Assurance Technology Program Office (ATPO)
Annual Report – FY2018
Office of Safety and Mission Success

Jet Propulsion Laboratory
California Institute of Technology

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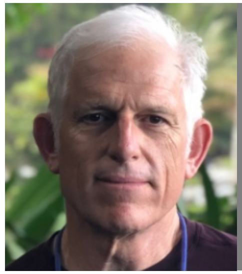
Overview from Program Management

The Assurance Technology Program Office (ATPO) is a broad technology portfolio of tasks designed to advance and develop understanding and capabilities in a wide array of assurance disciplines. ATPO program funding is provided from the NASA HQ Office of Safety and Mission Assurance (OSMA). This means ATPO activities are designed to support OSMA's mission of the development, implementation and oversight of agency-wide safety, reliability, maintainability and quality assurance policies and procedures.

In 2018 ATPO programs continued to support both heritage commitments as well as pursuing and developing several new technology opportunities. ATPO also continued to provide support and promote educational outreach and career development opportunities.

Highlights from 2018 include the development and application of modern data science tools to a wide variety of subjects, from the issue of supplier ranking to the classification and prediction of single event effect induced latchup, new precision measurement techniques for qualification of additively manufactured flight articles, and agency level guidance documents on such diverse topics as interactive checklists for auto-generated code to proton testing complex EEE parts.

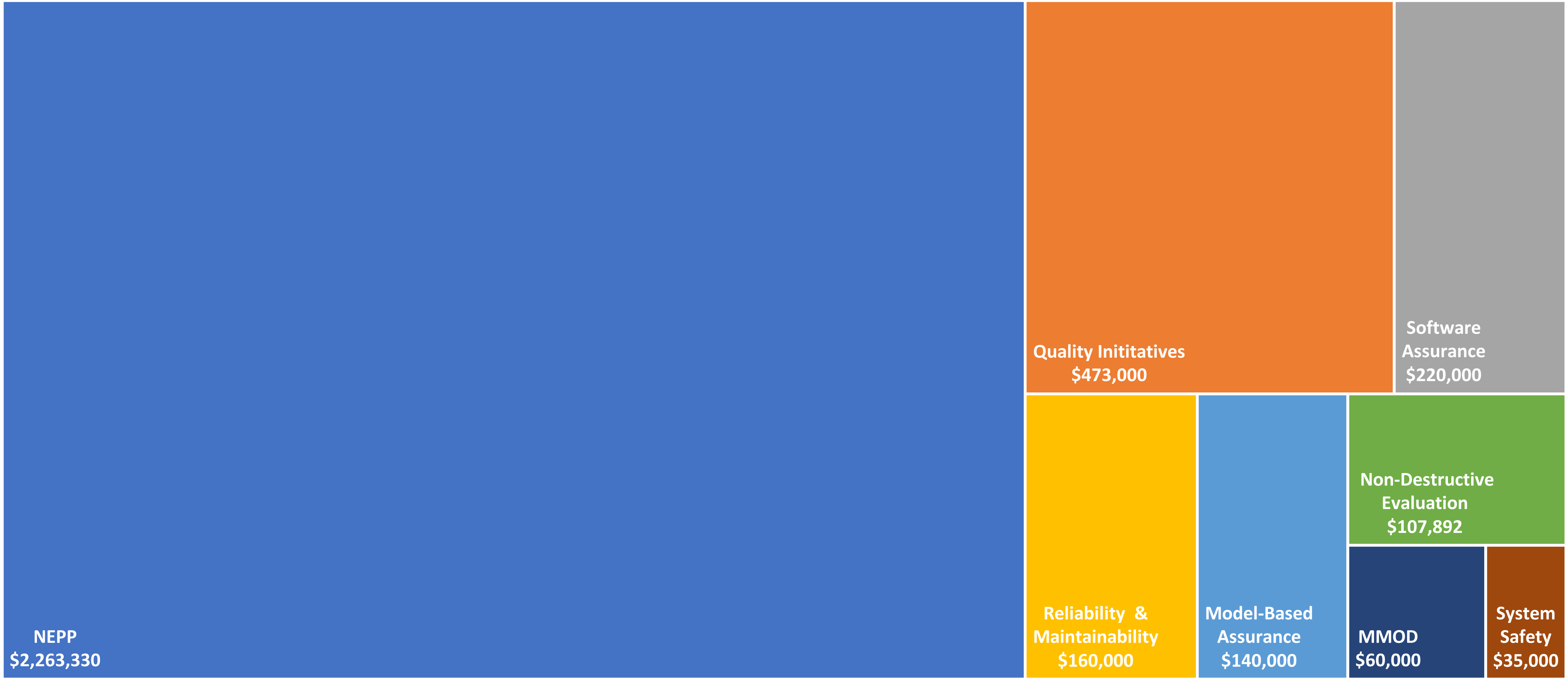
Assurance as a concept addresses several interconnected themes such as confidence, success, certainty, and capability. ATPO tasks reflect this interconnectivity and interdisciplinary nature. ATPO tasks are managed by investigators recognized for their technical and subject matter expertise. They also represent a complete spectrum of the Safety and Mission Success culture and responsibilities. ATPO deliverables range from test reports to guidance documents to audits and team collaborations. All investigators listed in this report are full time JPL employees expect were noted.



ATPO Program Manager
Dr. Douglas Sheldon

Structure and Financial

ATPO 2018 Budget - $3,459,000



The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

Micrometeoroid and Orbital Debris (MMOD)

Orbital Debris Measurement

ATPO's MMOD program enhances the NASA Orbital Debris model with radar observations at roughly two-week intervals of orbital debris at a unique size scale (2 mm -10 mm.). Amount of debris at this size is very large (99.3 % all < 1 cm), and is a potential hazard to humans on EVA in LEO, as well as the DragonX and the future SLS/Orion MPCV.

Using JPL's Deep Space Network (DSN) GSSR transmitter on the 70-m antenna (DSS-14) and a receiver at 3.5-cm wavelength on a nearby 34-m antenna (presently DSS-25/DSS-26), a two-station radar observations of orbital debris at a unique size scale (2 mm to 10 mm) is performed.

The MMOD Radar does not track the objects that are detected. Rather, it stays in a "staring mode" that essentially samples whatever objects pass through the field of view. Both telescopes currently point due East (azimuth =90 deg.) at elevations of 75 deg. for their "stare". While the debris is in the field of view, its range, Doppler shift, orbital inclination, and signal strength are measured. The signal strength is then converted to apparent radar cross section.

Martin Slade, Ph. D.

Software Assurance Research Program (SARP)

Software Assurance Guidance – Model Based Software Development & Auto-Generated Code (AGC)

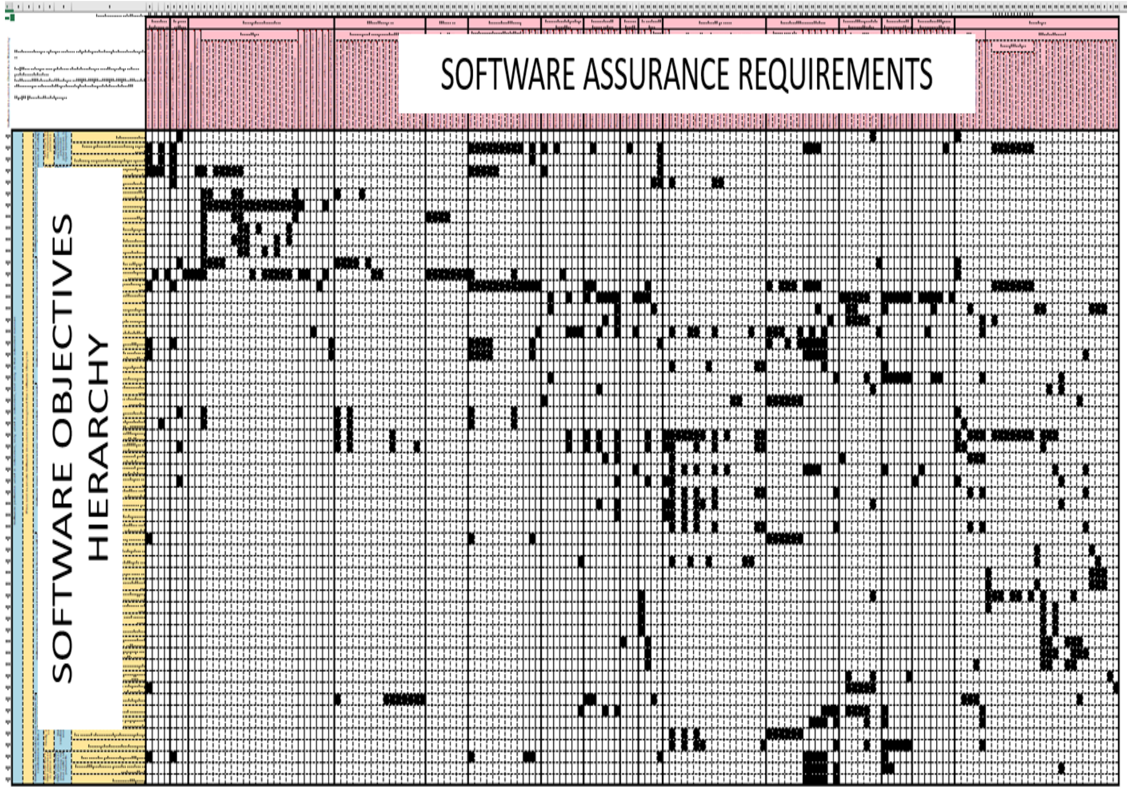
This task was designed to help Software Assurance engineers comprehensively identify project risks and plan appropriate assurance activities according to the variant of MBSD/AGC used and project context. The output of the task was two deliverables:

Assurance Guidance Interactive Checklist: Generates a set of detailed questions and associated information customized to the project's use of MBSD.

AGC Guidance Material for Software Assurance Handbook: Provides additional information on the Software Assurance Standard's requirements pertaining to AGC, covering; assurance of the decision to use AGC, assurance practices to follow during AGC use, and finally Assets, Lessons Learned, and References.

Adapting the Software Assurance Objectives Hierarchy to a Model-based Reuse Process

This task Investigated and characterized the extent of assurance that can be obtained using the Software Assurance Objectives Hierarchy (SOH) and Risk Informed Safety Case (RISC) concepts. SOH and RISC concepts define what assurance must show, while traditional standards define what assurance must do. A mapping of SOH and RISC concepts to Applicable Standards was part of the the functional deliverable.



Software Objectives Hierarchy mapped to Software Assurance Requirements

Each objective is supported by meeting one or more of the requirements and each requirement provides support to one or more of the objectives

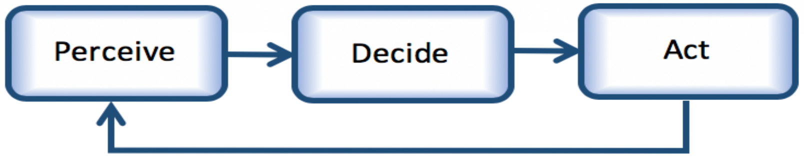
Martin Feather, Ph.D.

