AEROSPACE

GETTING IT RIGHT

COLLABORATING FOR MISSION SUCCESS

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COPING WITH INHERITED COMPONENTS

By JESSE LEITNER
Chief Engineer for Safety and Mission Assurance
NASA Goddard Space Flight Center

Over the last ten years, Goddard Space Flight Center (GSFC) has experienced an increase in the use of inherited components such as flight printed wiring assemblies, star trackers, inertial measurement units, and reaction wheel assemblies. An inherited component is an item brought into a project as a fully designed item, either in existing hardware or design drawings, that has some amount of prior history that may be built to different standards than those in project mission assurance requirements and may not have had NASA insight into the design or construction.

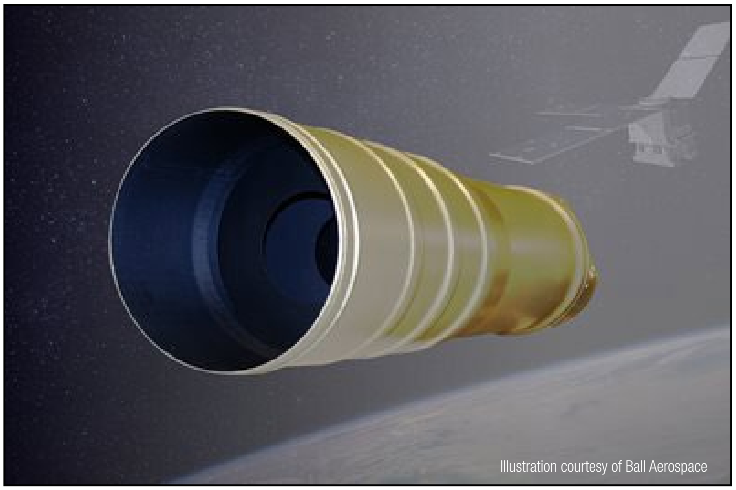

Illustration courtesy of Ball Aerospace

Ball Aerospace Star Tracker

Suppliers of these items prefer a commercial off-the-shelf (COTS) approach for standard components developed for multiple customers. Suppliers were not receptive to customization requests by NASA to meet unique NASA requirements. This customization can actually increase the risk associated with the use of these commonly used components and does not necessarily result in an improved product.

GSFC accordingly developed a new holistic approach for inherited and heritage items that factors prior history, successes, anomalies, and changes in the item. Standard reliability techniques were used to determine the risk associated with these heritage items, and results in many cases found no elevated risk.

GSFC has documented the use of a risk-based approach over a requirements-based one, which emphasizes the risk of the overall component based on a variety of historical factors.

To ensure lessons learned are referenced, NASA's new Commodity Usage Guidelines describe NASA's experiences with each standard product or inherited item. These documents highlight past use requirements, anomalies, inspection findings, and experiences in the lab or on orbit.

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TRUSTED AI AND AUTONOMOUS SYSTEMS

By RONALD J. BIRK and
TORREY O. RADCLIFFE
The Aerospace Corporation

U.S. aerospace companies are increasingly using intelligent agents, artificial intelligence (AI), and machine learning (ML) in their complex systems of systems, comprising hardware, software, networks, and human-machine interfaces. The aerospace and defense market for AI is already estimated to be $2B and growing rapidly.

The Executive Order on Maintaining American Leadership in Artificial Intelligence, released in February by the White House, emphasizes the need for trust in these complex systems.

Small abnormalities can spread unchecked in these intelligent complex ecosystems, resulting in unforeseen downstream impacts. An autonomous system can change its operating environment, which changes inputs to the system, causing feedback loops that are difficult to track and manage. There are multiple scenarios where time-critical autonomous systems require improved operational assurance.

Ensuring effective and safe operations of AI/ML-enabled aerospace systems requires ongoing monitoring of system state of health and verification and validation of end-to-end enterprise effectiveness. These needs drive mission assurance (MA) for AI.

AI/ML techniques are also needed to accommodate the increasing 5Vs (volume, velocity, variety, value, and veracity) that outpace the capacity of humans. To outpace future threats, assured mission success requires continual system performance assessment that is agile enough to identify threats and abnormalities, anticipate anomalies, and take remedial actions to ensure sustained and resilient operations. Space systems also require AI to counter adversarial intelligent actors. These needs drive AI for MA.

