AEROSPACE

APPROVED FOR PUBLIC RELEASE

GETTING IT RIGHT

COLLABORATING FOR MISSION SUCCESS

VOLUME 10 | ISSUE 1 | SEPTEMBER 2019

Image courtesy of Sierra Nevada Corporation, used with permission

CHASING THE DREAM

By JOHN V. TURNER
Sierra Nevada Corporation (SNC)
Space Systems

The recent focus on service contracts for human spaceflight programs, rather than government-directed development, has given NASA greater cost effectiveness but puts pressure on providers to make mission assurance even more value added and efficient. From the early days of development under the Commercial Crew Development program with NASA, the SNC Mission Assurance team set out to improve the paradigm for safety and mission assurance on the Dream Chaser® spaceplane. SNC implemented a number of practices that have served SNC well and allowed it to make excellent progress on NASA's Cargo Resupply program.

1. **Early Impact**—Systems safety, reliability, and risk analysis tools were applied early to guide spacecraft trade studies and design selections. In later phases, analysis tools became one of the most important drivers of vehicle channelization.

2. **Integrated Analysis**—Bottom-up failure modes and effects analysis, and top-down hazard analysis were tightly linked to assure capture of all significant risks along with a more comprehensive set of risk controls.

3. **Integrated Risk System**—Systems safety and reliability analysis was built into the systems engineering requirements database. This tool allows direct linkage of failure modes and hazard causes and associated controls, design requirements, test events, and verifications. This approach streamlines the verification process, avoids duplication of verification and test events, and better informs recurring operations.

continued on page 4

FAILURE IN A HAYSTACK

By RYAN ROSS
Jet Propulsion Laboratory

Failure analysis (FA) is the process of collecting and analyzing data to determine the mechanism and root cause of a part failure. The FA result may be sufficient to understand the root cause or it can be one of many data points that a multidisciplinary investigation team needs to systematically ferret out the anomaly.

The last 10 years have brought significant challenges to FA as technological complexity rapidly increased. Modern fin field-effect transistor microcircuits can have over 10 billion transistors, up to 17 layers of interconnect, and wiring across a die footprint reaching

continued on page 2

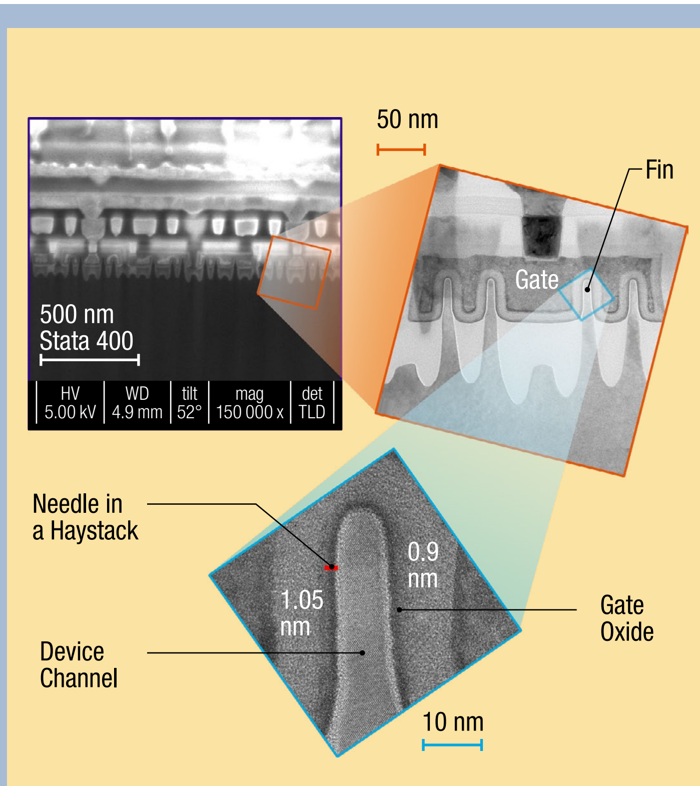


Image courtesy of JPL, used with permission

Failure analysis of microcircuits requires complex imaging and detection systems to root out the needle in the haystack defect.