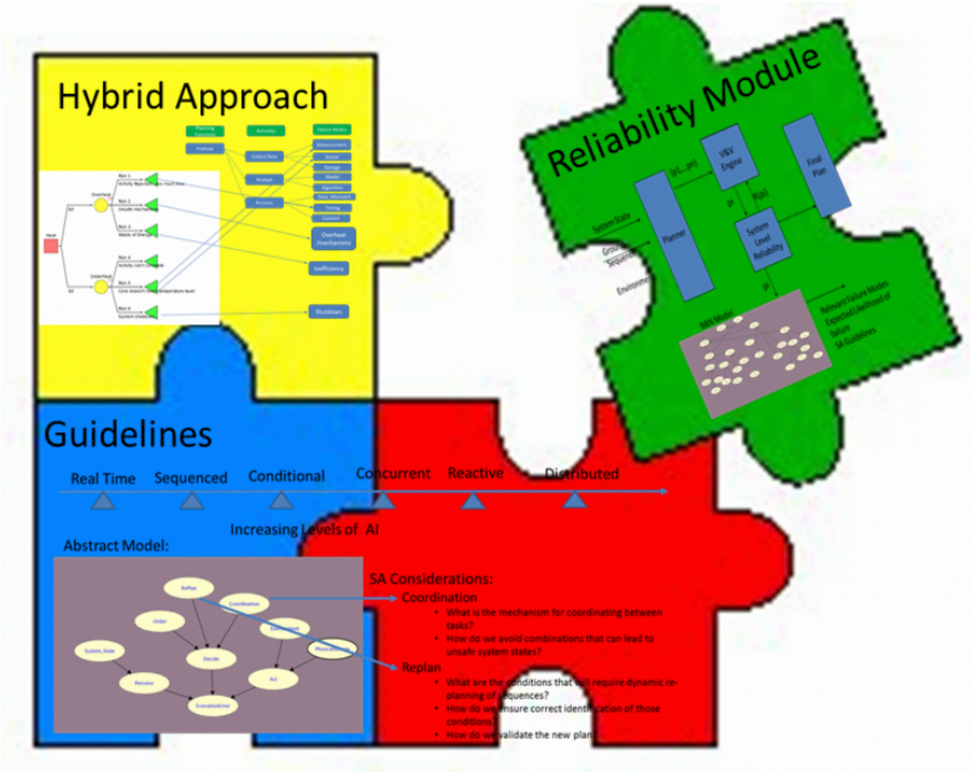
Software Assurance Research Program (SARP)

Method to guide assurance for autonomous software and operations
Autonomy is defined, as *"making decisions and taking actions, in the presence of uncertainty, to execute the mission and respond to internal and external changes without human intervention."* Each class of spacecraft autonomy includes a set of perceptions, decisions and actions, which depend on the level of autonomy involved and correspond with uncertainties and possible unreliability for spacecraft.

This task provides methods and tools for making informed decisions for assurance of autonomous software and operations. In 2018, we developed a hybrid modeling framework for the identification of failure modes and a suggested architecture for the systemic consideration of reliability for autonomous systems.

The hybrid modeling framework, which is based on combining Decision Trees and Bayesian Belief Networks, contributed to the development of guidelines for the assurance of the three key types of autonomy software: fault protection, command execution and planning. The suggested architecture fills an identified gap in the existing literature for the verification and validation of autonomous systems.





Lelia Meshkat, Ph. D.

Reliability and Maintainability (R&M)

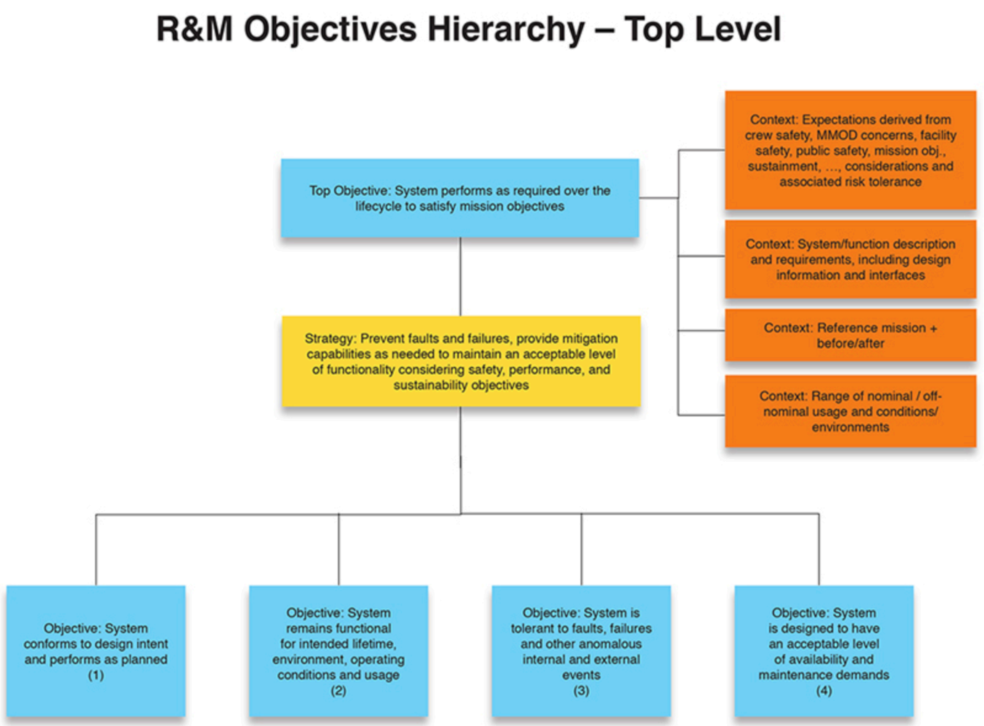
Guidebook for Reliability & Maintainability Standard

In 2014 OSMA started the development of a objectives hierarchy approach for the R&M discipline to systematically decompose technical considerations that form the basis for the R&M discipline. Based on elements of Goal Structured Notation (GSN), this logic-based formalism uses structures and symbols to document safety and/or assurance cases. The resulting R&M hierarchy has four sub-objectives; design conformance, longevity, tolerance to faults and failures, and maintainability.

This effort culminated in the new NASA's Reliability and Maintainability Standard for Spaceflight and Support Systems, designated as NASA-STD-8729.1A. The standard provides a comprehensive set of R&M objectives and strategies that spaceflight programs and projects can tailor as needed to ensure R&M is designed and built into their systems.

The standard was recently updated to better align with the objectives-based program- and project-management approach outlined in NASA NPR 7120.5, NASA's Space Flight Program and Project Management Requirements. That update included significant discussion of the objectives hierarchy.

This task is to designed to provide a companion guidebook that will help connect the new standard to more familiar and heritage R&M processes.



Top Level of R&M Objectives Hierarchy

Chet Everline

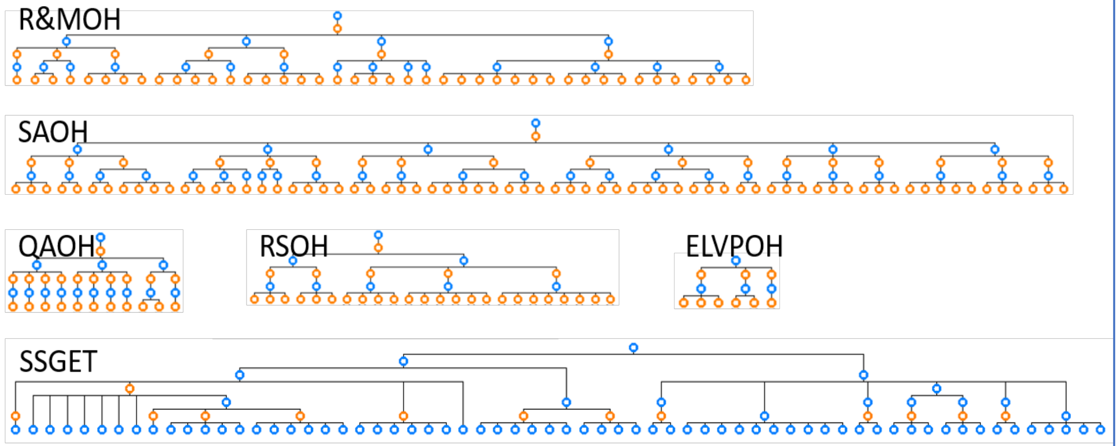
Reliability and Maintainability (R&M)

Trilateral Hierarchy Support

This task fostered and supported the ongoing collaboration between NASA, ESA, and JAXA regarding Reliability and Maintainability standards and approaches.

The approach was to look for commonalities and generalities among several of the NASA OSMA Objective Hierarchies (R&M, Software Assurance, QA and possibly System Safety), including transfer of ideas seen in one hierarchy to others. Visualizing the “shape” of the hierarchies helped identify such commonalities.

The 2018 TRISMAC (Trilateral Safety and Mission Assurance Conference) held at Kennedy Space Center provided a formal setting for joint meetings and discussions related to approaches to hierarchy and related topics such as Autonomy Assurance. A model based, hierarchical approach to autonomy assurance helps to identify testing modes, analysis formulations, methodologies and external architecture assessments.



- R&MOH = Reliability & Maintainability Objectives Hierarchy
- SAOH = Software Assurance Objectives Hierarchy
- QAOH = Quality Assurance Objectives Hierarchy
- RSOH = Range Safety Objectives Hierarchy
- ELVPOH = ELV Payload Objectives Hierarchy
- SSGET = System Safety Generic Evaluation Tree

Martin Feather, Ph.D.

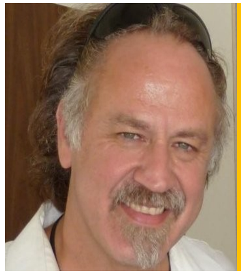
Reliability and Maintainability (R&M)

Model Based Mission Assurance

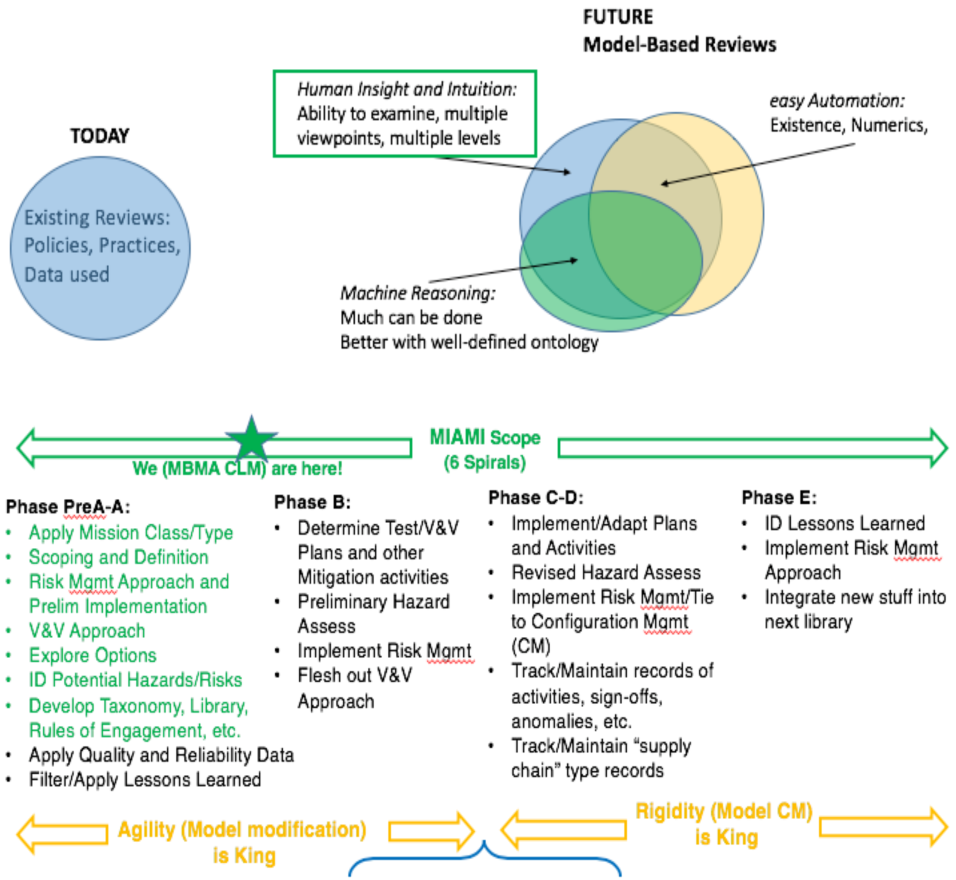
Model Based Mission Assurance (MBMA) describes the application of Model Based Systems Engineering (MBSE) methodologies to the Safety and Assurance disciplines. In MBSE, a virtual model of the system is created, typically while it is still in the designing and planning phase.

The model is used as a singular reference source — a "single point of truth" — for system concept, requirements and design, and verification and validation and associated data. Safety and Mission Assurance (SMA) can leverage that model to perform a variety of assurance analyses earlier in the life cycle reducing the occurrence of costly changes after the system design hardens. By using the MBSE model, SMA personnel will be able to run simulations and tests in real time, instead of having to work with often thousands of pages of documentation.

This task supports the NASA MIAMI initiative to pilot MBSE at Wallops Flight Facility. The NASA MBMA efforts are to define and explore integration of MBMA into system and analysis models. The MIAMI MBMA efforts are focused on 1) integrating WFF S&MA Elements (Hazards, Requirements, Procedures) into the Sounding Rocket/MaGIXS SysML model and 2) "lowering the barrier" to entry for non-experts to interact with the model using View, Viewpoints and external tools.