To advance U.S. leadership in space, we need both AI for MA and MA for AI. For reference, check out the Center for Space Policy and Strategy paper on *Assuring Operations of Autonomous Systems.*

For more information, contact Ronald J. Birk, 240.293.9006, ronald.j.birk@aero.org, or Torrey O. Radcliffe, 703.812.0655, torrey.o.radcliffe@aero.org.

CENTER FOR SPACE POLICY AND STRATEGY

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ASSURING OPERATIONS OF AUTONOMOUS SYSTEMS

RON BIRK, ELIZABETH HORTON, THOMAS KASHANGAKI, ZIGMOND LESZCZYNSKI,
JON NEFF, NICK PERLONGO, TORREY RADCLIFFE, CHRIS TSCHAN, JOSH TRAIN
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LAUNCH MISSION SUCCESS

By MICHAEL MOORE
The Aerospace Corporation

The Aerospace Corporation (Aerospace) periodically generates predictions of the probability of mission success (aka reliability) for upcoming national security space launches, using reliability models based on the success and failure history of over 800 U.S. and European launch missions. These predictions are a vital input to forward-looking studies such as functional availability analyses and constellation risk assessments, tools that mission planners utilize to ensure high confidence in enduring constellation success.

The predictions are based on the reliability growth principle, which is the continuous improvement in reliability as a system is operated or tested and as design or process defects are discovered and corrected. Analysis of historical launch data, maintained in the Acquisition Support and Systems Engineering Tool (ASSET), shows that reliability growth is one of the most significant factors affecting launch reliability—the more experience behind a launch vehicle family, the more reliable future launches are expected to be.

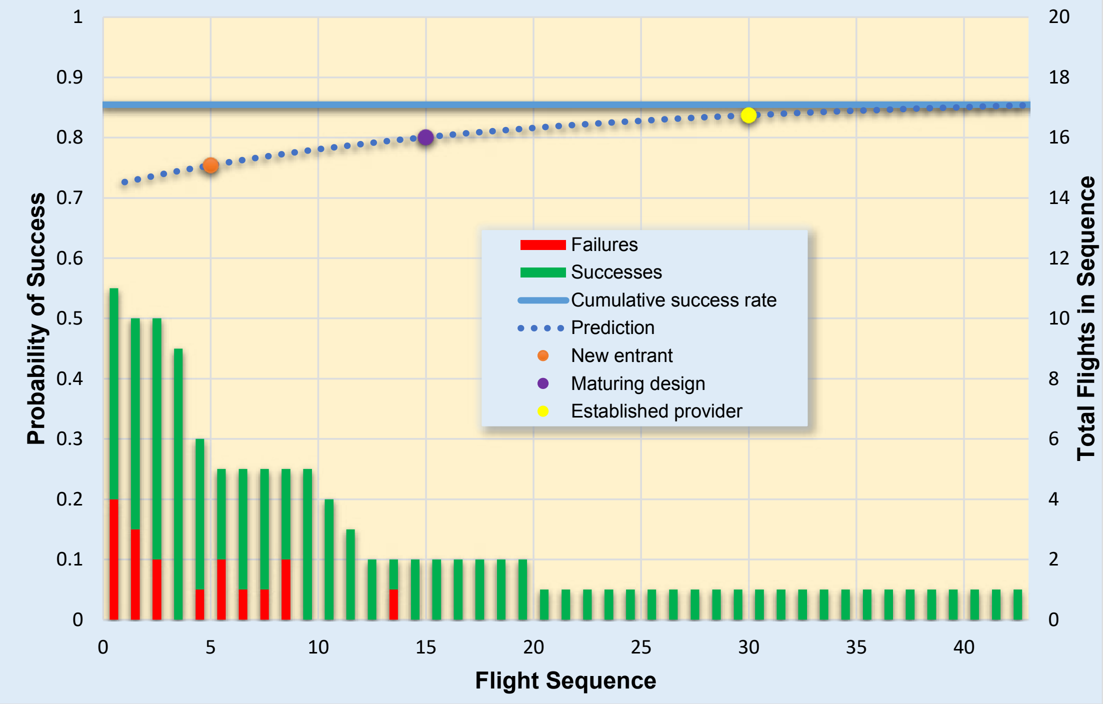
Another factor affecting launch reliability is payload capacity. Historically, medium-class vehicles like the Atlas V, Delta IV, and Falcon 9 have been the most reliable launch vehicles. Heavy-class and small-class vehicles have not fared as well. To account for these differences, Aerospace generates separate data-driven predictions for all three classes of vehicles.

The accompanying figure depicts the growth model and underlying data for small-class vehicles.