FROM DIPS TO SIPS

by DOUGLAS J. SHELDON
Jet Propulsion Laboratory

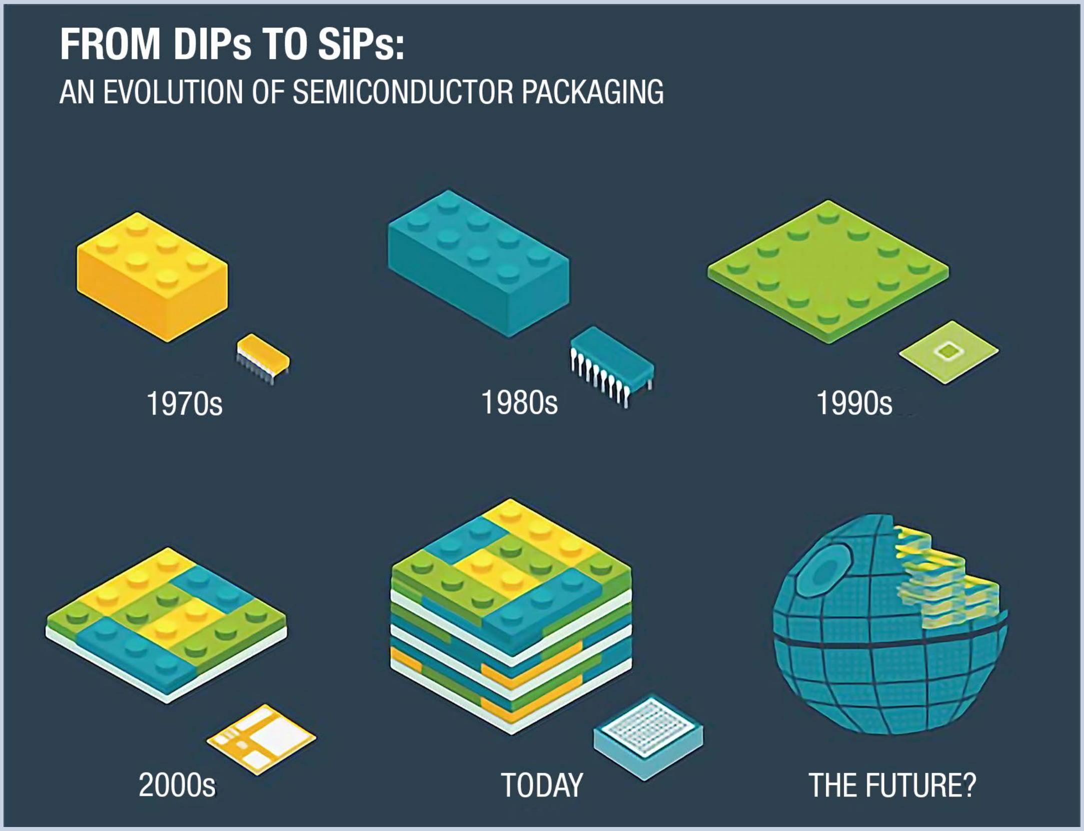


Image courtesy of JPL, used with permission

Evolution of packaging technologies

Packaging technology for semiconductor devices is complex and varied. Hermetically sealed ceramic packages with wire bonded die are still commonly used in high reliability space missions. However, this style of packaging has long ago disappeared from commercial applications. Driven by lower cost, lighter weight, reduced power, and the need to pack more devices into ever smaller forms like cellular phones, many semiconductor packaging technologies are now considered assemblies or systems of chips.

Dual in-line packages (DIPs) gave way to flip chip devices of the 1990s. High-density substrates, redistribution layers through silicon vertical interconnect accesses (vias), and different types and sizes of bumps now define the modern System in Package (SiP) landscape.

