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The Quarterly Newsletter of Mission Assurance
APPROVED FOR PUBLIC RELEASE
Volume 8, Issue 3 / March 5, 2018

GOING FASTER: ACQUISITION

By LT GEN JOHN "JT" THOMPSON
SMC Commander

Eighteen months ago, after an entire career acquiring air-breathing aircraft, weapons, and all manner of armaments, I received an assignment notification to become Commander of the Space and Missile Systems Center (SMC). The opportunity of a "space" assignment intrigued me, as truthfully, my closest affiliation with space was reruns of "Star Trek."

Ten months ago, immediately after taking command, I started climbing the steep learning curve of "space." First impressions were alarming, and for the first time in my career, I recognized we were not at parity or better than our adversaries, thus christened our "too" problem. We are too small, too old, and too slow with requirements; we make it too hard with funding instability, meaningless fights, bureaucracy, and paperwork. We have too many stakeholders, too many people who can say "NO," and we talk too much! So…why write this article? Well, here's the deal: When I look in the rearview mirror, our adversaries are closer than they appear…and it's our job—this team's job—to fix that…and leave our adversaries in the dust.

In order to attack our "too" problem, we've made a number of changes. First, as Air Force Program Executive Officer/Space, I delegated acquisition authorities to the absolute lowest levels possible: All 16 Acquisition Category III space programs and Service Category programs under $100M are now delegated to the SMC system program directors. This delegation includes all facets of program execution, including Milestone Decision Authority, Requirements Approval Authority, and Source Selection Authority. Across SMC, we're saving no less than 4–8 weeks for each acquisition event in the process, and we're delivering capabilities to the warfighter more rapidly. Improving acquisition timelines and reducing cost will enable capability modernization to outpace our adversaries.

The Space Enterprise Consortium (SpEC) Other Transaction (OT) is an innovative approach we've taken to tackle the "too" problem. The SpEC OT is a new contracting method which will improve access to

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SOFTWARE RESILIENCY

By DEWANNE M. PHILLIPS, Ph.D.
The Aerospace Corporation

Software-intensive space systems can harbor defects and vulnerabilities that may enable external adversaries or malicious insiders to disrupt or disable system functions, risking mission compromise or loss. Mitigating this risk demands a sustained focus on the security and resiliency of the system architecture, including software, hardware, and other components.

Cyber-attacks[1] are enabled by shortfalls in software. Robust software engineering practices and an architectural design are foundational to resiliency, allowing the system to "take a hit to a critical component and recover in a known, bounded, and generally acceptable period of time."[2]

A software architecture with designed-in resilient attributes can allow for mission-critical services and warfighter capabilities during and after an adverse condition or disruption. A greater probability of success is reached through prediction, detection, prevention, avoidance, mitigation, recovery, reconstitution, and acceptance (page 3 figure).

To achieve software resiliency for space systems, acquirers and suppliers must identify relevant factors and systems engineering (SE) practices to apply across the lifecycle in software requirements analysis, architecture development, design, implementation, verification and validation, and maintenance phases.

There are seven recommended steps to improve the resiliency of space systems software. These steps must be implemented with the similar rigor that space systems stakeholders and engineers apply when addressing other qualities, such as availability, reliability, and safety. The seven steps[3] are:

1. **Define Technical Resiliency Requirements.** Determine the architecture and software resiliency requirements early in the SE lifecycle. This is fundamental to reducing vulnerabilities due to software defects.

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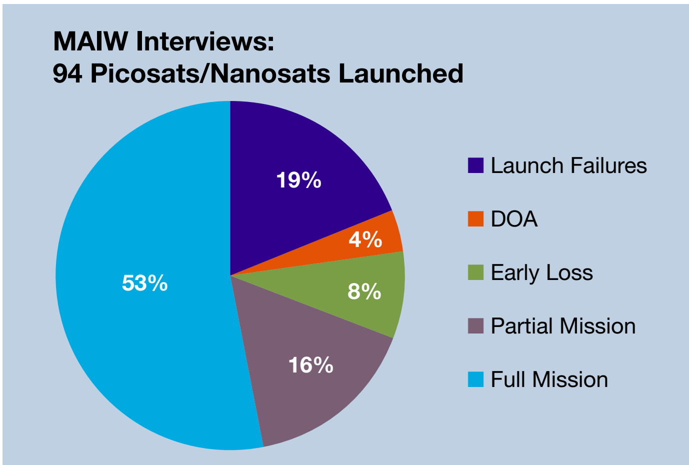
SMALL STEPS: IMPROVING CUBESAT MISSION SUCCESS