Steve Cornford, Ph. D.



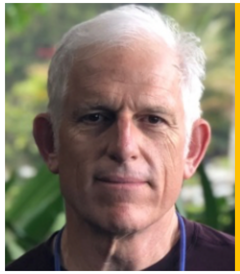
Reliability and Maintainability (R&M)

Small Sat Constellation Assurance

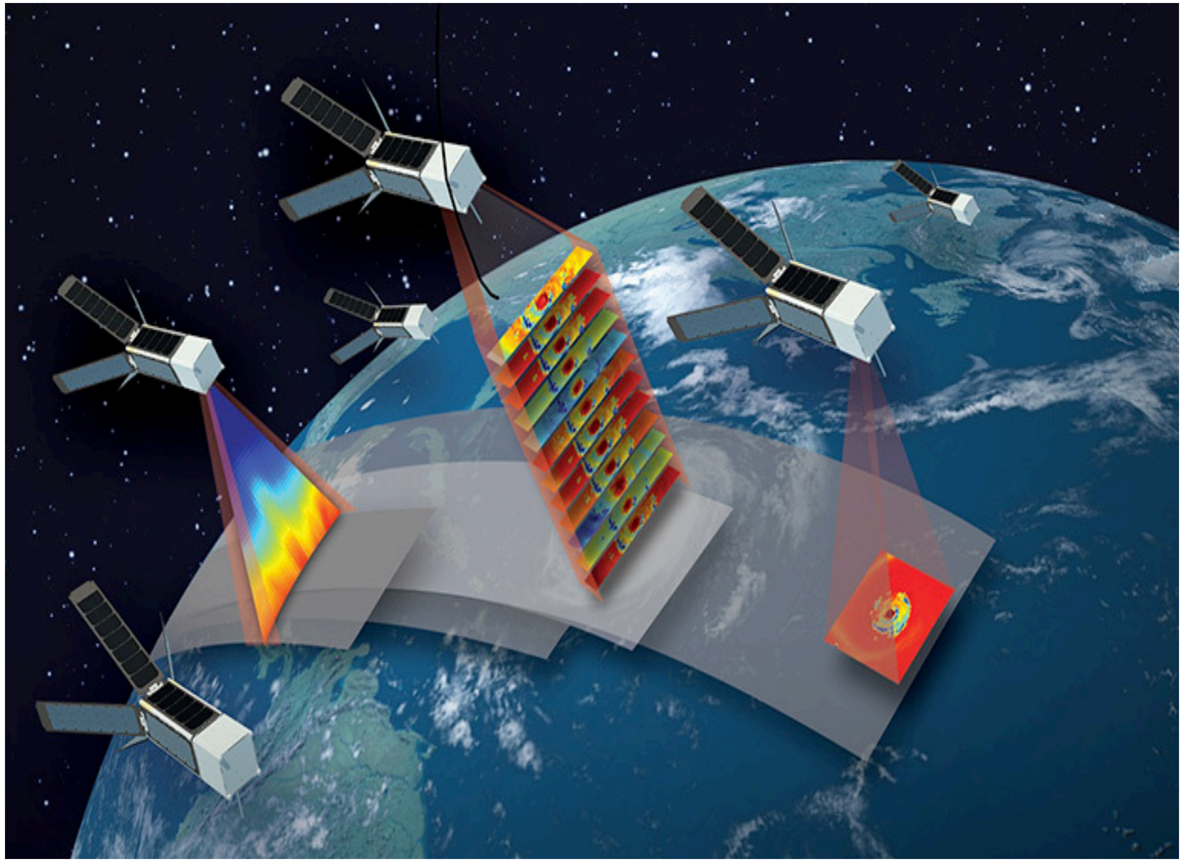
Small sat constellations continue to revolutionize all aspects of spacecraft design and mission systems engineering. There is significant interest by many organizations and companies to launch constellations of small sats. Such constellations can provide dramatic increases in coverage area. Relatively inexpensive instruments can be linked together to provide technical performance similar to a large and expensive instrument.

Assurance of small sat constellations highlights the challenges associated with a fast moving technology platform. The manufacture and orbital implementation of a variety of these constellations dramatically define the new ”entrepreneurial” space age. The rate of investment funding for commercial space projects has increased 250% over the years 2014 to 2018.

Constellation assurance covers many areas. Use of redundant parts within the platform are often excluded in order to keep costs low and the size and energy supply limitations. The overall life expectancy is less, often due to less fuel. Stable orbits sometimes cannot be maintained given these reductions in power. Operation of large constellations becomes too complex for manual operation and automated processes have to be implemented. Ground operating systems need to evolve as fast as satellite systems evolve. The use of artificial intelligence and autonomous systems both on the ground and in the constellation will be required to address the concerns and improve overall constellation reliability.



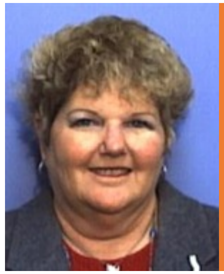
Dr. Douglas Sheldon



Quality Initiatives

Quality Leadership Forum (QLF)
ATPO leads the planning, scheduling and coordination of all QLF activities for 2018. Over 140 attendees at this year's QLF. The principal objectives of the QLF are to: Integrate quality approaches, standardize quality practices, resolve current problems, improve use of quality resources, define and analyze quality risks, communicate lessons learned, share best practices, and improve quality processes.

Joint Audit Planning Committee (JAPC)
The JAPC is a joint government-industry committee that collaborates through discussions on quality audits coordination and performance, and sharing of valuable relevant supplier quality information. The main focus of the JAPC is to share supplier quality data throughout NASA and Prime Contractors. This enhanced capability allows the identification of supplier risks and the ability to tailor Quality Assurance actions.
The JAPC also works to standardize supplier auditing practices that will yield consistency. This means sharing best practices and lessons learned. In 2018 new AS9100D high risk clauses were identified and where aligned to the audit guide and the new process/risk-based audit focus model.



Diana Shellman

Tony Gutierrez

Counterfeit Parts Awareness Training

Counterfeit electronic parts continue to be a significant concern and risk for high reliability missions. The total number of counterfeit incidents reported by the United States Department of Commerce is well over 5,000 individual cases every year. This task promotes greater awareness of the issue and involves the scheduling and completing periodic courses throughout NASA, other Federal Agencies and the Space and Defense Industry.

In 2018 this task collaborated with NASA Safety Center to film and release two Counterfeit training courses in NASA's Satern (System for Administration, Training, and Educational Resources). The ATPO Counterfeit Part Awareness task also continues to provide training to a variety of NASA meetings and organizations, including NASA Quality Leadership Forum, Kennedy Space Center, and the Jet Propulsion Laboratory. Also a new revision of the JPL Counterfeit Parts Avoidance Working Group was released.

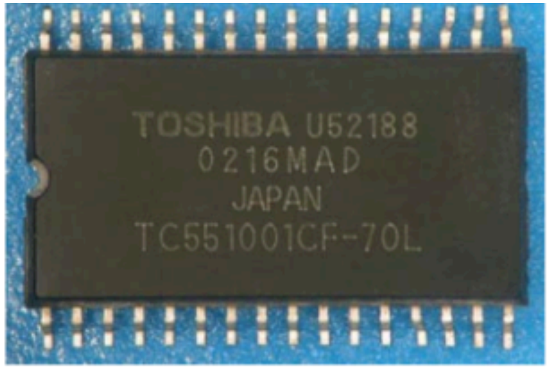


Figure 1(a): Optical photographs of two packages with same date code show very similar markings, but mold marks are missing on one device.

Figure 1(b)

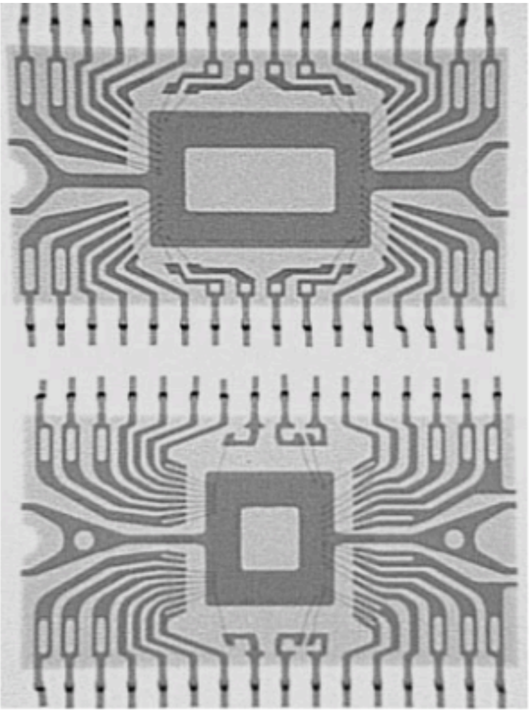


Figure 1(c): X-ray inspection of packages in 1(a) and 1(b) indicates two products that are clearly different. One has been re-marked and mixed in with authentic components to prevent detection.

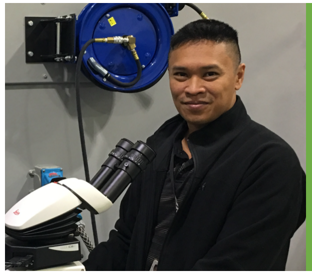
Mark LeBlanc

Non Destructive Evaluation

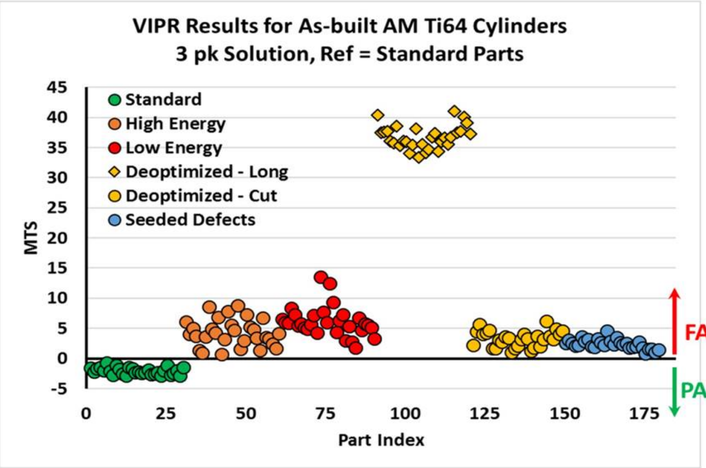
Process Compensated Resonance Testing (PCRT) of Additively Manufactured Materials
Additively Manufactured (AM) materials are quickly becoming a strategic game changing and mission enabling technology for all levels of NASA missions. The innovative AM structures and processing machines represent a challenge and an opportunity for the Assurance community in terms of risk reduction and meeting mission requirements.

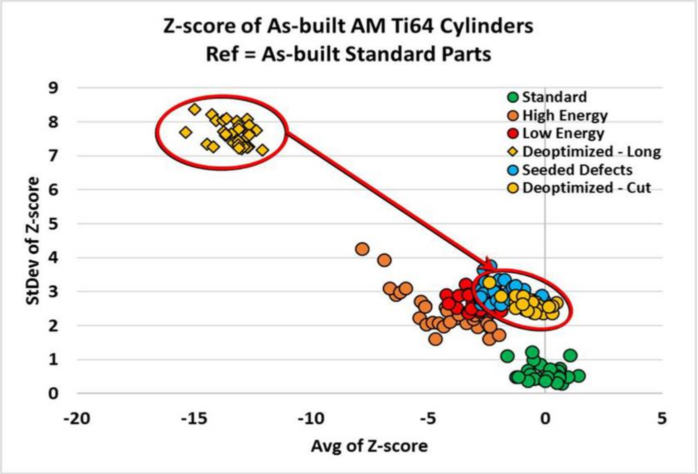
ATPO has emphasized the Process Compensated Resonance Testing (PCRT) as a flexible and quick turn evaluation tool to support process development and variation identification. PCRT combines the collection of broadband resonance data in the ultrasonic frequency range with advanced pattern recognition software to produce an accurate, fast and automated nondestructive inspection. Parts with flaws or changes in material and geometric properties affecting structural performance are immediately detected and flagged.