The dotted blue line in the figure is the idealized growth curve for small-class vehicles, with points highlighted representing what the predicted probability of success might be for a hypothetical new entrant, maturing design, and established provider. The green and red bars represent the number of historical successes and failures in the underlying dataset, organized by flight sequence and total number of flights in a sequence.

For example, the first bar on the left shows 11 small launch vehicles on their first flight: four failed and seven succeeded. As the number of flights increases, the total number of flights in the sequence decreases, as some launch vehicle families have a more extensive history than others. Only one vehicle family has flown more than 20 flights. As the number of flights increases and less data is available, the growth model predictions become more uncertain.

The launch vehicle landscape is a dynamic environment, with many new entrant providers and customers. Aerospace continually updates this analysis with the latest launch data to provide our customers with the best possible estimates of the probability of launch mission success to inform their acquisition decisions.



Small-class vehicles growth model

REFERENCE:

Launch Vehicle Mission Success by Michael Moore, TOR-2019-01315, The Aerospace Corporation.

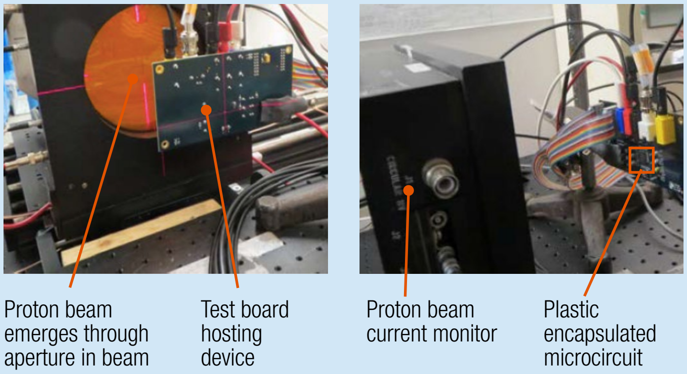
For more information, contact Michael Moore, 310.336.0097, michael.r.moore@aero.org.

JUST-RIGHT ADVICE FOR ALTERNATE-GRADE ELECTRONICS

By ALLYSON D. YARBROUGH
The Aerospace Corporation

In the past, only electrical, electronic, electromechanical, and electro-optical (EEEE) parts and materials that met the most stringent requirements and highly prescribed tests, controls, and analysis methods were selected for high-stakes space missions.

Today, with extraordinary advances in alternate-grade parts (i.e., commercial, automotive, industrial) and other nonspace-grade electronics technology combined with the underlying insight into failure modes, these parts can deliver unprecedented quality and reliability—in their intended application.



Proton radiation of circuit board and microcircuit test setups

One factor driving the attractiveness of these parts is the lower procurement cost relative to space-grade EEEE parts, but other benefits exist as well. Lower power requirements, smaller footprint, lighter weight, more rapid technology refresh rate, and shorter acquisition lead times are all highly desirable features.

How do these advantages balance against the additional risks in a space

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PIECING TOGETHER SYSTEMS INTEGRATION

By RAYMOND BONESTEELE
The Aerospace Corporation

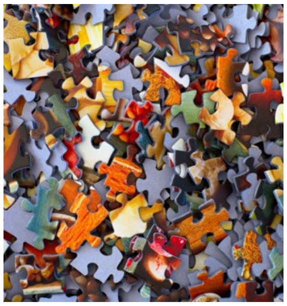
Systems integration employs a collection of interfaces, processes, and technical methods to ensure that the system performs its mission as required in the intended environment. The government has depended on the prime contractor in the past to manage these interfaces and deliver a complete system. Recently, the government has chosen to decompose large programs into smaller, more manageable segments to foster competition and innovation. With this strategy change, the government by default has the responsibility for planning, coordinating, and integrating tasks required to acquire the system segments to meet the overall mission objectives.

The Aerospace Corporation reviewed systems integration findings, recommendations, and lessons learned from past independent program reviews and other government sources. The following highlights the needs related to the government as the system integrator:

- Defined end-to-end integration function in the program office, with one government person responsible, reporting directly to the program manager
- Defined systems integration organization, separate but cooperating with the systems engineering office, with well-defined giver-receiver responsibilities, authorities, and accountabilities
- Defined scope of the systems integration office that includes consideration beyond the contracted segments (from piece parts to Congress)

Planning for systems integration needs to begin early in the acquisition process before the segment contracts are issued. Preparation includes: clearly understanding the intended operational use of the system; defining the system boundaries, interfaces, and stakeholders; defining end-to-end requirements and baseline; and developing a systems integration strategy and plan.