By RENELITO DELOS SANTOS
Space Systems/Loral (SSL)
and CATHERINE VENTURINI
The Aerospace Corporation

In recent years, CubeSats have proliferated at an astonishing rate. What started as a largely academic exercise has taken on much greater significance, with commercial entities gearing up to produce vast constellations of the small but capable spacecraft. Researchers continue to advance the technology, and even the government is exploring the potential for operational missions.

Amid all the hype, however, one fact tends to get overlooked: CubeSats do not have a great record of mission success.

In fact, based on a journal paper published in 2013,[1] on average, only about 45 percent of academic CubeSats operate on orbit for more than 60 days; commercial missions fare a little better, but even they have an average success rate of only 77 percent.



Causes of CubeSat mission failures

The Mission Assurance Improvement Workshop (MAIW) organized a team to investigate the causes of CubeSat mission failure and evaluate the prospects for improving the success rate. The group surveyed a number of academic, commercial, and government organizations engaged in the design and development of miniature spacecraft. The results[2] highlight a number of important themes and issues.

As shown in the figure, among the subset of CubeSats launched from the organizations that the study interviewed, over 50 percent had full mission success. This is attributed to many of the organizations having multiple CubeSat development experiences.

The first theme focused on the purpose and vision of the mission. For many academic programs, the goal is not to create an operational capability, but to educate students. Even a mission failure is viewed as a positive outcome if students learn from it. Other organizations use CubeSats to test new technologies; in these cases, a failure on orbit is viewed as a valuable data point.

Another theme centered on program structure. In the academic arena, teams with experienced designers and mentors typically achieved greater success.

Rigorous documentation helped maintain continuity as members joined and left the team. Regular reviews, both formal and informal, also tended to boost success rates. Schedule proved a difficult aspect of program structure, as most CubeSats could not dictate their own launch date.

Naturally, risk was a central theme. Many CubeSat programs are inherently more comfortable with risk than are traditional large space programs. Nonetheless, successful missions typically include a targeted risk-management plan. Given the inherent constraints and challenges in developing small spacecraft on a tight budget and short schedule, it's important to focus on those risks that present the greatest return on investment.

The study also underscored the importance of appropriate design. In general, simpler designs that can accommodate rework will pose fewer problems. Most CubeSats are assembled from standardized parts that are not fully protected against the space environment; designers should plan accordingly.

All organizations, without exception, emphasized the importance of testing, especially full-system functional testing. Many missions settle for system-level testing, rather than subsystem testing, as a result of budget and time constraints. Ideally, the full battery of tests would include thermal vacuum, RF compatibility, deployment, hardware-in-the-loop, and software testing—but many organizations lack the needed resources.

The study also identified the most common problem areas for CubeSats. These include the communication system, the ground segment, power systems, and deployables. The quality and availability of off-the-shelf parts and assemblies were also common issues.

Launch remains a significant driver of design and development problems. As a rule, primary payloads do not wait for secondary payloads, so CubeSat developers often have to compress their testing programs to meet inflexible launch dates. Conversely, some CubeSats have to wait a long time for a launch opportunity, increasing the chance of age-related failures. Not knowing the final launch vehicle at the outset can lead to overdesign and wasted effort.

Based on this information, the research team compiled a set of eight recommendations for CubeSat developers:

1. Define the scope, goals, and success criteria at program start
2. Allot sufficient time for integration, verification, and testing—ideally, one-third to one-half of the overall schedule
3. Conduct risk-based mission assurance, with an initial risk assessment to help prioritize tests and reviews
4. Design for simplicity and robustness
5. Include experienced personnel on the team
6. Stock spare components to enable parallel development and more rigorous testing
7. Perform at least four mission assurance tests—day-in-the-life testing, communication link testing, power system testing, and thermal testing
8. View subsystem datasheets with skepticism

Most of these broad recommendations can be tailored and implemented without much cost. Many would seem to be common sense—but the study team found that few CubeSat developers followed them all.

