Evaluation of Active Parts for use on NASA Deep Space Missions

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AGENDA

• Introduction to NASA/Caltech/JPL and their Missions
• Pictures from un-manned Missions
• NASA Mission requirements
• Approaches used to identify Various active parts and Results
• Summary
• NEPAG, a new space parts initiative
“(There are) many aspects of space and space technology ... which can be helpful to all people as the United States proceeds with its peaceful program in space science and exploration. Every person has the opportunity to share through understanding in the adventures which lie ahead.

President Dwight D. Eisenhower
“Introduction to Outer Space”
March 26, 1958
“The exploration of space will go ahead, whether we join it or not, and it is one of the greatest adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in this race for space...

We set sail on this new sea because there is new knowledge to be gained and new rights to be won, and they must be won and used for all people...

We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because the goal will serve to organize and measure the best of our energies and skills...”

President John F. Kennedy
Address at Rice University on the Nation’s Space Effort
September 12, 1962
NASA

50 years of exploration and discovery
1958 – 2008

NASA Centers

- ARC
- DFRC
- GRC
- GSFC
- HQ
- JPL
- JSC
- KSC
- LeRC
- MSFC
- SSC
Jet Propulsion Laboratory (JPL)
www.jpl.nasa.gov

- Government (mainly NASA)-funded unit of the California Institute of Technology (www.caltech.edu)
- Charter: Un-manned (robotic) missions
The image of Saturn captured by Voyager 2 spacecraft
August 1981
NASA’s Cassini spacecraft produced the most detailed global color portrait of Jupiter. The smallest storms visible are the size of Earth’s largest hurricanes.

December 2000
NASA/JPL Missions – Mars Rovers

Roving Mars surface

June 2003
During its close encounter with comet Wild 2, the Stardust spacecraft imaged an intensely active surface, jetting dust and gas streams into space, leaving a trail millions of miles long.

January 2004
NASA/JPL Missions – Phoenix Lander

May 2008
NASA/JPL Missions – Phoenix Lander

May 2008
Parts for Space Flight

- There are a wide variety of parts used on a spacecraft: Passives (capacitors, resistors, etc.), magnetics, connectors, discretes (diodes, transistors), actives (gates, flip/flops, OP AMPs, FPGAs, etc.), and others

- This presentation will confine discussion to the active parts
Active Parts for NASA/JPL Deep Space Missions
Typical Parts Program Requirements

• The parts requirements are determined by the mission life, thermal and radiation requirements as specified by the Project Environmental Requirements Document.

• Specify parts reliability standard, such as MIL-PRF-38535, Class V for microcircuits; MIL-PRF-38534, Class K for hybrids.

• Specify minimum upgrade requirements for non-standard parts. Non-Standard Parts Approval Requests (NSPARs) are required for approval of all nonstandard parts.

• Additional requirements for hybrids, programmable devices (e.g. FPGAs), digital and mixed-signal ASICs

• Perform RGA when specified

• DPA to be performed when specified
Active Parts for NASA/JPL Deep Space Missions
Typical Parts Program Requirements – Cont’d.

- Review part manufacturer’s screening and lot sample flows for optimizations. Recommend corrective action.
- All parts having tin plated materials shall be shown to have at least 3% lead.
- To protect static-sensitive parts from ESD, handling of parts shall be controlled by an approved plan.
- Each part used in flight equipment shall meet the established derating criteria
- Perform worst case analysis of the application
Evaluate all parts for radiation: single event effects (SEE), total ionizing dose (TID), and displacement damage (DD). Perform additional tests / analyses as required. These effects are technology / process dependent.

Perform failure analysis as needed. Determine the root cause to the extent possible.

Procure parts from authorized distributors or directly from the manufacturers. Have a plan to mitigate risk from counterfeit parts.
A new technology is defined as a product family, material, or process that has never been previously characterized or qualified by the manufacturer.

Characterization testing of new technologies is intended to understand the part, material and process to ensure the items’ capability. The manufacturer should evaluate all aspects of their process to ensure long term reliability of the product.

Qualification is the validation that the characterization testing and evaluations of failure mechanisms show the technology meets or exceeds documented requirements. The qualification methodology will vary depending on the technology.
Active Parts Evaluation for NASA/JPL Deep Space Missions
New Technology Insertion – Cont’d.
(MIL-PRF-38535, Proposed Appendix K)

- Although the new technology appendix is still not completely defined, the major manufacturers have taken the initiative to start collecting data on their new product families. That data is being submitted to DSCC and the space community for review and approval.

- DSCC and the space community have started addressing new technology evaluation during the audits of manufacturers.

- The space community would still have to evaluate new technology for their unique requirements, such as low temperatures on NASA’s missions to Mars.
Electronic Parts for Deep Space Missions
Some Realities

- Strive to save power; design-in low power parts
- Operate in space radiation environment; consider the effects of radiation
- Mission reliability; worst case analysis, derating
- Don’t forget that missions are Non-repairable; can’t send a repairman up there
- Operate at low temperature, if required
- Small, light weight packages; use light weight hardware
- Functional integration; use parts that offer higher functionality
- Other, mission specific
Active Parts Evaluation for NASA/JPL Deep Space Missions
Some Realities – Radiation

- Evaluate parts for radiation effects:
  - Total Ionizing Dose (TID), consider enhanced low dose rate sensitivity (ELDRS), displacement damage (DD) as applicable
  - Single Event Upset (SEU)
  - Single Effect Transient (SET)
  - Single Effect Latchup (SEL)
  - Single Event Functional Interrupt (SEFI)
The testing of parts down to -130C is not easy. There are tester and equipment limitations. Users need to make compromises as to how much testing is adequate.

