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GETTING IT RIGHT

COLLABORATING FOR MISSION SUCCESS

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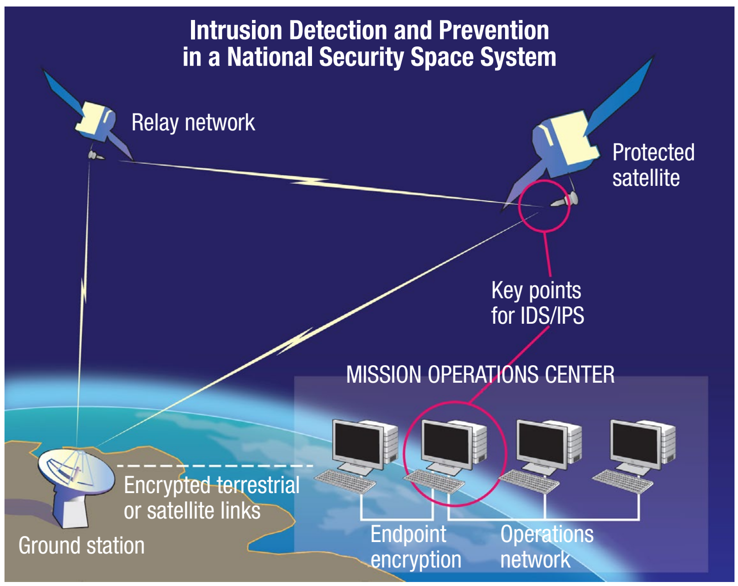
CYBER DEFENSE FOR CLOUD-BASED APPLICATIONS

By THOMAS A. FITZGERALD
Director of Engineering, Space and Missile Systems Center

Sometimes a small problem can lead to a major innovation. That's what happened recently when a team at The Aerospace Corporation embarked on a pathfinder project to move data and applications to a cloud computing environment for an Air Force customer. The project was intended to identify, virtualize, and migrate instantiations of a mission system to both the Defense Information Systems Agency MilCloud and a FedRAMP-certified commercial cloud. As the project got underway, the team faced challenges in finding someone to provide cyber defense services. This was essential before the applications could be allowed to use live data.

Unable to find a suitable commercial solution, the researchers set about building their own. The team developed a suite of tools for cyber monitoring, endpoint protection, and zero-day attack protection, incorporating threat models for space data and using early indicators and cyber alerts based on nominal data footprints and signatures.



During both lab simulations and cyber exercises involving on-orbit spacecraft, the tool—dubbed Eirene Sceptre—successfully detected:

- State-of-health anomalies simulated through radio frequency interference that produces abnormal health data
- Command sequence anomalies simulated through attempts to take control of a satellite by sending abnormal commands
- Malware with unknown signatures simulated through firewall traffic data affected by such malware
- Abnormal data trends simulated through time-series data, in which all values are within normal bounds, but the sequence over time is abnormal

continued on page 4

GET SMART: THE FUTURE OF SPACE SYSTEM MANUFACTURING

By JEFF JURANEK and
GAIL JOHNSON-ROTH
The Aerospace Corporation

Smart manufacturing increases production efficiency through the digitization and fusion of manufacturing and design data. It achieves a state of operations in which all relevant information is made available to all stakeholders across the engineering, manufacturing, and supply chain areas—when, where, and how it is needed. The Aerospace Corporation conducted a study to assess the maturity of smart manufacturing and to understand how it will affect the space industry.

Smart manufacturing can be envisioned as the intersection of three domains: digital engineering, the industrial internet, and smart facilities (see figure). Digital engineering starts with product design data and uses model-based engineering to drive a digital workflow throughout the product lifecycle. The industrial internet enables monitoring of production through networked equipment and data analytics. Smart facilities apply automation and self-diagnostic sensors and controls to a connected enterprise backbone to increase efficiency.

The integration of these three domains into a proactive cyber-physical system is made possible by the advancement of sensors, processors, and internet technologies that allow information to be analyzed and applied faster and more efficiently on a larger scale than ever before.