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[1] Swartwout, M., "The First One Hundred CubeSats: A Statistical Look," *Journal of Small Satellites* [online journal], Vol. 2, No. 2, December 2013. Retrieved from: http://www.jossonline.com/

[2] Venturini, C., *Improving Mission Success of CubeSats*, TOR-2017-01689, The Aerospace Corporation, El Segundo, CA, June 12, 2017.

For more information, contact Catherine Venturini, 310.336.5923, catherine.c.venturini@aero.org.

SPACE COLLABORATION COUNCIL (SCC) MAKES PLANS, DISCUSSES ISSUES

By DEWANNE PHILLIPS, Ph.D.

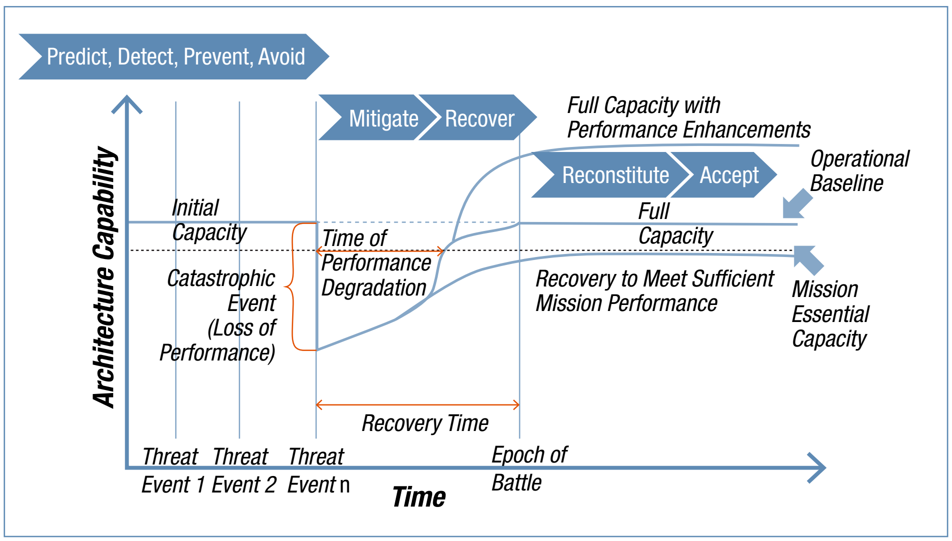
The November 2017 Space Collaboration Council (SCC) classified session focused on cyber, resiliency, and Space Warfighting Construct (SWC) topics. The council, the successor of two other groups, brings together senior leaders from government and industry to address today's emerging challenges in space.

At the session, The Aerospace Corporation made presentations on the SWC; Resiliency for Space Systems; Project West Wing—Threat Perspectives; and Space Traffic Management.

Ball Aerospace presented a briefing on "Performance Mission Modeling for the Space Enterprise, Indication, and Warning." SSL provided a presentation to prompt discussion about on-orbit servicing and applicability to situational awareness and resiliency. NASA offered a brief on Blue Team Assessment regarding ground assessments, and the NRO gave briefings on the supply chain as well as "Continuity and Critical Infrastructure Protection Assessments."

Based on this meeting, Aerospace's Corporate Chief Engineer's Office (CCEO) created a follow-on action plan to address the SCC summary actions and future topics. This plan identifies objectives, tasks, success criteria, time frame to achieve tasks, and resources to achieve the goals and objectives.

Operational concepts paired with acquisition requirements were identified as potential topics for the next SCC, including in-orbit service; standard approaches for contested environment; advancement of innovative cyber acquisition and system engineering resiliency activities; model-based progress; supply chain; and identification of tools to improve Mission Assurance practices for efficiency and effectiveness.



Software resiliency architecture capability loss.[3] *Used with permission.*

SOFTWARE RESILIENCY

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Standards and policies should jointly be a basis for, and should feed, requirements development; otherwise you're trying to retrofit security into a product or service again.