It would be desirable to attach the low temp set up to the test head of the VLSI tester being used. We tried it at JPL but were able to go down to only -120C. An alternate low temperature dedicated fixture had to be used (without the VLSI tester) and amount of testing down-scoped to collect rest of the data.

The correlation with tester used by the manufacturer is another factor to keep in mind.
Methods to Achieve Low Power Parts

- Evaluate Rad Tolerance
- Commercial
- Evaluate at Low Voltage
- Evaluate Rad Tolerance
- Low Power Commercial
- Radiation Hard
- Evaluate at Low Voltage
Active Parts for NASA/JPL Deep Space Missions
Use of Plastic Parts (PEMs)

- Requires extensive evaluation
- Perform DPA, radiation test
- Measure glass transition temperature, to establish burn-in voltage
- Perform 100% screening: initial electricals, x-ray, temp cycling, CSAM, burn-in with interim and final electricals
- Engineering evaluation of data is extremely important
- Perform life test and temp cycling on a sample
Some major manufacturers now offer value added plastic parts: T.I. has enhanced plastic; Linear Tech would supply screened 16-bit A/D converters in plastic package; and there are probably others.

Cameras used in Spirit and Opportunity Mars rovers had upscreened plastic parts.

Perform life test and temp cycling on a sample.
Active Parts for NASA Deep Space Missions
Example: Digital Logic

- Rad hard grade 1 parts generally available from major suppliers.
- Obsolescence has become an issue. However, one major manufacturer is planning to offer radiation tolerant versions of HC/AC families.
- NASA/JPL did extensive evaluations of CD4000A/B series and HCS/ACS families. They were used on our deep space missions such as the Voyagers (CD4000A), Galileo (CD4000B), Cassini (HCS/ACS), and others.
- Although over 30 years old, the CD4000B family is still a favorite of many designers. However, it has become extinct; only a handful of functions are available.
- A couple of major suppliers are active in offering logic functions such as 16-channel drivers and transceivers including voltage translators.
Active Parts for NASA Deep Space Missions
Example: Linear, Interface

- Basic functions available as rad hard high reliability from major suppliers.
- JPL has evaluated various parts for different projects mainly for radiation some of which led to the development of space level products, e.g. commercial dual OP AMP was tested for low and high dose rates. It met project requirement. The data was shared with the vendor. They now offer dual and quad space radiation hardened versions.
Active Parts for NASA Deep Space Missions
Example: Data Converters

• Applicable General Spec: MIL-PRF-38535.

• Only a handful parts available as rad hard high reliability. This creates a challenge for space users. Extensive evaluations are needed.

• Mission specific requirements such as radiation and temperature should be taken into consideration

• NASA/JPL has performed evaluation of A/D converters in 12-16 bit resolution range. Not all evaluations yielded desirable results. However, several products were developed from the effort.

• NASA A/D converter guide provides a summary of evaluation effort
Active Parts for NASA Deep Space Missions
Example: Data Converters – Cont’d.

- **New Issues:**
  - In order to cut down on noise, the manufacturers are inserting capacitors within the packages, which puts such parts in a grey area: should they be called hybrids?
  - The parts are becoming complex, number of bond wires in ceramic packages is making it difficult for manufacturers to perform non-destructive bond pulls without concern for potential damage to the part.
Active Parts for NASA Deep Space Missions
Example: Hybrid Crystal Oscillators

- In addition to invoking elements of the oscillator general specification, the procurement of crystal oscillators should also include provisions from the hybrid general specification, MIL-PRF-38534
- Mission specific requirements such as radiation and temperature should be taken into consideration
- Pre-cap inspection is recommended
Active Parts for NASA Deep Space Missions
Example: Hybrid DC/DC Converters

- The hybrid general specification is currently being reviewed for changes by the space community.
- There are many issues: workmanship, element evaluation, radiation tolerance, worst case analysis, etc.
- Mission specific requirements such as radiation and temperature should be taken into consideration
- Pre-cap inspection is recommended
- Use an SOW to supplement the requirements of SMD, e.g. add tri-temp testing at final electricals.
Active Parts for NASA Deep Space Missions
Example: FPGA’s

- Many government and other organizations have done extensive evaluation of FPGAs
- Several issues: Power management, packaging, electrical testing, ESD, post programming burn-in, etc.
- Recently raised questions: (a) Does MIL-PRF-38535, appendix B specifically say that Class V parts need to be packaged in hermetic packages? (b) Do we need a new classification for space non-hermetic parts?
- Potentially poor configuration control: DSCC SMD refer to vendor data sheet for electrical specification
- Published information can be mistakenly interpreted to mean that the vendor has QMLV certification
Acquiring Electronic Parts for NASA/JPL Missions

Summary

• NASA deep space missions are unique and they are non-repairable

• Finding parts that will meet mission reliability, radiation and other specific requirements is a challenge

• A pro-active approach is needed to look beyond the standard offerings

• Thorough engineering review of data is important

• Any upscreening by the user should factor in the yield losses

• Use of plastic parts requires extra attention
• NASA evaluations have yielded successful results (there have been disappointments as well where the parts didn’t perform to expectation)

• Sharing data with manufacturers was useful: in several instances, they were able to offer standard space products based on users’ data and their own evaluation

• Although there is a lot of work yet to be done in putting together a new technology evaluation appendix, this is a step in the right direction
NASA’s NEPAG Initiative

- Acronym for NASA EEE (Electrical, Electronic, Electro-mechanical) Parts Assurance Group
- A forum to exchange information on EEE parts across NASA and the space parts user community
- 24 member organizations representing worldwide space community
- Communicate via weekly telecons, other means; participate in DSCC (Defense Supply Center Columbus) audits as technical experts; support NASA projects; organize technical meetings; other activities
NASA / JPL NEPAG Organization

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* ATPO (Assurance Technology Program Office)