Assurance processes to characterize this modern generation of packaging technologies has shifted substantially from the end user to the vendor. End users still rely on historical component stress-based test approaches like temperature cycling, long-term high temperature life test, and humidity + bias testing to benchmark reliability. While providing an overall benchmark, such tests cannot guarantee coverage for all combinations of material and electrical interactions.

Modern SiP devices consist of multiple different size die with thousands of microbumps, various via technologies, and dozens of different dielectric layers. Known good die processes, built-in self-tests, and multiple wafer probing insertions require physics of failure-based design rules and formal tool suites. The goal is to adequately characterize the long-term performance and expected degradation of these state-of-the-art packages. These capabilities are an integral part of the design and manufacturing process and therefore reside with the vendors. Strategic partnerships with vendors are required to both obtain access to their capabilities as well as protect and manage the proprietary nature of this information.

The benefits of modern packaging technologies are profound for the space industry as 10 to 100 times reductions in size, weight, and power are now possible with 10,000 times improvements in processing capabilities. Effective assurance will require a new level of collaboration and intellectual property management to be successful.

For more information, contact Douglas J. Sheldon, 818.393.5113, douglas.j.sheldon@jpl.nasa.gov.

FAILURE IN A HAYSTACK

continued from page 1

$800mm^2$ ($1.24in^2$). This results in hundreds of billions of potential fault locations where the defect may only be a few nanometers in size. Even a seasoned FA expert armed with standard sample preparation, optical imaging, static fault isolation, microprobing, scanning electron, and focused ion beam microscopy tools is challenged without adopting new techniques and tools.

To successfully deploy these modern technology products, the design must include "Design for Testability" diagnostics for failure location, i.e., a "map" to a group of components (netlists) or to a specific transistor: the street address of the defect. Automated test equipment dynamically communicates with fault isolation systems to bound the anomaly location into a reasonable search area for physical deconstruction.

The physical deconstruction process leverages computer-aided design to overlay the failing netlists and narrow down the failure location. In addition to a scanning electron microscopy inspection at each layer, conductive atomic force microscopy and electrical nanoprobing are conducted to further physically isolate the defect. After isolation is adequately completed, a focused ion beam system is used to create a ~20nm-thick transmission electron microscopy sample containing the defect to analyze.

Custom microcircuit design on advanced modern semiconductor technologies requires enabling FA capabilities in the circuit design phase. Modern FA techniques may require custom fixturing, which can take up to six months' lead time to design and build. Early interaction between designers, foundries, and FA teams is critical to ensure the right capabilities are accessible.

The writing and publication of the paper underpinning this article was supported by the Jet Propulsion Laboratory (JPL), California Institute of Technology (Caltech), under a contract with NASA. Any reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement by the United States government or JPL/Caltech.

For more information, contact Ryan Ross, 818.393.5113, ryan.ross@jpl.nasa.gov.

LEADING ADOPTION OF MODEL-BASED SYSTEMS ENGINEERING

By ALBERT HOHEB
The Aerospace Corporation

Model Based Systems Engineering (MBSE) is a key enabler and necessary entry point to go faster in defining, acquiring, and operating as a space enterprise. Integrated models developed with close government–industry coordination can replace a document-centric approach with a model-centric one that provides better capabilities and offers an enterprise solution.

Advancing the practice of MBSE has been cited numerous times by the Office of the Secretary of Defense and by our government partners in addressing near-term and end-state approaches to enable the enterprise, improve acquisition execution, institutionalize evolved systems engineering, and advance MBSE tools.

Here are the top six things leaders should do to drive MBSE adoption:

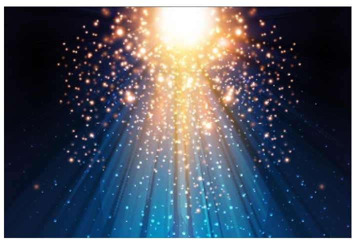
1 **Get smart**—self-educate and benchmark to prepare for organizational change. Identify MBSE subject matter experts and recognized project leaders to coach and engage

them on upcoming decision opportunities. Benchmark with like organizations and give something to get something.

