATIONS FOR ADDITIVE MANUFACTURING

By MICHAEL O'BRIEN, Ph.D.
The Aerospace Corporation

Additive manufacturing is an emerging technology with the potential to replace many current manufacturing techniques on a select array of parts for satellites and launch vehicles. The process creates parts directly from digital drawings by depositing and fusing layer upon layer of a source material. Additive manufacturing of plastics and metals is now common, and similar techniques for ceramics, glass, fiber-reinforced composites, and electronics are under development.

Traditional machining, on the other hand, creates parts by cutting them from a block of material, which generates a large amount of scrap chips and turnings. For example, each F-22 fighter plane started with 50 tons of titanium alloy that were conventionally machined to a net of 5 tons of final parts, with 45 tons of waste—resulting in a "buy-to-fly" ratio of 10:1. Additive manufacturing offers a buy-to-fly ratio close to 1:1.

A disadvantage is that additive manufacturing is a "process-sensitive" technique that displays large variation from run to run on the same

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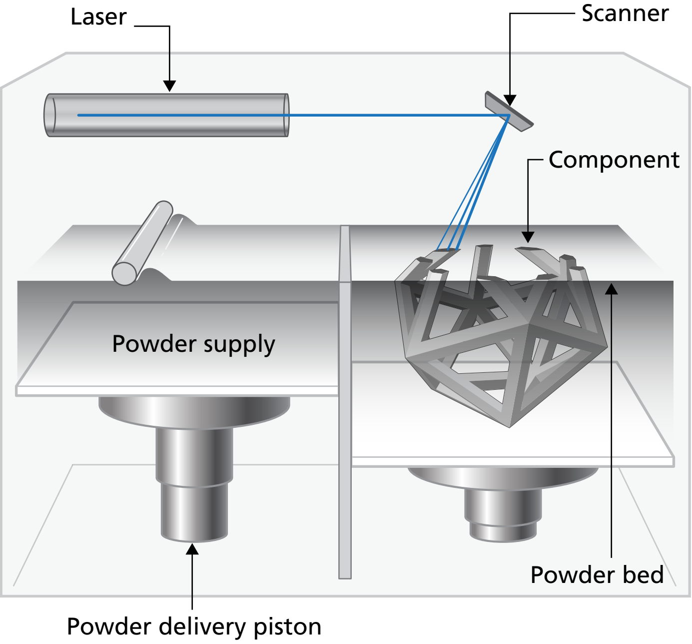


An illustration of the powder-bed technique, which is the leading additive manufacturing method for metals.

REPEATING THERMAL VACUUM TESTING AS A RISK-BASED DECISION

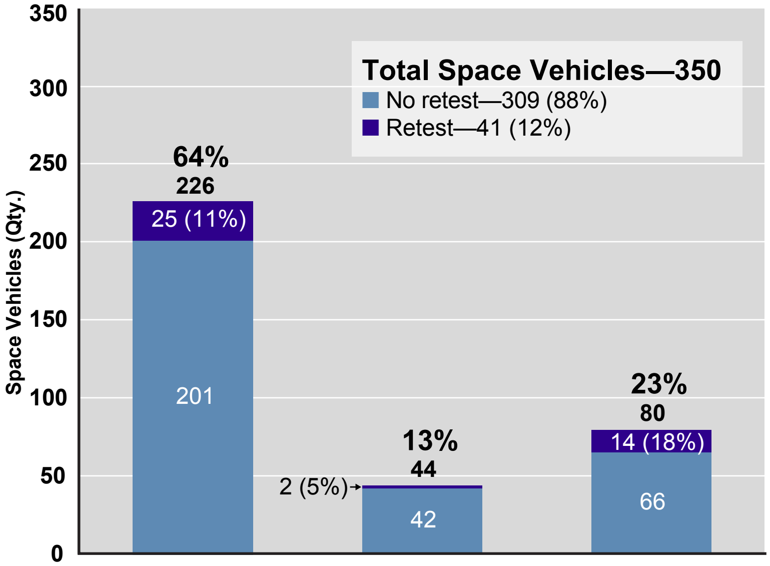
JOHN WELCH, CHARLES WRIGHT,
and JEFF JURANEK
The Aerospace Corporation

Space vehicle (SV)-level environmental thermal vacuum (TVAC) retesting is sometimes necessary following an initial TVAC test for the purpose of verifying workmanship rework/repair and reintegration, and demonstrating mission performance requirements. Two consequences of retesting are added cost and critical path schedule in SV assembly, integration, and test (AI&T). In some cases, the additional testing may reduce the useful life of the flight hardware.