In 2018 multiple builds of Ti6Al4V tensile coupons with variations in energy density for melting were compared to the standard manufacturing process. PCRT was used to compare the differences in their resonant responses to identify pass/fail criteria. Results of the task shows that the PCRT method can identify coupons that exhibited different melting characteristics during build. It was also determined that small variations in mass between the tensile coupons amplify the differences in resonant response.



Ian Luczon



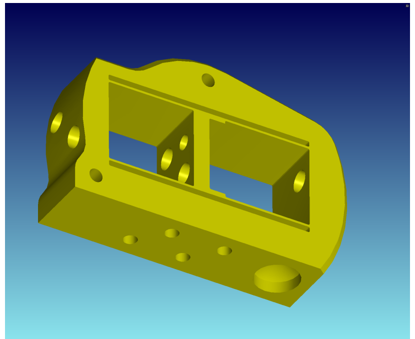


Non Destructive Evaluation

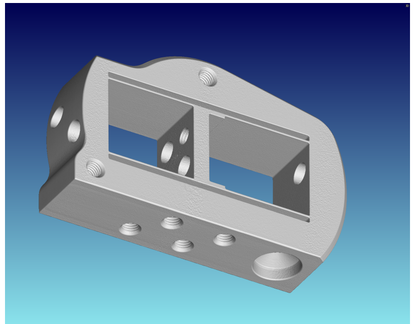
3D/4D X-Ray Computed Tomography Analysis

Computer Aided Drawing (CAD) tools and models represent a foundational basis for success in the Additively Manufactured (AM) assurance processes. The more the CAD tools accurately reflect the final produced AM structure, the higher the confidence the mission has in the fitness for the structure to meet requirements. Deviations between expected CAD drawings and final real world samples represent a state of the art assurance task for ATPO in 2018.

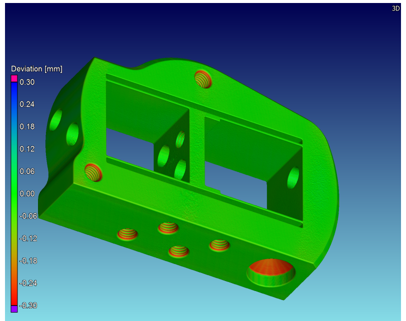
This tasks utilizes JPL's state of the art 3D Computed Tomography X-Ray Inspection machine and software. This X-Ray inspection capability provides detailed analysis for dimensionality comparison to initial CAD drawing. Colorized visualization of deviations between CT data of actual part versus original CAD Drawing. Metrology tools are also used to visualize anomalous material density features like inclusions, porosity, voiding, or cracks, and colorize defects by size. In 2018 the initial workflow has been implemented and training completed, first part to CAD comparison result of a Mars 2020 gripper flexure has been accomplished as a reference example.



CAD drawing



X-ray CT data



CAD-CT deviation

John Bescup

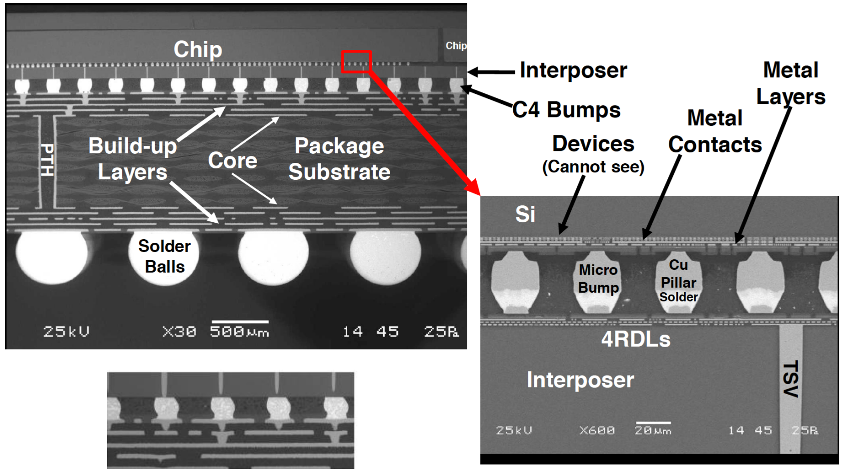
NASA Electronic Parts and Packaging (NEPP)

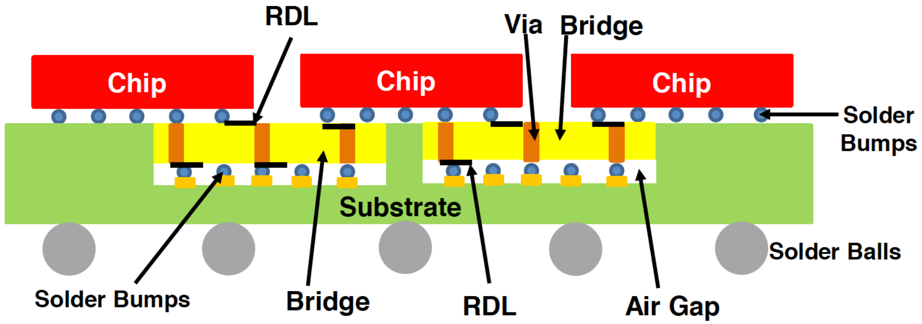
2.5 and 3D Packaging

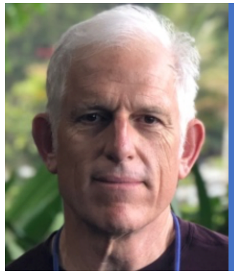
In collaboration with the NEPP program, ATPO has taken a leadership role in the analysis, qualification and infusion of the 2.5 and 3D packaging technologies into NASA missions. These packaging technologies represent a fundamental shift in how semiconductor die are attached and assembled for system. By providing vertical (Z-dimension) interconnect technologies, both via and bond pad, true revolutions in Size, Weight and Power (SWaP) are now possible. The benefits to space missions are profound.

The technologies are driven by enormous demand in the consumer market, particularly mobile phone industries. There are many different solutions that become customized to very particular sub-markets and implementations. This means that there are a wide array of dielectric and conductive materials sets and connection methodologies. Each of these represents a new qualification and risk management challenge. Mil-aero industries are also keenly interested in this technology space and working to provide 2.5 and 3D packaging options to their customers.

ATPO has conducted detailed screening and physics of failure experiments for a wide variety of 2.5/3D technologies and provided body of knowledge/best practices documentation. Understanding thermal/mechanical stress at these wide variety of interfaces represents the foundational tool for long term reliability activities. ATPO/NEPP also support industry outreach through agency wide telecons and meetings.





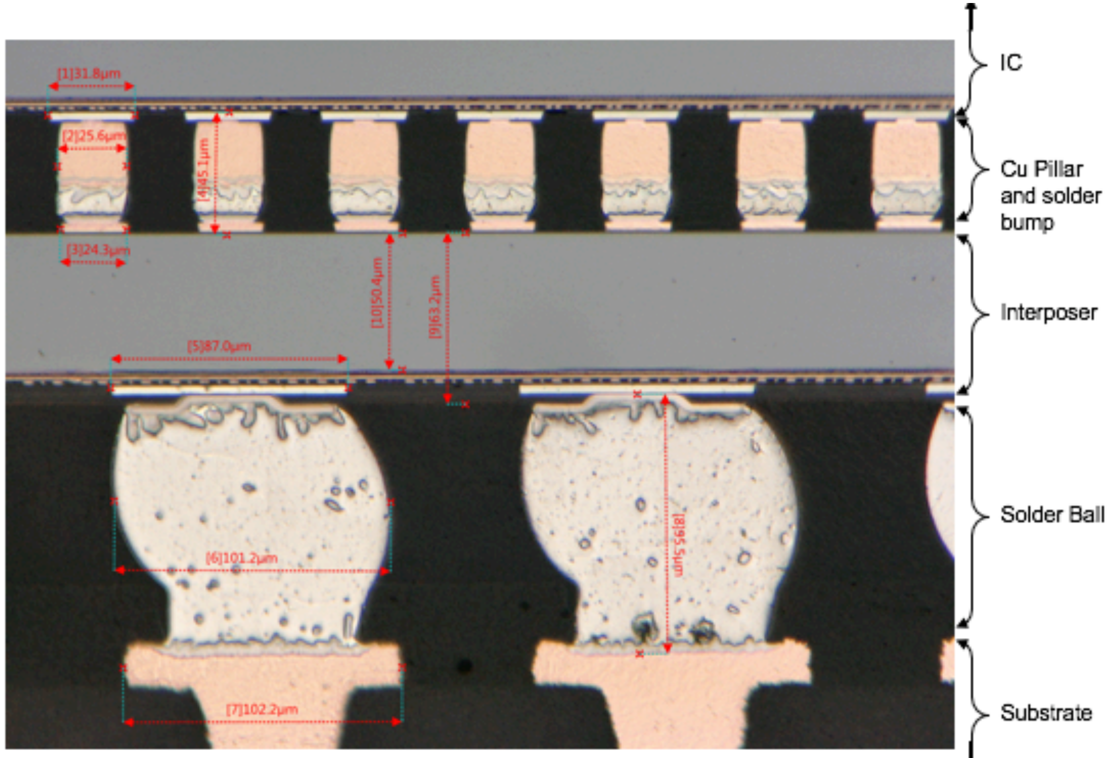


Dr. Douglas Sheldon

NASA Electronic Parts and Packaging (NEPP)

2.5D/3D COTS Packaging Technology Evaluation
The commercial semiconductor industry is constantly adjusting trying to accommodate the technology and manufacturing requirements needed for competitive 2.5/3D packaging solutions. Some wafer fabs are extending their processing expertise to develop such solutions while historical back end assembly and test companies are moving to develop much more capable technology bases as part of the OSAT (Outsourced Semiconductor Assembly and Test).

This task seeks to leverage and established relationships with a variety of state of the art 2.5/3D packaging technology providers. This partnership has resulted in obtaining a variety of test vehicles representing the limits of modern 2.5/3D packaging. This includes 5um 10:1 aspect ratio TSV (Through Silicon Via), 50um die thickness, and <1mm BGA pitch. These samples are being subjected to a variety of thermal cycling conditions to determine upper and lower operational temperature boundaries. This information is needed to help assess the viability of these modern technologies for ruggedness in spaceflight operation.



High magnification optical photo with feature measurements.

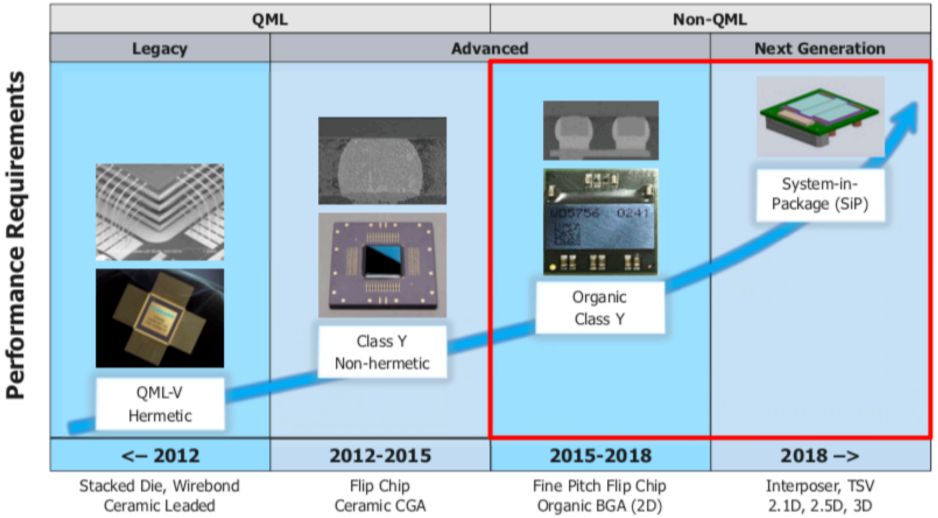
Ryan Ross

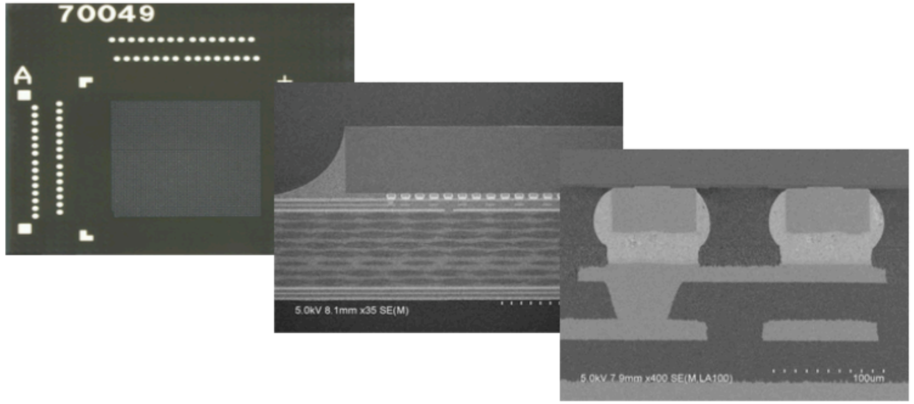
NASA Electronic Parts and Packaging (NEPP)

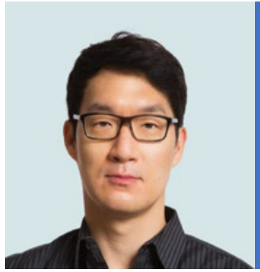
Cu Pillar Flip Chip Collaboration with Cobham

NEPP and Cobham have a long established collaborative relationship for a wife variety of packaging technology evaluations. Cobham is a leading provider of a wide range of mil-aero parts technologies and systems. Copper pillar flip chip is the commercial state of the art interconnect technology for very high-density 2D devices.