2 **Set the stage**—not the implementation. Explain the motivation for the move toward MBSE, the reasons for desiring change, the

urgency, and how to demonstrate being onboard. Set modeling objectives to cap the amount of modeling and assess its effectiveness. Create an MBSE deployment roadmap to organize efforts contributing to the MBSE vision.

3 **Be the change**—be the role model. Set visible examples by participating in classes, asking for model demonstrations, and above all using the MBSE language to



demonstrate that culture change is underway.

4 **Build the culture and stakeholder commitment**—not the product. Establish the organization's MBSE vision, goals, objectives, roadmap, and resources

with stakeholders. Have conversations to learn from resistant voices. Get stakeholders' commitment to get it done—find leads to get it done even if it takes going the extra mile.

5 **Provide the right capabilities**—align needed capabilities to the organization's transformation objectives. The

continued on page 4

SMALL SATELLITES GOING BIG IN SPACE

By BARBARA BRAUN
The Aerospace Corporation

"I'm really not a fan of launching stuff in space that's not ready or vetted."

Greg Wyler, founder of the space telecommunications company OneWeb, addressed these words to participants of the 33rd Annual Conference on Small Satellites in his keynote address. Held in Logan, Utah, this year's SmallSat conference was the biggest ever, with more than 3,400 participants from 45 countries, representing over 1,000 organizations.

The theme of the conference was "Small Satellite Production," and this was reflected throughout the preconference workshop and during the main conference itself. There were multiple presentations on small satellite constellations, efficient build of multiple small satellites, and options for launching large numbers of small satellites. Carrie O'Quinn led a side session on The Aerospace Corporation's Launch Unit effort, which aims to make small satellite launch more efficient through standardization.

These and other papers also explored small satellite mission assurance approaches. A CubeSat development team from New Mexico State University discussed its experience building its first CubeSat and advised developers to "test early and often" as well as to "create well-documented processes early, keep them updated, and follow them."

Representatives from the Air Force Research Laboratory and the Space Dynamics Laboratory examined mission assurance for constraints-driven missions where schedule, cost, and technical constraints—rather than requirements—drive the mission scope. "Constraint-based missions require tailored systems engineering practices that prioritize demonstrated capability with lower performance over undemonstrated capability with higher performance," the team concluded.

A presentation from Spaceflight Industries in the "Space Access" session discussed the unique challenges of bringing 64 satellites from multiple agencies together on a single rideshare launch. Other sessions included topics as diverse as communication, commercial mission assurance, technology transfer, and the CUMULOS mission.

continued on page 4

2019 & 2020 EVENTS

October 8–10
Satellite Innovation 2019, Mountain View, CA

October 18
12th Annual Nebraska Space Law Conference: Global Perspectives on U.S. Space Law and Policy, Washington, DC

November 5–7
21st Annual Global MilSatCom, London, United Kingdom

November 12–13
Mission Assurance Summit, Chantilly, VA

December 3–5
Spacecraft Anomalies and Failures Workshop, Chantilly, VA

December 10–12
Verification Sciences and Engineering Workshop, Chantilly, VA

January 6–10
IAA Science and Technology Forum and Exposition, Orlando, FL

February 4–6
Microelectronics Reliability and Qualification Workshop (MRQW), El Segundo, CA

March 2–5
Ground System Architectures Workshop (GSAW), Los Angeles, CA

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

April 20–23
Space Power Workshop (SPW), Torrance, CA

SMALL SATELLITES GOING BIG IN SPACE

continued from page 3

Since the first conference in 1987, the small satellite industry has grown from a small group of mostly research and development missions to a booming industry with military, civil, and commercial applications.

Mission assurance approaches for small satellites have also evolved, but as Peter Beck told participants during a presentation on Rocket Lab's debris management approaches, "The safe and sustainable management of [space] must be a global priority."

For more information, contact Barbara Braun, 505.846.8413, barbara.m.braun@aero.org.