Data collected from 350 SVs across six major aerospace contractors between 2000 and 2016 were compared against commercial, civil, and Department of Defense (DOD) categories. Of the SVs studied, 64% were commercial vehicles, 13% were civil vehicles, and 23% were DOD vehicles. Results identified 41 SVs (12%) were retested following the initial TVAC test environment. The percentage was higher (18%) for DOD programs than for commercial programs (11%), with the lowest rate observed for civil programs (5%).

There are typically items to rework/repair due to either failures that occurred as a result of the test, failures in tests, post-test design modifications, or reachback item rework/repair. The level and degree of intrusiveness and test perceptivity following rework/repair are key factors when evaluating the need or risk of whether or not to subject the SV to retest. For the 41 SV TVAC retests, the primary reason for retesting are anomalies in the initial test associated with unit workmanship and subsystem interfaces.

A TVAC retest risk decision assessment should consider units removed and replaced, flight harness/connectors, handling and access, design and test history, and performance verification. Sixteen items have been documented as the most common considerations for SV TVAC retesting to including considerations for potential mitigations and alternative approaches.



Number of space vehicles tested and retested in thermal vacuum (2000–2016).

Thermal Vacuum Retest Considerations

- Units Removed and Replaced (R&R)
  - Number of Units Removed and Replaced
  - Number of Reworks/Repairs
  - Percentage of the SV Touched during R&R
  - Type of R&R Unit Thermal Interface
  - Power Dissipation/Density
- Flight Harnesses and Connectors
  - Flight Harness Modification/Manipulation/Routing
  - Number of Connector and Conductors Demated/Remated
  - Type of Connectors Demated/Mated for Each Unit
  - Type of Signals Running through Each Demate/Remate Connectors (DC, Analog, Digital)
  - Number of Blind Mates
- Handling and Access
  - Installation Difficulty/Access Difficulty Including Special GSE
  - Potential for Collateral Damage
- Design and Test History
  - Mission Criticality and Redundancy Architecture for All R&R Units
  - Previous R&R Unit Failure History
- Performance Verification
  - Degree of Post-Rework/Repair Vehicle Performance Testing
  - Confidence Testing Required

Several key recommendations were generated from a recent Mission Assurance Improvement Workshop:

- Center TVAC retest decision process on technical risk using the 16 industry-defined considerations to quantify and potentially mitigate risk, including alternative verification methods in lieu of a full SV retest
- Establish risk assessments through existing board reviews (e.g., failure review boards, program review boards) to ensure completeness of the decision process
- Ensure rigorous unit-level thermal testing to reduce the number of unit-level defect escapes

With decreasing government budgets and a need to be more efficient in AI&T, technical considerations must be a key part of the risk-based decision process of determining when an SV TVAC retest is warranted.

Reference

Aerospace Report No. TOR-2017-01693

*For more information, contact John Welch, 310.336-6556, **john.w.welch@aero.org**.*

DID YOU KNOW…?

A conceptual hierarchy for resilience design

Resilience can be defined as the ability to deliver mission capabilities in the face of manmade or natural interference. In developing systems for an increasingly crowded and potentially hostile domain, designers should treat resilience as an important consideration to be traded along with cost and capability. Aerospace has developed a conceptual hierarchy (see figure) to help system designers think about resilience in a formal, structured manner.

The hierarchy begins with mission requirements, such as data rate or resolution. These capabilities may be vulnerable to manmade and natural hazards such as debris or jamming. Overarching strategies such as disaggregation or reconstitution can be devised to address such threats. Different strategies can be implemented through actions such as hardening or maneuvering. Specific actions require certain enablers such as an on-orbit spare or payload guidance and propulsion. System and architecture resilience requirements (SARRs) emerge as a result of identifying the enablers—for example, does the system have to retain 100% capability, or can it operate in a functionality-reduced safe mode? Metrics apply to every level of the hierarchy, providing the tools to quantify system requirements.

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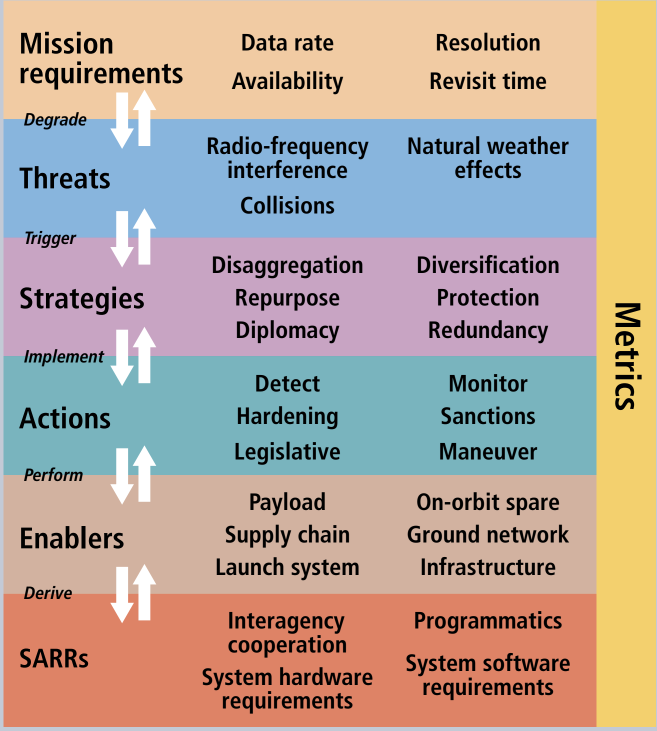