In collaboration with Cobham Semiconductor Solutions, a Cu pillar flip chip test vehicle was developed to study the reliability and to help identify the effective space level requirements for the technology. 80 samples were fabricated to evaluate 10x10mm and 20x20mm die. Initial characterization of die attach and temp/humidity exposure have been performed and thermal cycles testing is being performed.







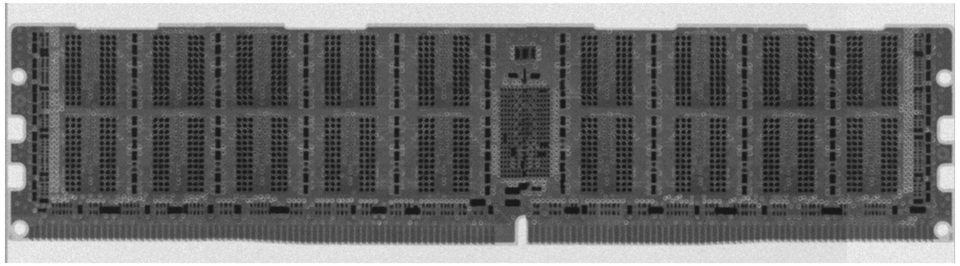
Eric Suh, Ph. D.

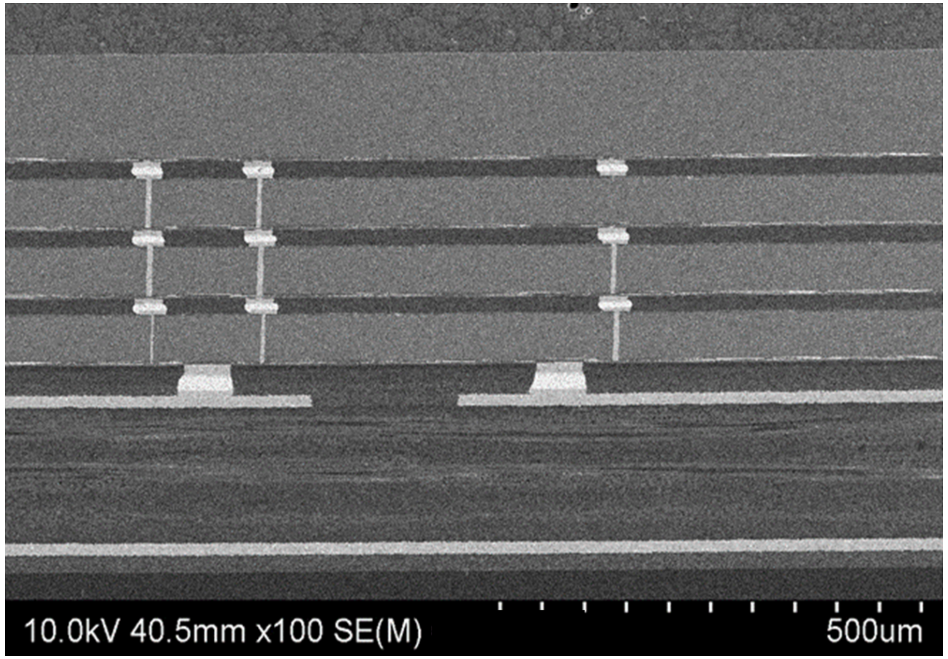
NASA Electronic Parts and Packaging (NEPP)

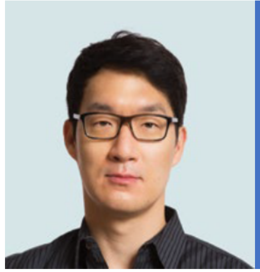
DDR4 TSV Reliability

Through silicon via (TSV), the key enabling interconnection technology for 2.5D and 3D devices, was evaluated using 3D COTS SDRAM. Memory devices are often the most logical device to implement a wide variety of stacking technologies. Signal propagation delay is mainly determined by wiring length and pin capacitance. Three-dimensional integration of identical memory devices is a robust solution to improve performance without increase of power consumption.

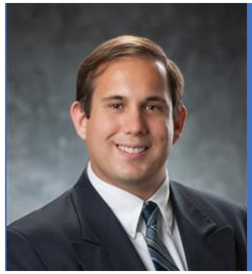
TSV solutions for DDR4 devices have been available for 3 generation of technology, 40, 30 and 20nm. This task used 30nm Samsung 3D DDR4 DIMMs. These DIMMs were procured, environmentally stressed, functionally tested, and destructively analyzed to understand reliability. 10 DIMMs (each with 36 devices) were thermal cycled between 1000 and 4000 cycles from -55C to +125C and evaluated for functionality and failure modes.







Eric Suh, Ph. D.



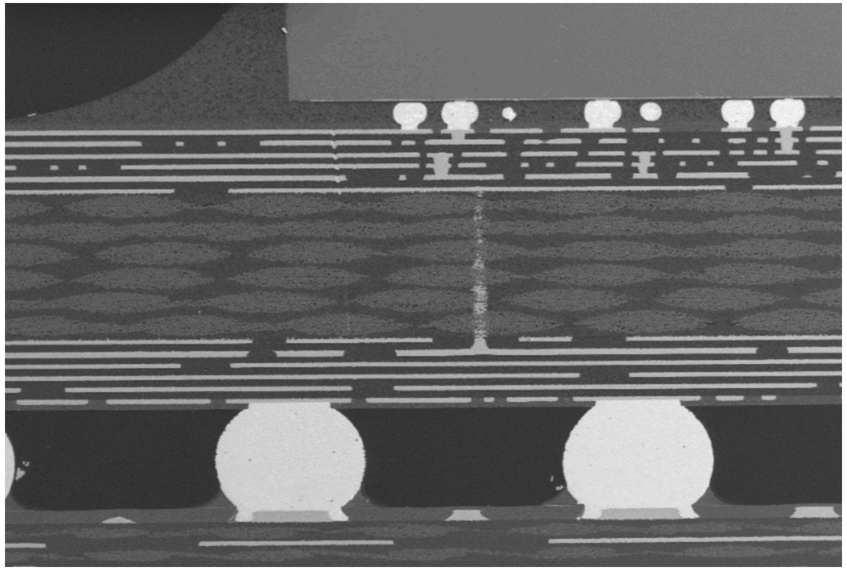
Joe Riendeau, Ph. D.

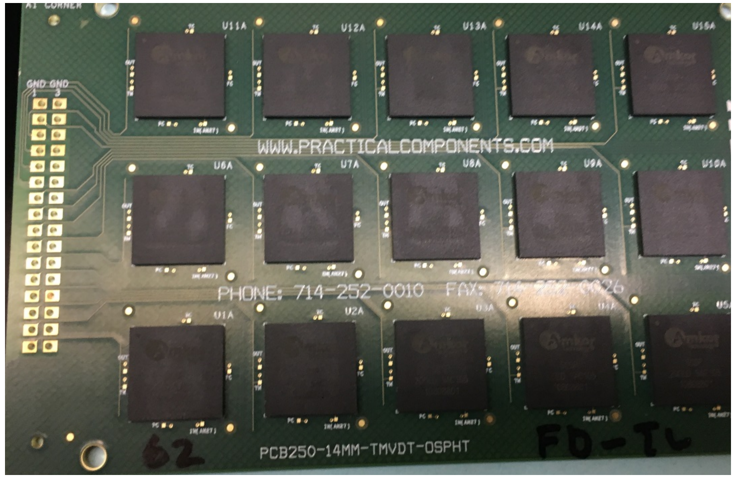
NASA Electronic Parts and Packaging (NEPP)

2.5D Packaging Daisy-Chain Evaluation

Daisy Chain devices are simple resistive links that allow for high precision measurement of subtle changes in materials properties. Testing daisy chain samples forms the basis for physics of failure and baseline qualification testing prior to final complex part testing.

This task reviewed and stressed a wide array of different daisy chain vehicles that represented many different aspects of the 2.5D packaging technology. This includes through mold via, various solder ball material combinations, and different dimensional scaling of TSV and stacking materials. Testing involved PC board level stressing using a variety of thermal cycling profiles.





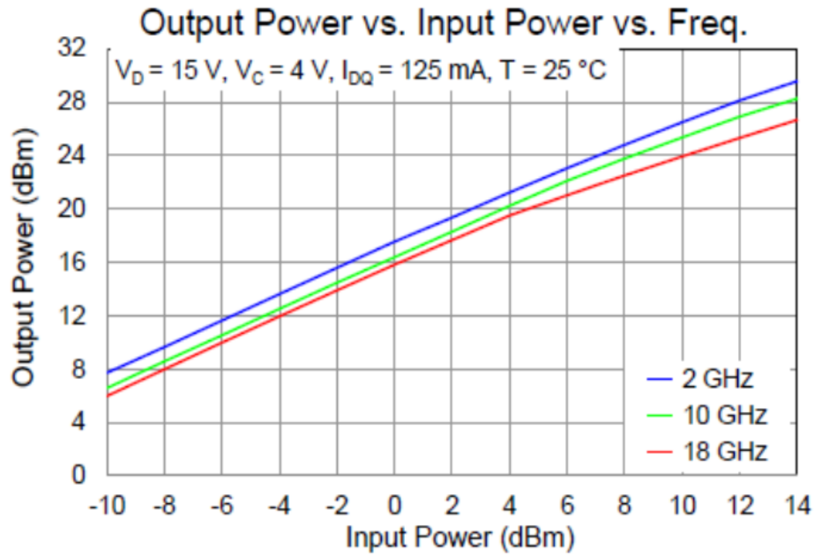
Reza Ghaffarian, Ph. D.

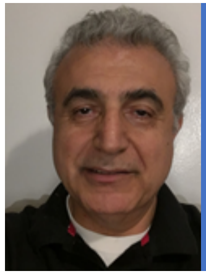
NASA Electronic Parts and Packaging (NEPP)

Radio Frequency (RF) Small Satellite Device Degradation

Small sat missions use a wide array of COTS EEE parts for RF communications. The frequency bands range from VHF to UHF and above. Radio system design is often viewed as one of the most complex subsystems in any spacecraft design. For small sats with first time satellite designers, errors in RF systems are one of the leading cause of on early (<90 day) on-orbit failures. Variation in part quality and/or limited performance margins can result in mission ending radio failures. Understanding how COTS RF parts degrade over time is an important result to support NASA's small sat missions.

This task seeks to understand the relationship of RF EEE part degradation using both standard DC biased life test as well as RF biased life test. Typical DC life tests use temperature and current density to define failure mechanisms. Various degradation mechanisms like hot electron trapping, dielectric breakdown, etc. each have a unique activation energy and acceleration constant. RF operation metrics like power output and gain often reflect different operational bias conditions for transistors that need to be accurately accounted for with respect to long term reliability stress.