2. **Develop a Request for Proposal/ Statement of Work for Space Systems.** "Build resiliency into" the architecture and incorporate software assurance considerations and demonstrations throughout the software acquisition process.

3. **Define Software Resiliency Goals.** The software architecture should be derived from the overall resiliency goals of the stakeholders.

4. **Determine Software Quality Attributes.** Quality attribute requirements stem from business and mission goals (e.g., resiliency). Quality attributes requirements drive the design of the software architecture.

5. **Perform Architectural Analysis of Alternatives.** Existing and next-generation software-intensive space system architectures must be assessed to mitigate resiliency capability gaps. Define alternative architectures to provide passive resilience and enable protection in depth.

6. **Conduct Architecture Assessments as Part of the Procurement Process.** Verify that the architecture of software-intensive space systems is durable, defensible, and survivable during perturbations, disturbances, failures, or malicious attacks.

7. **Ascertain Space System Software Architecture Resiliency Metrics.** Acquisition offices must determine the appropriate metrics for the resiliency or proxy metrics for resilience, such as availability and reliability of the system.

Resilient space systems and their corresponding software are in a nascent phase. As these areas mature, additional studies should review the best practices and refine the seven steps. As further data is collected and reported on software resiliency and impacts to software-intensive space systems, there will be greater opportunities to discover and study threats and vulnerabilities, identify effective and efficient risk mitigation techniques, and keep apprised of an advanced persistent threat. Future research should also be identified to measure the cost benefit and effectiveness of new techniques.

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[1]Steinberger, J., *A Survey of Satellite Communications System Vulnerabilities*, Dayton, OH: Air Force Institute of Technology, 2008.

[2]Marcus, E., & H. Stern, *Blueprints for High Availability*, 2nd edition, Indianapolis, IN: Wiley Publishing, 2003.

[3]Phillips, D., T. Mazzuchi, & S. Sarkani, "An Architecture, System Engineering, and Acquisition Approach for Space System Software Resiliency," *Information and Software Technology*, 150–164, 2017. Also at: https://www.sciencedirect.com/science/article/pii/S0950584917300575

For more information, contact Dr. Dewanne Phillips, 571.304.7645, dewanne.m.phillips@aero.org.

RECENT GUIDANCE AND RELATED MEDIA

Resilience for Space Systems: Concepts, Tools and Approaches by K. O'Donnell et al.; ATR-2017-02226; OK'd for public release

2016 MAIW Product List by J. Wyrwitzke; TOR-2017-01275; OK'd for public release

Existing Standards as the Framework to Qualify Additive Manufacturing (AM) of Metals by M. O'Brien; TOR-2017-01880; OK'd for public release

Improving Mission Success of CubeSats Interview Summaries by C. Venturini; TOR-2017-01971; OK'd for USGC

Oscillators and Oscillations by J. Meekins et al.; TOR-2017-02160; OK'd for USGC

The Pre-Acquisition Process for Major Space Systems: A Brief Guide by M. Callaway et al.; TOR-2017-02728; OK'd for USG

Survey of Small Satellite Systems by A. Reaves et al.; TOR-2017-02731; OK'd for USGC

Joint Mission Assurance Council (JMAC), 29 Nov 2017 by G. Johnson-Roth and W. McKeithan; TOR-2018-00586; OK'd for USG

Enterprise Early Problem Alert Process Monthly Forum on January 16, 2018 by W. McKeithan; TOR-2018-00768; OK'd for USG

Part Evaluation for Additive Manufacturing by A. Kabe and M. O'Brien; TOR-2017-02432; OK'd for USGC

Evaluating Software Architectures in Space and Ground Systems by A. Unell et al.; ATR-2018-00205; OK'd for USGC

Application Guidelines for Unit Climatic Tests Section of TR-RS-2014-00016, Test Requirements for Launch, Upper-Stage, and Space Vehicles; Part C: Climatic Exposure Tests: Humidity, Sand/Dust, Rain, Salt Fog, Fungi, Ozone, and Hail and Foreign Objects Tests by M. Easton et al.; TOR-2016-02926; OK'd for public release