Mission requirements	**Data rate** **Availability**	**Resolution** **Revisit time**	**Metrics**
Degrade			
Threats	**Radio-frequency interference** **Collisions**	**Natural weather effects**	
Trigger			
Strategies	**Disaggregation** **Repurpose** **Diplomacy**	**Diversification** **Protection** **Redundancy**	
Implement			
Actions	**Detect** **Hardening** **Legislative**	**Monitor** **Sanctions** **Maneuver**	
Perform			
Enablers	**Payload** **Supply chain** **Launch system**	**On-orbit spare** **Ground network** **Infrastructure**	
Derive			
SARRs	**Interagency cooperation** **System hardware requirements**	**Programmatics** **System software requirements**	

GUEST COLUMN

Can We Stop Saying ‘Model-Based’ Now?

By STEVEN JENKINS
Jet Propulsion Laboratory
California Institute of Technology

The term “model-based systems engineering,” while not in itself incorrect, creates a misleading impression, namely that it is possible to do systems engineering without creating models. All engineering has always been model-based, and systems engineering is no exception. A differential equation is a model. A breadboard circuit is a model. A scale model is (by definition) a model. But modeling isn’t the point.

Modern engineering practice is distinguished from other fields of endeavor, at least in part, by the notion of rigor. There are multiple aspects to rigor, but one that I particularly like comes from the *NASA Return to Flight Report, Annex 2.* It characterizes rigor as “scrupulous adherence to established standards for the conduct of work.”

Rigor in engineering manifests itself along three principal dimensions:

1. The use of precise language. We readily recognize that “sound pressure level 118 dB” is more rigorous language than “pretty loud,” even though both convey essentially the same idea. The difference is that the former is more precise. In particular, it is expressed using a reference that allows us to compare the relative loudness of sounds.
2. The use of abstractions. Expressing sound volume in dB not only lets us compare loudness, but it relates the loudness of sound to fundamental physical quantities like energy, which allows us to predict the power required to produce a sound of a given loudness.
3. The use of automation. While there’s no question one can practice engineering without automation, the wide range of capabilities and performance available today increases productivity and decreases error rates, at lower costs.

These three dimensions are intimately linked. Engineering language typically is closely bound to abstractions so that analysis of behavior can follow directly from description of structure. For example, the structure of an RC circuit can be specified very concisely. The main reason we describe such is that the behavior of an RC circuit can be specified by a concise set of differential equations that can be solved. The descriptive language corresponds in a principled, direct way to useful analytical abstractions. Language shapes abstraction and vice versa.

Discipline-wide consensus on precise language for systems engineering lags other more mature specializations of engineering. We all recognize terms from systems engineering vocabulary (e.g., component, interface, function, requirement, stakeholder, objective, etc.), but I don’t think we can claim that our language is rigorous.

Systems engineering lacks a discipline-wide consensus on its fundamental abstractions. All mechanical engineers understand the importance of calculus and probability in the study of dynamics; all control engineers understand why functional analysis is fundamental to optimal control.

Systems engineers have an obligation to exploit techniques that have been crucial to other engineering fields: precise language, mathematical abstractions, and automation. If we do that, then we’re modeling. If we don’t, it’s not certain we’re even engineering. Mission assurance has to meet a higher standard than that.

This column was written at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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MISSION ASSURANCE CONSIDERATIONS FOR ADDITIVE MANUFACTURING

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production machine, between identical production machines, and across machines from different manufacturers. Other process-sensitive techniques—such as investment casting, powder metallurgy, welding, and fiber-composite fabrication—required two or three decades of development before they could be widely adopted by the aerospace industry. These techniques often suffered early failures, such as the rupture of a powder-metallurgy turbine disk in an F/A-18 Hornet flying home from the 1980 Farnborough Airshow. This history underscores the need for rigor and understanding in examining new production techniques.