The systems integration staff needs to anticipate problems, develop backup plans, and proactively influence the future.



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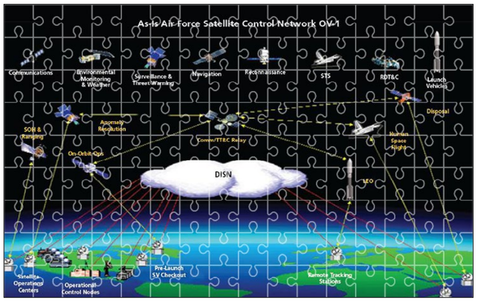

REFERENCE:

Systems Integration: The Path to Successful Program Execution
by Raymond Bonesteele et al.,
TOR-2018-02374,
The Aerospace Corporation.

For further information, contact Raymond Bonesteele, 310.336.2350, raymond.g.bonesteele@aero.org.

LESSONS LEARNED

GROUND CONTROL TO MAJOR OPS

By THANH TRAN
The Aerospace Corporation

One of the biggest challenges of transitioning from a heritage ground system to a new ground system is not to disrupt current operations. Adequate training time must be provided for ground operators.

The new system should be able to process telemetry from operational satellites while full operational control is maintained by the heritage system. This enables testing in a test-like-you-fly environment early and throughout the campaign. Because the operators have an early opportunity to use the system before delivery, they can provide valuable feedback during the development cycle for incorporation. Contractor-only testing is not adequate.

Often the transition from the old to the new system is a discrete cut-over that effectively places both the operators and system in a “trial by fire” situation while taking the heritage system offline. An incremental, phased approach should be implemented to the transition instead of a “big bang” cut-over. Full system testing (use of equipment, processing of telemetry, determination of mission performance) in an operationally realistic environment should be conducted prior to the official transition to the new system.

Design the program contract to decompose a major program delivery into multiple incremental deliveries to keep the program manageable and on schedule. Programs placed on contract with major new capability

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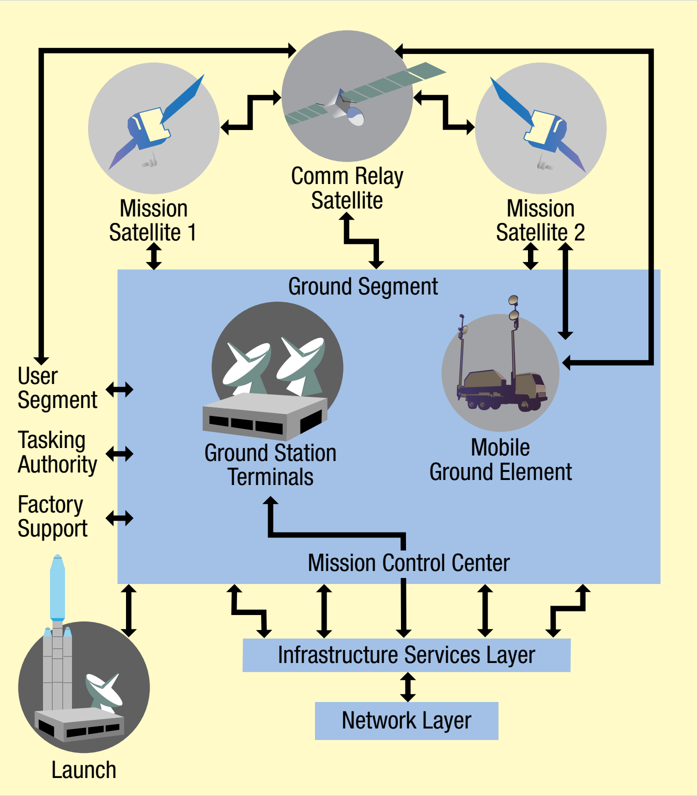

COPING WITH INHERITED COMPONENTS

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Some of the challenges for this new doctrine relate to lack of a prior historical database, timing of supporting data deliveries, and needed contracting changes to support risk-based implementation across the projects.

The implementation has been largely successful, requiring engineers and safety and mission assurance personnel to look at heritage components differently. Using a risk-centric rather than requirements-centric approach has prompted a cultural shift for GSFC.

Furthermore, use and assessment of inherited items is one piece of a bigger transition for the GSFC and the agency to risk-based safety and mission assurance.