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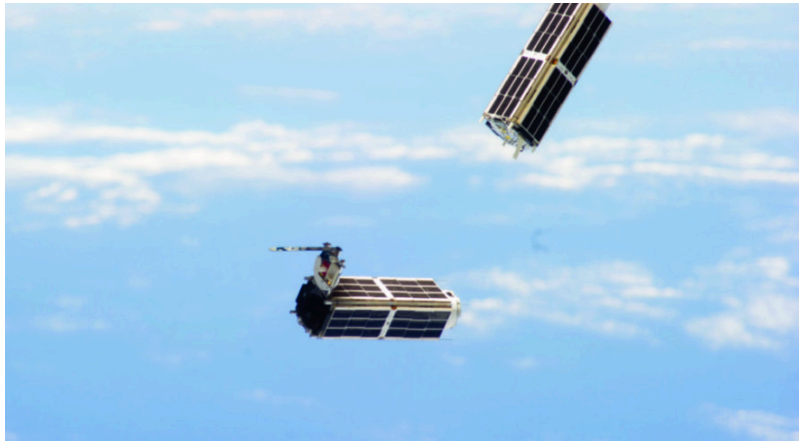

NASA Electronic Parts and Packaging (NEPP)

Non-volatile Memory Technology Reliability

Nonvolatile memory technology is a fundamental mission building block for all spacecraft systems. Reliability of memory technology is a key deliverable of the NEPP program as memory errors often represent the #1 error signature encountered on all space programs. Nonvolatile memory can easily be categorized into two basic technologies, floating gate and everything else. Floating gate devices are most often NAND memory devices. Such NAND memory devices represent the absolute state of the art in terms of memory density. COTS NAND devices have for several years used 3D process technology to stack individual memory cells on top of one another to provide the significant increases in density (>128Gb/device). NAND devices are well known to have complex error structures because of the advanced levels of scaling. Understanding these error signatures as a function of environmental and device stress conditions was a key deliverable of this tasks.

Resistive Random Access Memory (RRAM) represent one the several different non floating memory technologies that NASA is considering. All non floating gate technologies provide improvement in radiation tolerance over NAND based devices, usually both in Total Ionizing Dose as well as Single Event Effects (SEE). The RRAM technology evaluated for this task uses a voltage pulse applied to a metal oxide thin film, creating massive changes in resistance to record ones and zeros. Reliability as a function of memory pattern, number of program/erase cycles and long term data retention was evaluated.

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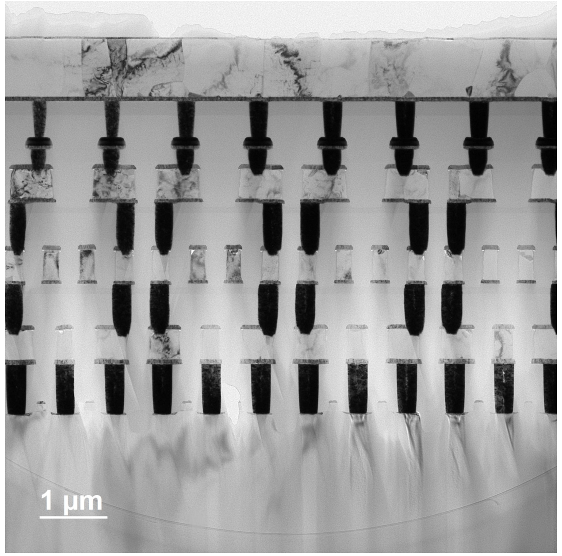
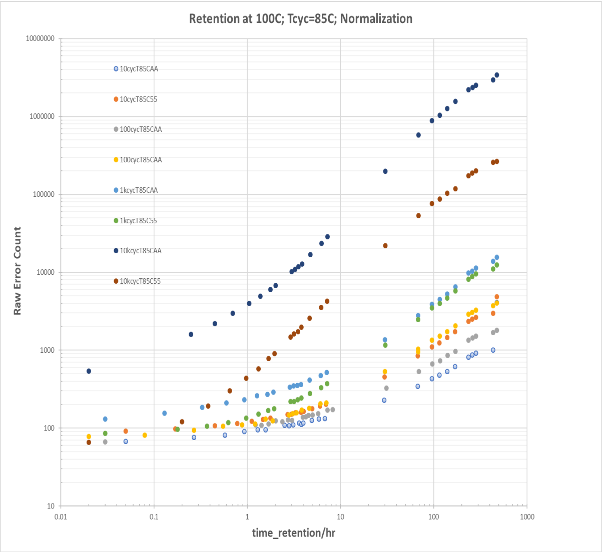
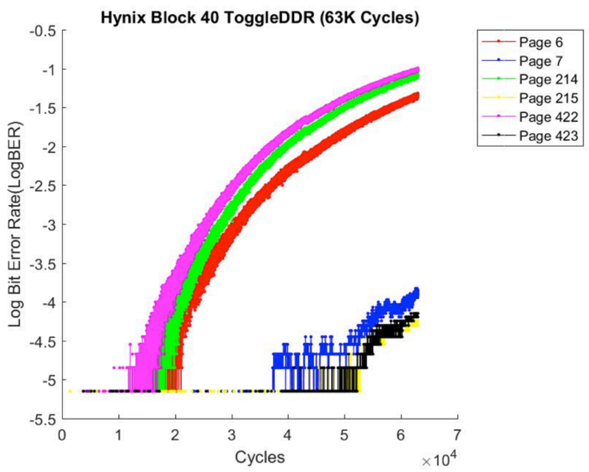
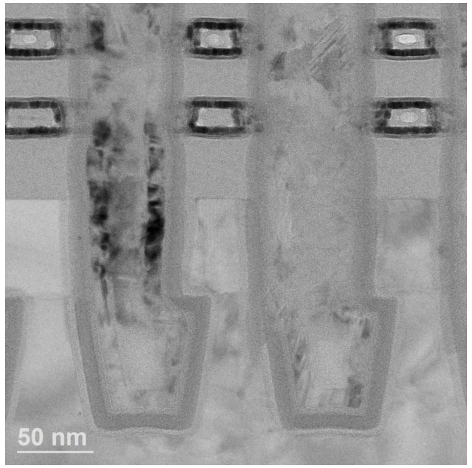




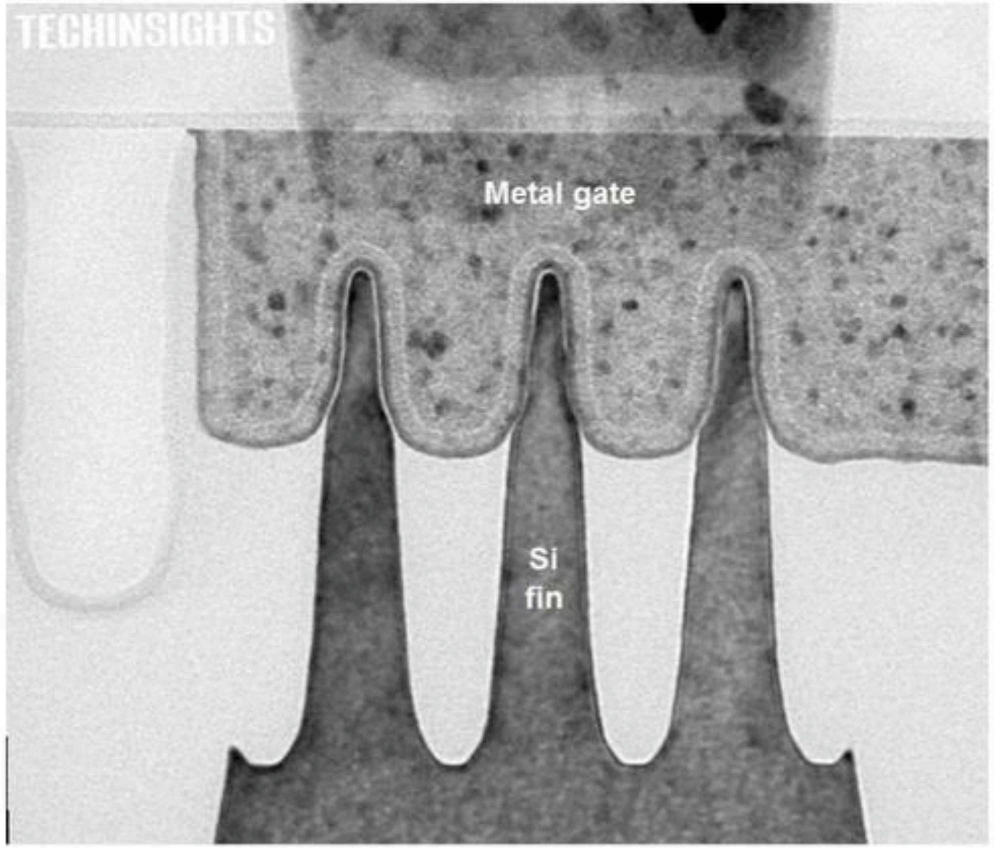




Physics of Failure of FinFET Transistors

In this survey, the basic Fin-Field-Effect-Transistor (FinFET) operations and its key salient features are identified and discussed. Next, the current 14/16nm- 7nm FinFET roadmaps and readiness are surveyed amongst four major manufacturers – Intel, Taiwan Semiconductor Manufacturing Corporation (TSMC), Samsung and Global Foundries (GF). Six key reliability concerns for FinFET are reviewed and addressed after revisiting the non-ideal elements associated with a FinFET structure.

Of particular interest are self-heating effecting leading to destructive thermal runaway, as well as negative bias temperature stability leading to long-term chip reliability. Finally, this report concludes with an initial recommendation to add thermal analysis in the derating guidelines for FinFET-based microelectronic chips. Experimentally derived degradation profiles would be necessary to generate recommendations for long term circuit effects and to create data-based quantitative derating pathfinders for the selection and qualification of FinFET based devices in NASA missions



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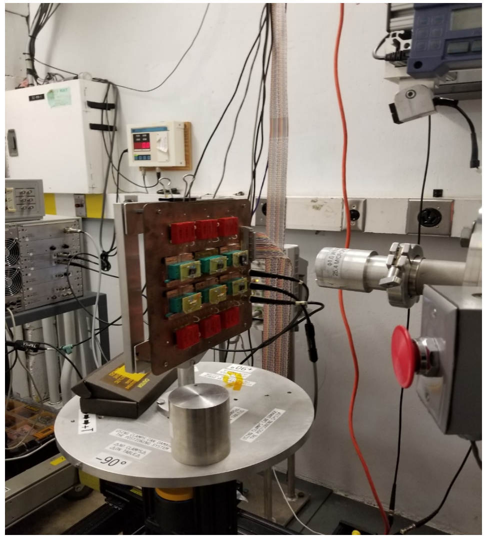
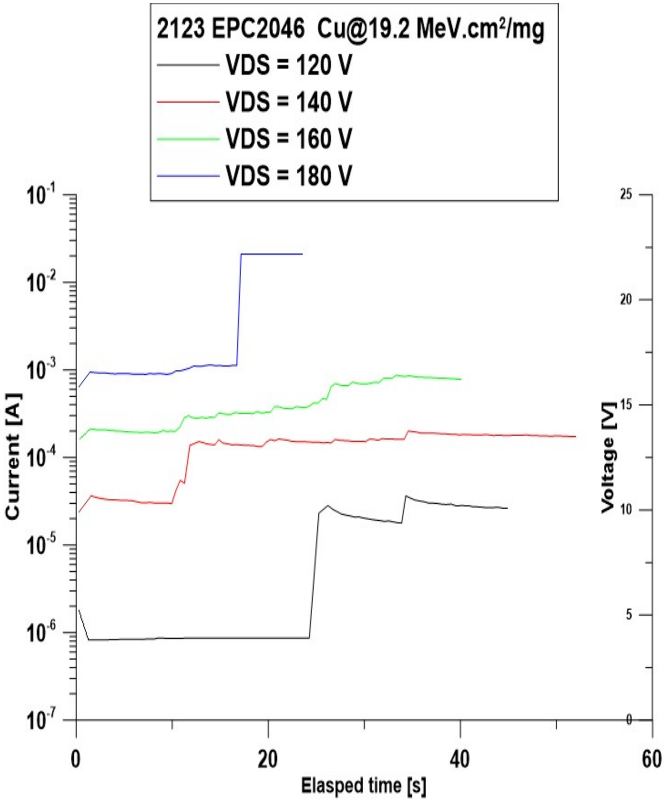
Radiation Effects on Emerging GaN Devices

Gallium Nitride devices have the potential to be 100 time more efficient in power management than silicon devices and present a critical opportunity to bend the size-weight-and-power (SWAP) trade in NASA's favor. This effort investigates the radiation effects in emerging enhancement mode devices, which are engineered for power management and distribution (PMAD) applications, including but not limited to device testing, modeling and assurance guidelines.