A recent MAIW composed of experts from industry, government, and FFRDCs recommended that the government should foster research and promote sharing of information and material testing across the industry. This team also developed guidance for additive manufacturing. The team identified gaps in published specifications and best practices regarding material properties, process control, powder reuse, design and analysis, contamination control, inspection, qualification testing, and more. These gaps need to be addressed to make additive manufacturing repeatable and reliable.

One benefit of additive manufacturing is the ability to create intricate parts with internal cavities and complex features—all in one piece, without assembly. However, these internal features are not accessible for traditional inspection and surface finishing, so testing and qualification remains a challenge.

A broadly accepted method for certification and qualification of additive manufacturing parts is needed for space system applications.

Reference

Aerospace Report No. TOR-2016-02147

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*For more information, contact Michael O'Brien, 310.336.2878, **michael.j.obrien@aero.org**.*

SPACE COLLABORATION COUNCIL BEGINS NEW ERA OF GOVERNMENT–INDUSTRY COOPERATION

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Aerospace Corporation decided to merge and refocus the SQIC and MAIW. The result is the new Space Collaboration Council (SCC), established to bring together senior leaders from government and industry to address today's emerging challenges in space. No longer will industry only present solutions to the government for consideration but will actively work with the government to develop and apply them.

On June 20, Aerospace hosted the first meeting of the SCC. Industry participants included Ball, Boeing, Harris, Lockheed Martin, Northrop Grumman, Orbital ATK, Raytheon, and SpaceX. Government organizations represented included SMC, National Reconnaissance Office, Missile Defense Agency, NASA, and Defense Contract Management Agency.

The new approach was well received, and the discussions covered a range of key space enterprise issues, including: requirements for small payload ridesharing; hosted payload interface specification and design guidance; challenges in qualifying parts created via additive manufacturing; common specifications and standards; differences between government and commercial timelines; opportunities for lean developments; agile mission assurance; and early problem alert systems.

Future SCC meetings will focus on a few key topics to allow for in-depth discussion. The next SCC will be held in the late fall and will concentrate on cybersecurity and resiliency of space systems, as requested by the SCC.

Reference

Aerospace Report No. TOR-2017-02259

2017–2018 EVENTS

Sept 12–14 *AIAA Space and Astronautics Forum and Exposition, Orlando, FL*

Sept 19–22 *AMOS Conference, Maui, HI*

Oct 2–3 *Satellite Innovation Symposium, Mountain View, CA*

Oct 17 *Systems Engineering Forum: Agile Software Development, Chantilly, VA*

Oct 17–20 *Women in Aerospace Awards Dinner, Washington, DC*

Oct 23–26 *National Defense Industrial Association (NDIA) Systems Engineering Conference, Springfield, VA*

Oct 31–Nov 2 *NSISC Space INFOSEC Technical Information Exchange, El Segundo, CA*

Nov 7–9 *Space Additive Manufacturing: Manufacturing Problem Prevention Program, JPL Data Analysis, AM Consortium WG, El Segundo, CA*

Nov 7–9 *19th Annual Global MilSatCom, London, UK*

Nov 9 *A New Space Age, Seattle, WA*

Nov 13–15 *1st International Academy of Astronautics (IAA) Conference on Space Situational Awareness, Orlando, FL*

Jan 8–12 *AIAA Science and Technology Forum and Exposition, Kissimmee, FL*

Jan 22–25 *64th Annual Reliability and Maintainability Symposium (RAMS), Reno, NV*

RECENT GUIDANCE AND RELATED MEDIA

Space Collaboration Council by D. Phillips and G. Johnson-Roth; TOR-2017-02259; OK'd for USGC

Operational Aspects of Spacecraft Propellant Quality: Where, When, and Why of Sampling and How to Assess Issues by M. Mueller; ATR-2016-01393; OK'd for public release

Mission Assurance Implications of Space Vehicle Thermal Vacuum Retest by J. Welch et al.; TOR-2017-01693; OK'd for public release

The Test Like You Fly (TLYF) Process Tutorial by J. White and L. Tilney; TOR-2017-01412; OK'd for public release

Stakeholder Review of Proposed New Standard: Evaluation and Test Requirements for Liquid Rocket Engines by K. Behring et al.; TOR-2017-00779-REV A; OK'd for USGC

Assessment of Aggregate Mission Risk for Program Risk Management and APR/ASMR Processes by S.Guarro; ATR-2017-01147; OK'd for public release

The Test Like You Fly Process Guide for Space, Launch, and Ground Systems by J. White and L. Tilney; TOR-2014-02537-REV A.; OK'd for public release

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USG = Approved for release to U.S. Gov't Agencies
USGC = Approved for release to U.S. Gov't Agencies and Their Contractors

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