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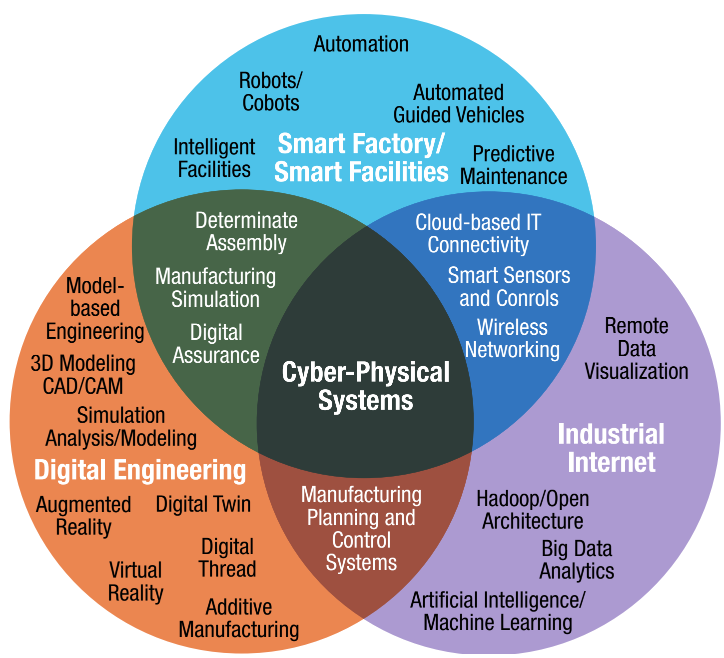


Smart manufacturing defined

DID YOU KNOW...?

DELTA II WAS AWESOME!

By GABRIEL SPERA
The Aerospace Corporation

The last remaining Delta II rocket lifted off from Vandenberg AFB on September 15, 2018, marking the true end of an era. The Delta II had one of the most successful track records of any launch vehicle in history, with 154 successful launches out of 155 attempts. The Delta rocket was developed by placing an upper stage on the Thor ballistic missile—in fact, its original name was Thor Delta, which was later shortened to just Delta. Following the Challenger disaster in 1986, the Air Force revamped the Delta rocket to produce the Delta II; it became the rocket of choice for launching GPS, ultimately lifting 48 of the navigation satellites. The medium-lift rocket could haul more than 4000 lbs. to geosynchronous transfer orbit and sent several missions off to Mars, including the Spirit and Opportunity rovers. The first Delta II launched on February 14, 1989, from Cape Canaveral, carrying the initial GPS Block II satellite. The last one carried a NASA payload along with a number of secondary CubeSats. The final launch marked 100 consecutive launch successes—truly an impressive feat!

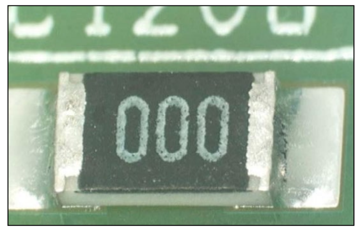
TIN WHISKERS: PREDICTING THE RISK

By DAVID PINSKY and TOM HESTER
Raytheon

For many years, the space industry has been seeking reliable methods to predict and mitigate the risk of conductive whiskers forming in electronic components. These whiskers, which can grow on the tin leads and terminals used to attach chips and components to circuit boards, have been implicated in past failures on orbit. One common approach to mitigating risk is to solder the pure tin leads using leaded solder. In many cases, this solder attachment does not require significant process changes. The solder used to attach the components to printed circuit boards mixes into the existing pure tin lead finish and such components are said to be "self-mitigating."

A 2010 study by Raytheon indicated that the geometry of component leads could be used to predict self-mitigation—at least for one common fabrication technique. More recently, researchers sought to determine whether the same was true for a wider range of chips and fabrication techniques. If so, then manufacturers could use tin-terminated components in certain cases without further mitigation.

The study examined several different component packages, circuit-board finishes, pad sizes, and manufacturing processes. Seven assemblers were provided with eight boards, each of which would contain more than 50 components. The finished boards were then inspected via x-ray fluorescence and scanning electron microscope; some were further examined using an M4 TORNADO spectrometer.



Solder covers the entire termination: self-mitigating.

The results indicate that package geometry is the most significant factor for achieving self-mitigation. Most components exhibited a moderate probability of self-mitigation. Some—in particular the 0603 and SO14G chips—were nearly certain to self-mitigate under all process conditions, while others would do so only for a particular process. One chip—the 0612—was highly unlikely to self-mitigate.

Process also plays an important role; vapor-phase and oven reflow can produce different results for the same parts, as can the peak oven temperature. On the other hand, board finish does not seem to affect self-mitigation.