For 2018, the task focused on maturing reliability processes with high reliability device houses that have paired with GaN manufactures. Examples of these partnerships include E2V with GaN Systems, Panasonic with Infineon, Freebird Semiconductor with Efficient Power Conversion (EPC), Inc and Spirit Electronics also with EPC. The radiation and reliability flows used by the respective companies were reviewed for assessment for fast infusion info NASA projects. Emerging GaN devices were also in radiation testing for 2018.

The body of knowledge (BOK) document for GaN prepared in conjunction with Glenn Research Center (GRC) was delivered and is in final review. The outline for a best practices document of radiation assurance has been reviewed and approved. New generations of devices from EPC and GaN Systems have been tested.





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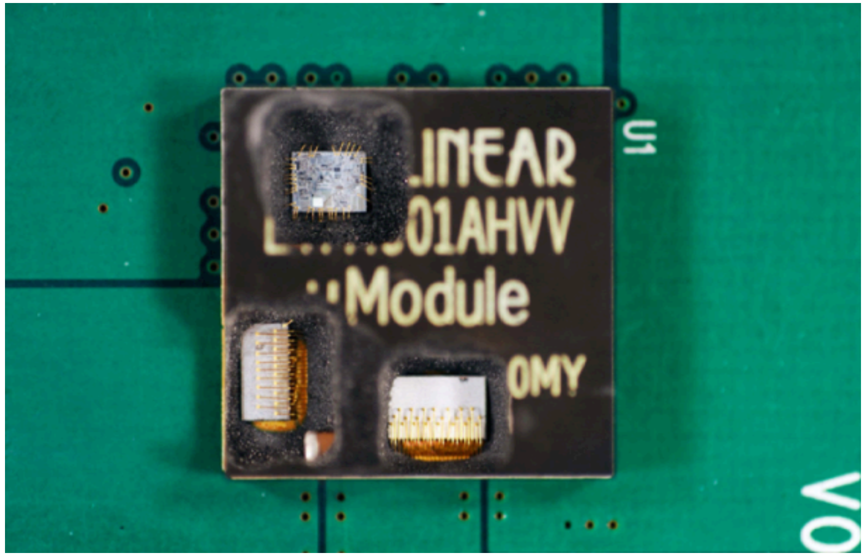
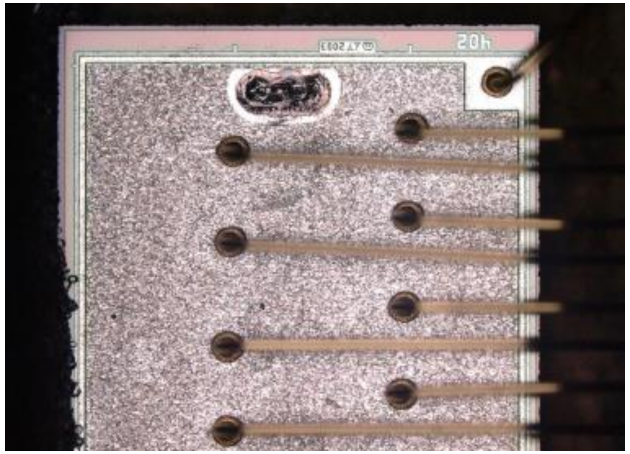
NASA Electronic Parts and Packaging (NEPP)

Power Modules Single Event Effects
With the advancement of the SmallSat and CubeSat formfactor and implementation approach becoming a reality in today's aerospace market, SWaP is a stronger driver than ever for designers. Power Modules are fully integrated system-in-package power management solutions with integrated DC/DC controllers, power transistors, and compensation components within compact surface mount packaging.

During 2018, we evaluated and reported on the single event evaluation of six devices from various manufacturers based on input from JPL and GSFC designers. Trends in architecture, technology and bias conditions are evaluated as part of the overall final report. This information helps define future part testing roadmaps and conditions.





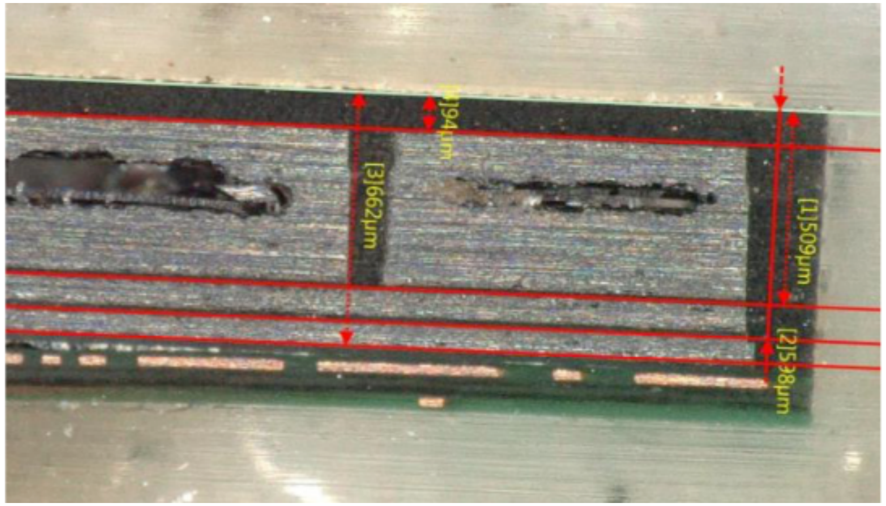
Greg Allen

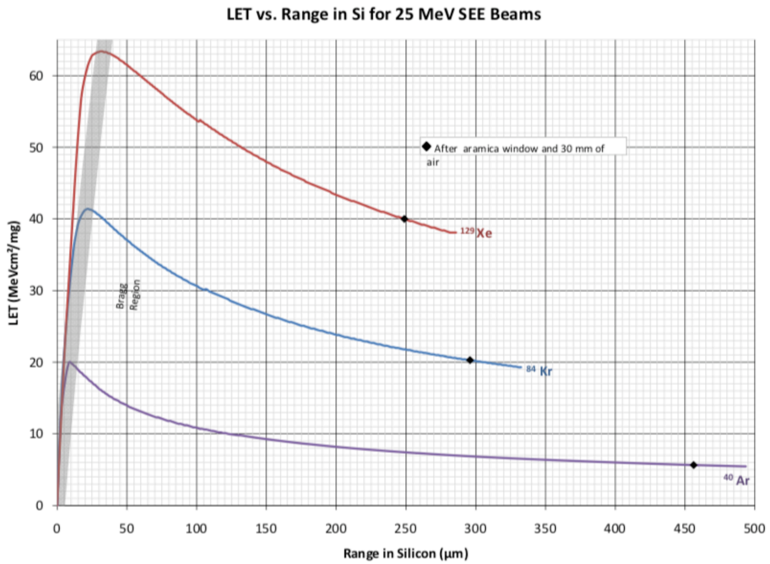
NASA Electronic Parts and Packaging (NEPP)

COTS Depackaging

The fundamental technical detail of any heavy ion test is accurately accounting for the incoming ion and its effective linear energy transfer (LET) into the silicon device to be tested. Accelerator facilities provide detailed information of this process and it is up to the experimenter to prepare the samples for test to be able to effectively use this information.

Deprocessing and de-packaging EEE parts for use in a heavy ion test requires significant understanding of materials properties, chemical reaction rates and mechanical stress and removal processes. This task is developing a white paper discussing problems and solutions associated with deprocessing. During 2018, we evaluated and documented several new tools and techniques that aid in the de-packaging (die exposure) of COTS devices. The resultant paper will describe to anyone from a radiation effects novice, to a senior design engineer, to an experienced radiation engineer the process, pitfalls, and various techniques required to prepare devices for heavy ion exposure.





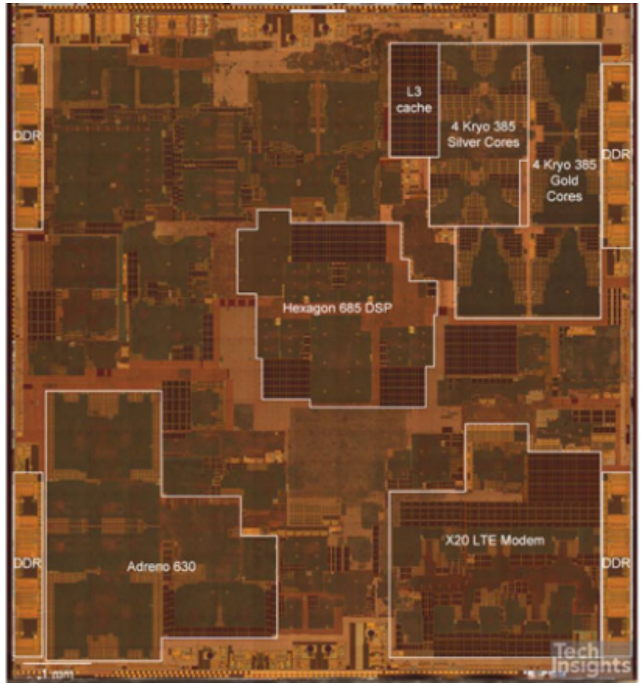
Greg Allen

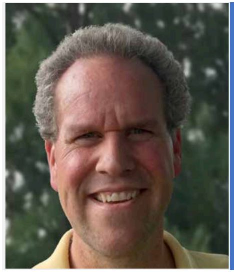
NASA Electronic Parts and Packaging (NEPP)

Single Event Effect Testing of System on a Chip (SoC) Architectures
SoC devices represent the ultimate integration of digital device technologies. These are multi-billion transistor structures, often made with vertical transistors. The architectures of these SoCs provide heterogeneous computing platforms that include multi-core computing focused, graphical processors, and digital signal processors.

This task evaluates these emerging architectures for radiation tolerance. There is a strong agency partnership given the complexity and significance of these devices. Included in this task are both COTS as well as Mil-Aero offerings. The overall goal of this effort is to enhance qualification processes and provide independent assessment of radiation performance. Significant test and qualification methods often need to be developed to support these testing campaigns. In 2018 a design and prototype for beam chopper to achieve ~3/cm^{2}s flux for high LET testing of very sensitive processors was developed.

Test results support the overall agency knowledge base of processor architectures, information on various fabrication facilities and CMOS nodes, and overall resilience of commercial technologies.





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NASA Electronic Parts and Packaging (NEPP)

Field Programmable Gate Array (FPGA) TID Testing

The radiation-induced charging of device oxides involves several different physical mechanisms, including electron-hole generation, transport and trapping. These take place on very different time scales, with different electric field and temperature dependences. Understanding these mechanisms and processes are key to providing accurate and precise information on device degradation in a variety of space radiation environments.

Complex FPGA devices made with 20nm planar CMOS technology were evaluated with two different ionizing particles to understand these mechanisms for this next generation technology node. Both photons from JPL's Cobalt 60 source as well as 2 MeV electrons from JPL's Dynamitron were used to irradiate these devices. These FPGAs are very high speed (>Gbps data rate) with extremely complex IP and functional blocks.

The ATPO sponsored testing developed a series of highly sensitive design blocks and data. The physical processes of charge generation are significantly different between the photon and electron interactions with silicon. Taking advantage of these differences provides a tool to help understand how to best quantify the possible TID degradation of these FPGAs and providing assurance guidelines and recommendations.