Curtis Iwata of The Aerospace Corporation is "GEOpardy" game host at the Small Satellites conference, with game contestants (from left) Andrew Sloan of Cosma Schema, David Mauro of KBR at NASA Ames, and Sara Richardson of Space Dynamics Laboratory.

CHASING THE DREAM

continued from page 1

4. **Probabilistic Risk Assessment**—A simulation-based engineering risk assessment tool was developed in partnership with Ames Research Center to determine Loss of Vehicle, Loss of Mission, and Loss of Personnel risk estimates.
5. **Reliability Allocation**—Reliability analysis and subsystem/dynamic event allocations served to drive resiliency into the design and flag design improvement priorities.
6. **Decision Package Risk Assessments**—All design decision packages received safety, reliability, and quality risk assessments using a standard template.
7. **Wingman Concept**—Analysts were deployed to subsystem teams while maintaining consistent methods, tools, and training to assure continued consistency and rigor in our practices.
8. **Safety and Mission Assurance (SMA) Wiki**—Documents, schedules, team assignments, and other information were shared programmatically through an SMA wiki site, making efforts more transparent and understandable to the team.

Enhancements to traditional mission assurance practices provide high-performance, innovative space solutions that are changing how we reach, explore, and utilize space while reducing the cost and complexity of mission assurance tasks.

For more information, contact John Turner, 720.287.6329, john.turner@sncorp.com.

RECENT GUIDANCE AND RELATED MEDIA

Stakeholder Review of Updated Lithium Ion Battery Standard for Spacecraft Application by V. J. Ang et al.; TOR-2016-01667-Rev B; USGC

Recommendations for Updates to SMC Standard SMC-S-012 for Software Development by D. J. Harralson et al.; TOR-2017-01955-Rev A; USGC

Anomaly Detection in MIL-STD-1553 Bus Commands by M. Mozumdar; TOR-2019-02103; USGC

Cloud Architecture Design Patterns by C. A. Warack et al.; TOR-2018-00402; USGC

Recommendations for Test and Evaluation of Rapid Prototype and Rapid Fielding Programs by D. J. Byrne et al.; TOR-2019-00162; USGC

Stakeholder Review—Tailoring for AIAA S-121A-2017, Electromagnetic Compatibility Requirements for Space Equipment and Systems by R. M. Putnam; TOR-2019-00179; USGC

Differential Capacity Analysis and Apparent OCV Analysis Methods for Lithium-Ion Cells by A. H. Zimmerman; TOR-2019-00829; USGC

Top Six Things Leaders Can Do to Drive MBSE by A. C. Hoheb; ATR-2019-01583; Restricted

Model-Centric Source Selection by A. C. Hoheb; ATR-2019-01782; Restricted

Application and Tailoring Guidance for Standards on Space System Acquisitions by B. Shaw; TOR-2019-02267; USGC

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

For reprints of these documents, except as noted, please contact library.mailbox@aero.org.

LEADING ADOPTION OF MODEL-BASED SYSTEMS ENGINEERING

continued from page 3

resultant plan should be unique to the organization and may be roadmaps, digital engineering compliance plans, enterprise architecture development plans, acquisition plans, system engineering plans, etc.

6 **Start small**—the right pilot project. This could be a research project or a shadow on an existing effort that assists a project on a noninterference basis to show value. The idea is to build capabilities, understand when/how to apply MBSE, and to build trust by using the MBSE results with decisionmakers.

REFERENCES:

Hoheb, A., *Leading Model-Based System Engineering (MBSE) Adoption—Top Six Things Leaders Can Do to Drive MBSE*, OTR-2019-00913, The Aerospace Corporation, El Segundo, CA (2019).

Noguchi, R., *Lessons Learned and Recommended Best Practices from Model-Based Systems Engineering (MBSE) Pilot Projects*, ATR-2016-02309, The Aerospace Corporation (June 14, 2016).

For more information, contact Albert Hoheb, 310.336.0472, albert.c.hoheb@aero.org.

AEROSPACE
GETTING IT RIGHT
COLLABORATING FOR MISSION SUCCESS

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.

Click here to subscribe.