The study yielded additional insights. For example, it showed that x-ray fluorescence is effective for evaluating self-mitigation, as confirmed by subsequent cross-sectioning and microscopy. Short-term aging of components (about a year) did not seem to affect self-mitigation, but longer aging periods (about five years) did in some instances. Lead geometry affects self-mitigation for quad flat packages, with shorter leads exhibiting a higher probability than longer and taller leads.

Self-mitigation is attractive for manufacturers, as it does not add any process steps or material requirements. This study should help increase confidence in self-mitigation as an effective approach to controlling tin-whisker growth.

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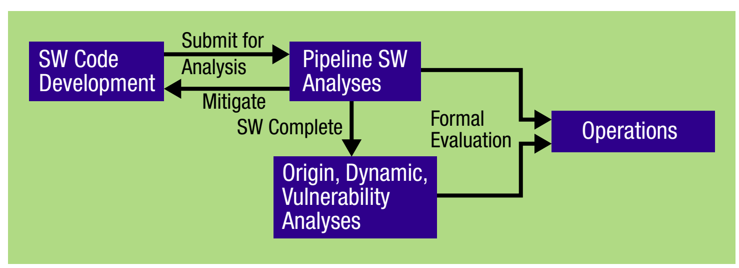
SOFTWARE ASSURANCE FOR RESILIENT GROUND ENTERPRISE

By ALAN D. UNELL
The Aerospace Corporation

Software intended for operational ground systems must be tested to ensure that it meets technical requirements and doesn't introduce security vulnerabilities. Often, the software assurance process is not as robust as it could be.

As part of this process, developers will analyze the code against a list of common weaknesses[1] to demonstrate immunity. A single static analyzer is often used for this step. While various analyzers can check a few hundred of the 714 common weaknesses, no single tool catches more than about half of the 50 most critical weaknesses for a satellite ground station.



The pipeline process for analyzing software weaknesses can expedite transition to operations.

In light of this, Aerospace built an automated web-based tool that creates a pipeline capable of executing several software analyzers that collectively catch from 90% to 99% of those critical weaknesses (depending on the coding language). Results from each analyzer are available to developers, and a combined report is prepared for the authorizing officer to support rapid transition to operations.[2]

While automated analysis of software is not new, combining the tools that best catch this level of critical weakness for satellite ground stations is a step forward. Using it in a rapid development environment will expedite the release of software to the operational site.

REFERENCE

[1] https://cwe.mitre.org

[2] Unell, A., et al., *Software Assurance Pipeline Recommendations for the Space Defense Task Force*, Aerospace Report No. TOR-2018-01105. The Aerospace Corporation, El Segundo, CA (April 30, 2018). Restricted distribution.

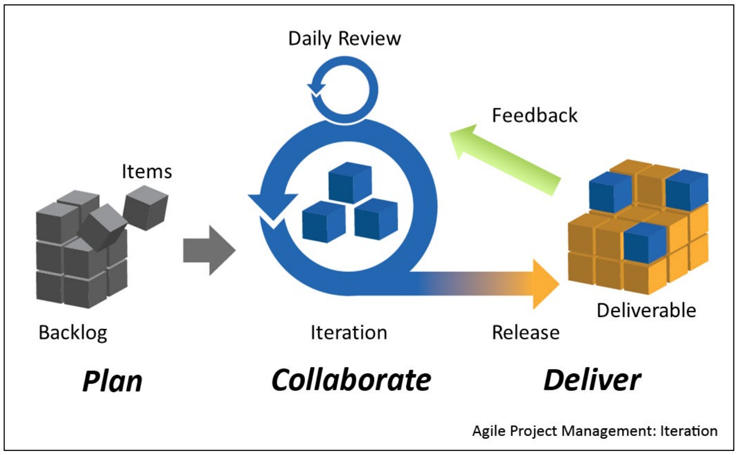
For more information, contact Alan D. Unell, 626.873.7718, alan.d.unell@aero.org.

PROS AND CONS OF AGILE SOFTWARE DEVELOPMENT

By DAN INGOLD
The Aerospace Corporation

Aerospace contractors are increasingly turning to agile software development, which strives for early and frequent deliveries of software iterations, with incremental improvements as the project evolves. This contrasts with the traditional approach, which delivers working software infrequently, late in the lifecycle, and often after a lengthy test-and-fix phase. Agile development patterns itself after Air Force Col. John Boyd's "observe-orient-decide-act" loop; it progresses through ongoing cycles of observing a need, implementing a solution, and testing and delivering it.