Photo courtesy of Honeywell Aerospace

Honeywell reaction wheel assembly

REFERENCE:

Safety and Mission Assurance Acceptance of Inherited and Build-to-Print Products, Goddard Space Flight Center Procedural Requirements (GPR) 8730.5.

For more info, contact Jesse Leitner, 301.286.2630, gsfc-smace@mail.nasa.gov.

GROUND CONTROL TO MAJOR OPS

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or functionality deliveries can lead to onerous program management complexity and schedule pressures.

The following best practices should be considered:

- Plan ground transition early in the development lifecycle—architecture features/designs that empower effective transition usually are not placed on contract.
- Track software development performance metrics.
- Allocate special effort and resources to cybersecurity tasks—needs are typically more than planned due to continued proliferation of threats.
- Perform segment- and system-level testing concurrently.
- Establish a Transition Director as liaison between contractor and operators.

REFERENCE:

Development Test/Operational Test Transitions to Operational Accepted Lessons Learned by Geoffry A. Larsen et al., TOR-2018-00669, The Aerospace Corporation.

For more information, contact Thanh Tran, 310.336.1159, thanh.t.tran@aero.org.

JUST-RIGHT ADVICE FOR ALTERNATE-GRADE ELECTRONICS

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environment for which they were not designed? One of the most daunting impact is exposure to the space radiation environment: galactic cosmic gamma rays, protons, electrons, and heavy ions.

The Aerospace Corporation (Aerospace) is conducting collaborative research with industrial, government, and academic partners to characterize the tolerance of selected alternate-grade electronics to particle radiation encountered in space. A goal is to develop data and insights into parts selection and tests that are neither overkill nor too risky, but "just right" for the selected mission's needs.

A range of simple plastic encapsulated devices such as a realtime clock, metal oxide semiconductor field effect transistor (MOSFET), diode, operational amplifier, field-programmable gate array (FPGA), microcontroller, analog-to-digital converter, and digital-to-analog converter has been examined. The tests include gamma ray radiation to characterize degradation due to total ionizing dose and single-event effects issues such as data corruption and circuit damage due to protons exposure. The radiation test results are shared with the space community to accelerate the parts selection and testing process, especially for short-duration missions and those willing to accept more risk.

Contact Aerospace for copies of existing reports, opportunities to contribute data to the repository, or to recommend parts and materials for future radiation testing.

REFERENCE:

A Proposal to Harvest Mission Assurance Efficiencies Through Alternate-Grade Parts Data Sharing by Allyson D. Yarbrough et al., 2018 Space Parts Working Group Proceedings, OTR-2018-00594.

For more information, contact Allyson Yarbrough, 310.336.1499, allyson.d.yarbrough@aero.org.

2019 SPRING/ SUMMER EVENTS

June 11–12 *Military Space USA, Los Angeles, CA*

June 12–14 *The Sixth International Conference on Tethers in Space (TiS2019), Madrid, Spain*

June 17–21 *AIAA Aviation and Aeronautics Forum and Exposition (AIAA AVIATION 2019), Dallas, TX*

June 25–27 *2nd Cognitive Communications for Aerospace Applications (CCAA) Workshop, Cleveland, OH*

June 26–27 *MilSatCom USA 2019, Arlington, VA*

July 23–25 *Malware Technical Exchange Meeting, El Segundo, CA*

July 30–August 1 *IEEE International Conference on Space Mission Challenges for Information Technology, Pasadena, CA*

August 19–22 *AIAA Propulsion and Energy Forum, Indianapolis, IN*

October 18 *12th Annual Nebraska Space Law Conference: Global Perspectives on US Space Law and Policy, Washington, DC*

RECENT GUIDANCE AND RELATED MEDIA

Space Collaboration Council, 28 March 2019 by G.Johnson-Roth, T. Tran; ATR-2019-01805; USGC

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

Launch Vehicle Mission Success by M. Moore; TOR-2019-01315; USGC

Environmental Test Thoroughness Assessment (ETTA) Process Description by J. Juranek et al.; ATR-2015-03548; USGC

Tin Whisker Modeling Technical Exchange Meeting Minutes by J. Juranek; TOR-2019-00888; USGC

Space Collaboration Council by G. Johnson-Roth; TOR-2019-00762; USGC

Agile Fit Check 2.0 Overview by S. Rosemergy; TOR-2019-01624; USGC

SMC/ENE Common Payload Interface Standard (CoPaIS) by V. Sather; TOR-2019-01574; USGC

PR = Approved for public release
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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