Tailoring of IEEE 15288.1: Specialty and Systems Engineering Supplement by B. Shaw; TOR-2015-01949-Rev A; OK'd for USGC

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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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.*

SPRING/SUMMER 2018 EVENTS

Mar 3–10 *IEEE Aerospace Conference, Big Sky, MT*

Mar 12–18 *Satellite 2018, Washington, DC*

Mar 20–22 *Spacecraft Thermal Control Workshop, El Segundo, CA*

Apr 9–12 *Earth and Space 2018, Cleveland, OH*

Apr 10–11 *Space Parts Working Group, Torrance, CA*

Apr 16–19 *Space Symposium, Colorado Springs, CO*

Apr 23–26 *Space Power Workshop, Los Angeles, CA*

May 2–3 *Improving Space Operations Workshop, San Antonio, TX*

May 8–10 *AIAA Defense Forum, Laurel, MD*

May 22–24 *Space Tech Expo 2018, Pasadena, CA*

May 24–27 *International Space Development Conference, Los Angeles, CA*

Jun 4–7 *DATT (Defense & Aerospace Test & Telemetry) Summit, Orlando, FL*

Jun 25–29 *10th AIAA Atmospheric and Space Environments Conference, Atlanta, GA*

Jun 25–29 *AIAA Modeling and Simulation Technologies Conference, Atlanta, GA*

Jun 26–28 *Spacecraft and Launch Vehicle Dynamic Environments Workshop, El Segundo, CA*

GOING FASTER: ACQUISITION

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emerging technology and rapid prototyping capabilities resident among nontraditional DOD contractors in the space industry. In November, we awarded the $100M Consortium Manager (CM) contract to Advantaged Technology International (ATI). The SpEC OT allows SMC to demonstrate emerging capabilities more quickly and at a lower cost than traditional acquisition options. Since the SpEC OT is not based on the Federal Acquisition Regulation, it can be flexible enough to significantly lower the barriers to entry for nontraditional defense contractors possessing unique or commercial innovations not generally accessible by the DOD. Moreover, participation by traditional defense contractors provides capability expansion and risk reduction within legacy mission areas, as well as experience navigating government processes. To get the best of both worlds, the SpEC OT participation requirements incentivize traditional defense contractors to partner with nontraditional defense contractors.

Organizationally, I'd like to mention our successful use of partnerships, as The Aerospace Corporation and SMC have marched in lockstep since the days of "Corporation A" and Air Force Ballistic Missile Division. Recently, our partnership and the use of the Assured Space Access Model saved the USAF more than $18M by accurately predicting launch schedules. This is an example of Aerospace improving SMC's agility, and we need more of this! Interagency partners are also invaluable, and we spearheaded a partnership with the National Reconnaissance Office (NRO) to share investment, pool engineering expertise, and deliver space situational awareness. Partnerships like this will be expanded as we keep our foot on the gas pedal.

As a "Center," we are adopting an enterprise view across mission areas; two examples are the Enterprise Systems Engineering Council (ESEC) and the Space Defense Task Force (SDTF). The ESEC establishes a single enterprise architecture and configuration control, and enables prioritization of resources. The SDTF delivers the ESEC's identified top priority: enterprise battlespace management command and control. Both ESEC and SDTF are necessary but not sufficient, and we must consider new partnerships and collaboration efforts to speed development of command and control solutions, ground control infrastructure, and space capabilities.

Moving forward, my charge to the team is simple: Leverage technology to our advantage. I am committed to managing the space portfolio as an enterprise to reduce cost and consolidate knowledge capture, and this team must be willing to go after groundbreaking big bets. The big bets will be focused on space control in the Allied/commercial space market, and we'll use the market to drive more robust competition, with minimal barriers to entry, so we can use new and emerging space suppliers.

It's been a whirlwind 10 months at SMC, and we're going to continue driving fast. We need this team—Aerospace and SMC—to continue delivering innovative technologies and mission architectures to meet enterprise, portfolio, and our needs. As the Commander, it's my call: We need Aerospace riding shotgun as we leave our adversaries far in the rear view.