While the agile philosophy derives from certain fundamental tenets, the basic approach can be adapted to suit individual program needs. The benefits for mission assurance become evident as the government customer gets to try out each software release



Agile software development progresses through a series of iterations designed to achieve incremental improvements based on customer evaluation and feedback.

and provide feedback to enhance future development, ensuring that the final product will meet operational requirements.

Still, not all programs are a good fit for agile software development. System characteristics may preclude the decomposition of program capabilities into incremental deliveries.

The government may lack contractual flexibility to redefine scope to meet the time-constrained deliveries or to slip schedule to maintain quality goals. The contractor may not have the management commitment, core software development capabilities, or culture needed to successfully implement agile processes.

Programs that can adopt agile software development processes can increase the odds of achieving operational requirements.

Aerospace recently published a report[1] to help program offices navigate this new agile landscape. It discusses when agile software development is appropriate, how to transition to agile processes, which contract vehicles work best, and how to tailor the request for proposals and evaluate contractor responses. The goal is to ensure the maximum benefit of agile processes for those programs that can apply them.

REFERENCE

[1] D. Houston et al., *Program Office Guidance for Acquisition of Systems Developed Using Agile Software Development*, ATR-2018-00552; OK'd for public release.

For more information, contact Dan Ingold, 310.336.8818, dan.ingold@aero.org.

DISRUPTIVE MANUFACTURING TECHNIQUES ADD UP

By GAIL JOHNSON-ROTH
The Aerospace Corporation

Additive manufacturing is a rapidly advancing technology that promises process agility along with cost and schedule savings. The technique is well suited for forming complex shapes with near net volume for low production runs. Additively manufactured parts are already flying on some space systems. Implementation challenges include process-sensitive variability, knowledge gaps in defects and nondestructive testing, and a lack of published processes and characterization results.

The Aerospace Corporation recently partnered with the Space and Missile Systems Center to host a series of workshops focused on additive manufacturing. The event provided a platform to highlight progress, share lessons learned, address needs for future planning, and identify challenges and unknowns.

Participants actively brainstorm and collaborate to define challenges for implementing additive manufacturing.

Highlights included a meeting of the Manufacturing Problem Prevention Program under the theme *Quality Strategies for Additive Manufacturing*. Technical presentations discussed materials for space structures, with an emphasis on ensuring material quality. Contributors from government and industry described advances involving in-line monitoring and control with automated tools to predict product quality. Exhibitors showcased new developments in nondestructive and precision imaging techniques.

Kevin Bell, VP of Space Program Operations at The Aerospace Corporation, challenges workshop participants to innovate and implement additive manufacturing to enable faster development and manufacturing of space systems.

The Space System Additive Manufacturing workshop engaged the community to collaborate on comprehensive additive manufacturing guidelines. This activity followed up on a 2017 effort that resulted in a detailed framework for a guidance document. The result, *Guidance for the Development and Qualification of Additive Manufacturing,* covers more than 200 technical topics in 19 chapters; it is currently under final peer review.

Four working groups addressed recognized knowledge gaps in the areas of qualification, outsourcing, defect detection, and production lifecycles. Each group was tasked to identify challenges, solutions, and specific actions for industry, government, and researchers. Each group provided a summary of findings that will be made available to inform future collaboration.

continued on page 4

GET SMART: THE FUTURE OF SPACE SYSTEM MANUFACTURING

continued from page 1

The space industry is transitioning toward new architectures involving constellations of smaller, simpler satellites. To increase production, space contractors will need to move from project-based manufacturing (focused on producing a small number of complex units) to flow manufacturing (focused on producing a high volume of standardized units). Dramatically different workflows based on smart manufacturing will rearrange the value streams and lead to new processes and products. Lean techniques will play an important part in this transition.

Challenges for the space industry include digital engineering with relevant information technology and supplier controls. Space companies have mature design processes but have only just started to digitize the engineering chain. Technical and business processes are being re-engineered to eliminate silos and allow data to flow among different organizations and software tools. Digitization of the engineering process will allow seamless integration across the enterprise.

The space industry is gradually phasing in smart manufacturing technologies. As capital equipment is replaced and updated, contractors are installing "smarter" equipment and creating "islands of automation," which achieve greater efficiency for part of the process but do not represent a complete end-to-end solution. Perhaps the greatest benefits of the newer equipment are enhanced process capability and greater precision, which result in higher repeatability.