Greg Allen

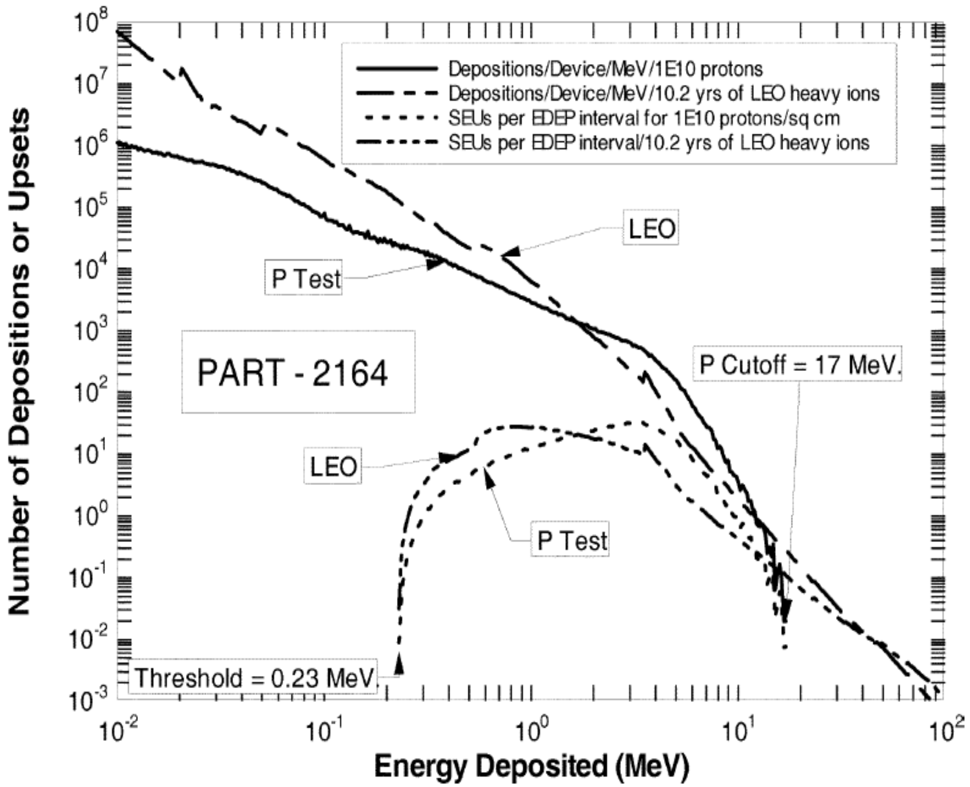
NASA Electronic Parts and Packaging (NEPP)

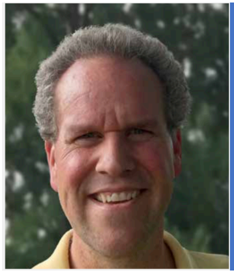
Proton Guidelines for Single Event Effects

Traditional component focused radiation qualification uses testing to establish total ionizing dose performance of a component's flight lot and establish SEE performance of representative device. SEE testing is based on expensive heavy ion testing at very limited facilities. Protons offer a limited scope of effective energies that provide a new option for some limited yet practical radiation assurance.

Protons generate higher LETs through secondaries provided by the target. Theses secondaries have limited range however. Much less than 20um. This implies that the sensitive volume that can be effectively characterized is also limited in depth. Proton testing works best when a mission desires an approximate failure rate and not a measure of assurance.

Assurance approaches usually set standards of LET for example that proton testing cannot provide or ability to rule out the existence of a variety of processes like Single Event Latchup (SEL) and/or Single Event Burnout (SEB). Board-level proton testing has different rate goals. Protons seek to assure against an event type. Maximum assigned space rate depends on event type and can be as high as 0.01/system-day for SEL.





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NASA Electronic Parts and Packaging (NEPP)

Radiation Hardness Assurance

Radiation hardness assurance is an integral part of NASA's mission success. From requirements flow down, environments, component testing, and system parts list review, the RHA flow is an import part of mission assurance.

NASA wide radiation hardness assurance is a topic requiring buy-in from many different stakeholders. Subcontractors, government agencies, semiconductor manufacturers, and microelectronic screening facilities meet multiple times a year for modifications to test methods, screening procedures, documentation, and classification. Participation in these meetings keeps JPL well-informed of updates and allows input so center specific concerns are addressed.

For 2018, the task focused on Joint Electron Device Engineering Council (JEDEC) meetings where government agencies are heavily modifying the way government controlled microcircuit drawings are written. Changes in the way radiation hardness information is conveyed in those documents affects JPL from both an assurance perspective and from a vendor test coverage perspective.

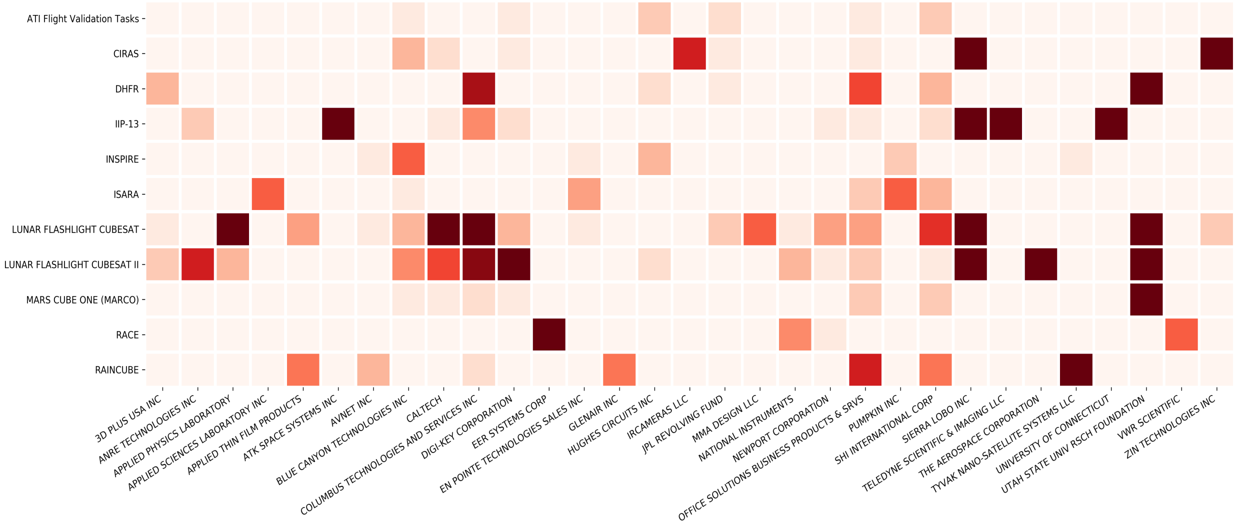
Andrew Daniel

NASA Electronic Parts and Packaging (NEPP)

Data Science – Supplier Evaluation

The Small Satellites Data Science project aims to support the reliable infusion of commercial part technologies into future small satellite missions by collating multiple disparate data sources into a single, searchable, interface. With the goal of extracting ALL the data, our team established a pipeline to capture various data related to parts, suppliers, and missions from across the web and ingest them, in tandem with internal JPL data, into a database that focuses on flexible searching.

We apply cutting edge approaches, like named-entity recognition, to identify latent features in the data and enable important relationships across data sources. The result: a one stop shop that includes a search engine providing relevant query results from internal and external data, and which further facilitates the analysis of small sat parts as well as the global small sat ecosystem



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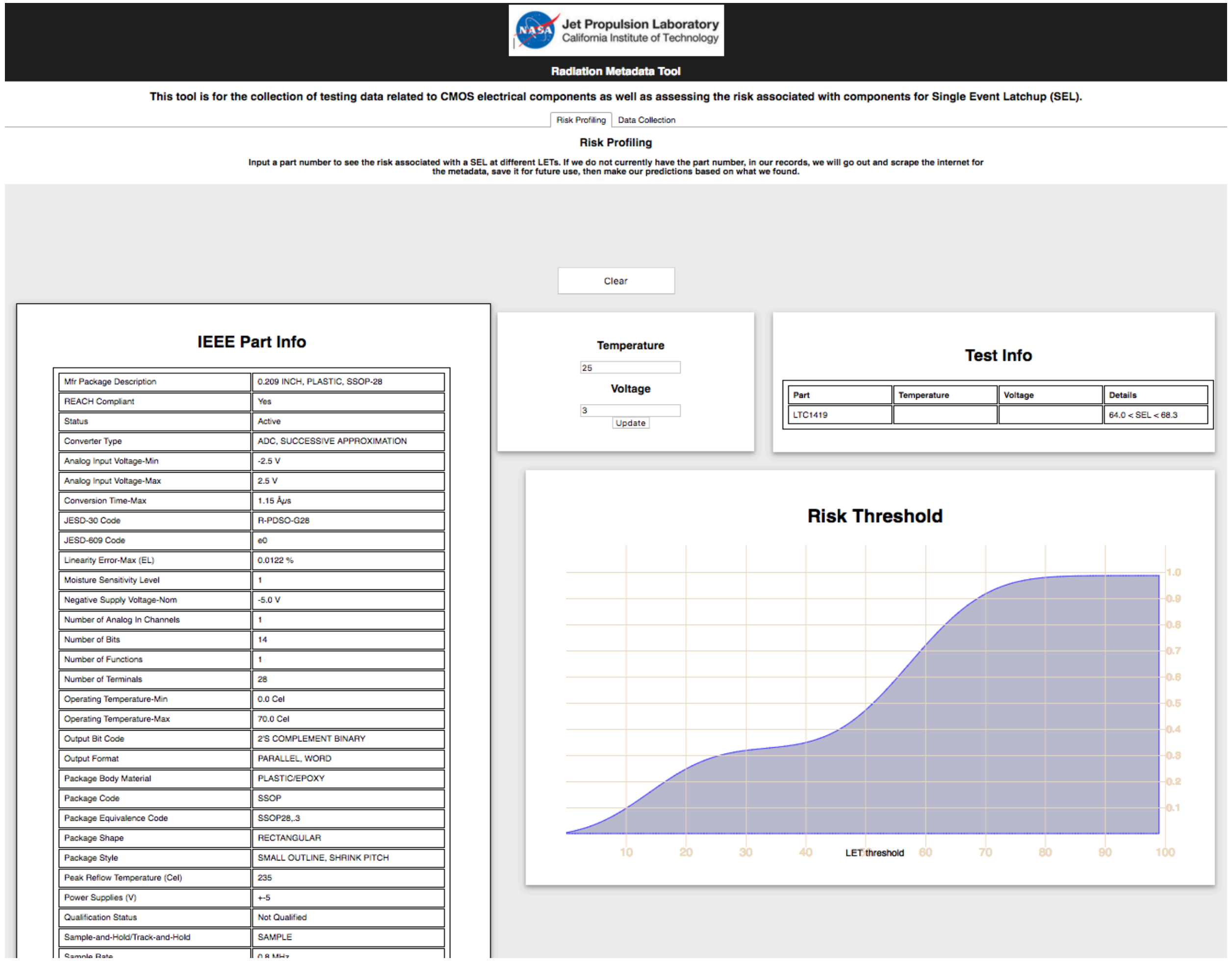

Data Science - COTS Metadata

Due to the paradigm shift in spacecraft technology utilization, and the shift towards COTS technology, a plethora of COTS-based devices have been tested in recent years in addition to the decades of radiation data available in literature and online databases. We are developing an agency-level available database that attempts to expose radiation trends in the metadata with the end goal is to expose buried trends to aid in part selection and MBSE analysis

During 2018, we developed a web scraping tool that allows a user to input a part number, and automatically determine risk to SEL based on datasheet parameters of similar devices, for example ADC.

Greg Allen

NASA Electronic Parts Assurance Group (NEPAG)

NEPAG is about parts standards. It involves efficient communication with the community through leadership roles in manufacturer audits/surveys, JC-13/CE-11/CE-12 meetings, new technology qualification data reviews/approvals, outreach initiatives, products evaluation, and presenting at domestic and international conferences.

The NEPAG program revolves around the weekly telecons: in 2018, there were 34 domestic telecons and 11 international. The average attendance per call was 30. NEPAG is also an active participant in manufacturer audits conducted by the Defense Logistics Agency (DLA). A total of 42 audits were supported in 2018. ESD surveys were also conducted in support of NASA parts programs. NASA/JPL is a part of the Qualifying Activity (QA) for standard microcircuits. A total of 16 standard microcircuit drawings (SMDs) for new microcircuit devices were completed.

NEPAG is one of the key NASA EEE parts outreach programs. NEPAG conducts Learn at Lunch (L@L) webinars with a wide variety of EEE parts suppliers. 18 L@L's were held in 2018. NEPAG also publishes NASA Parts Bulletins. These bulletins address the current parts issues and are distributed throughout the world.

NEPAG helps manage several industry groups, JC-13, CE-11 and CE-12 in support of standards development. In this role personnel act as the chair of Space subcommittee, and vice-chair of the CE-12 group. New standards efforts and task groups are active in Organic substrate Class Y devices; establishment of burn-in requirements for high speed microcircuits (in GHz range), and an to the update electrostatic discharge (ESD) requirements in the mil standards.

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