Technology often disrupts, rendering older methods obsolete. While significant change lies ahead, there is also optimism about the potential for new technologies to increase efficiency and provide widespread benefits across the space industry.

REFERENCE

Juranek, J., and G.A. Johnson-Roth, *Smart Manufacturing and Space Systems*, Aerospace Report No. TOR-2018-02099, The Aerospace Corporation, El Segundo, CA (May 14, 2018). Restricted distribution.

For more information, contact Jeff Juranek, 310.336.3190, jeff.b.juranek@aero.org or Gail Johnson-Roth, 310.336.0030, gail.a.johnson-roth@aero.org.

2018–2019 EVENTS

December 4–5 *Verification Sciences and Engineering Workshop, Chantilly, VA*

December 4–5 *Space Resiliency Summit, Alexandria, VA*

December 11–12 *Spacecraft Anomalies and Failures Workshop, Chantilly,VA*

December 11–13 *SIA 14th Annual DOD Commercial SATCOM Workshop, Arlington, VA*

January 7–11 *AIAA SciTech Forum 2019, San Diego, CA*

February 12–14 *Systems Engineering Forum 2019, El Segundo, CA*

February 25–28 *Ground System Architectures Workshop 2019, Los Angeles, CA*

March 2–9 *IEEE Aerospace Conference, Big Sky, MT*

April 18–21 *Space Access Conference, Fremont, CA*

April 29–May 3 *AIAA Planetary Defense Conference 2019, College Park, MD*

April 30–May 1 *Space Parts Working Group 2019, Torrance, CA*

May 7–9 *DEFENSE Forum, Laurel, MD*

RECENT GUIDANCE AND RELATED MEDIA

Space Collaboration Council by G. Johnson-Roth et al.; TOR-2018-02592; USGC

Space and Launch Requirements Addendum to AS91000 Quality Management Systems by R. Moorehead et al.; TR-RS-2018-00028; PR

Mission Assurance Baseline (MAB) Version 2.9 by N. Lao et al.; ATR-2018-01658; USGC

Program Office Guidance for Acquisition of Systems Developed Using Agile Software Development by D. Houston et al.; ATR-2018-00552; PR

The Handbook for the Prevention of Plasma Arcing in Spacecraft by D. Landis; TOR-2018-01805; USGC

Congested Space Issues: Effect on Launch Collision Avoidance by G. Peterson et al.; TOR-2018-01875; USGC

Neural Networks: An Educated Buyer's Guide by P. Slingerland; TOR-2018-01921; USGC

Smart Manufacturing and Space Systems by J. Juranek et al.; TOR-2018-02099; USGC

Systems Integration: The Path to Successful Program Execution by S. Aldana-Gutierrez et al.; TOR-2018-02374; USGC

Systems Integration: The Overlooked Program Office Role by G. Larsen; TOR-2018-02451; USGC

System Integration Best Practices by G. Larsen et al.; TOR-2018-02628; USGC

Assessment of the High-Cycle Fatigue Behavior of Inconel 718 Prepared by Selective Laser Melting by D. Witkin et al.; TOR-2018-01620; USG

Additive Manufacturing Prototype Lifecycle Model by M. Nguyen et al.; TOR-2016-03334; USG

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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CYBER DEFENSE FOR CLOUD-BASED APPLICATIONS

continued from page 1

Eirene Sceptre is ideally suited for the cloud; however, local deployments have also proved effective, even for antiquated MS DOS systems. The tool employs responsive machine-learning techniques to collect information on computing processes to help identify potential vulnerabilities.

Eirene Sceptre is being integrated with other cybersecurity tools for monitoring national security space (NSS) assets. Ultimately, the technology will help fill a critical gap in cyber defense specifically for the space domain.

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DISRUPTIVE MANUFACTURING TECHNIQUES ADD UP

continued from page 3

Overall, the workshops underscored how far additive manufacturing has progressed, and how much remains to be done before it becomes a routine part of space system development.

Significant engagement with experts from the space community will be critical to ensure that further adoption is not hindered by overly rigid requirements, knowledge gaps, or misunderstandings between partners in the space enterprise.

For more information about the guidelines, contact Michael O'Brien, 310.336.2878, michael.j.obrien@aero.org and Alvar Kabe, 310.336.7489, alvar.m.kabe@aero.org.

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