New Developments in Managing ESD for Electronic Components

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InSight, scheduled to launch in May 2018, will be the first NASA mission to observe the deep interior of Mars. The planets of Mercury, Venus, Earth and Mars are as similar as they are different, and the view granted by our human and robotic eyes only scratches the surface.

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  - 883
  - 38535
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NASA Concerns

- **MIL-STD-883, Test Method 3015**
  - Too old
  - Does not include the charge device model (CDM), only the human body model (HBM)
  - The Test Method needs to be revisited for new technology
    - ❖ Smaller feature sizes (down to 45nm)
    - ❖ Large number of contacts/pins (~1750 for Xilinx FPGA)
    - ❖ Time to test
    - ❖ Advancements in packaging (2.5D, 3D)

- **MIL-PRF-38535 -** Performance specification for microcircuits
  - DLA audits of microcircuit manufacturers and their supply chains
    - ❖ Are done to the requirements stated in 38535
  - 38535 is at revision K. Draft L revision is being worked.
  - Poor coverage for ESD
    - ❖ No CDM testing required
    - ❖ Confusing requirements
      - ❖ 883 vs. JEDEC (3 zaps/pin vs 1 zap/pin, for HBM test)
    - ❖ No requirements for wafer foundries
  - Needs to be updated
    - ❖ For new technology
    - ❖ For shipping and handling of products in multi-supply chain production of parts (which is becoming the norm)

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Activities to Improve ESD and Electronic Parts/PCBs

- **NASA Is Highlighting ESD in Parts Bulletins**
  - Released two special editions on ESD.
- **Invited ESD Talks**
  - By STS at Space Subcommittee chaired by NASA (Sep.'16)
- **Conducted DLA Engineering Practice (EP) Study on ESD**
  - EP study is a survey of manufacturers, users and other interested entities (Jan.'17)
- **JC-13 Started a Task Group on ESD (Chair: P. Coe)**
- **JEDEC/ESDA Are Continuing Joint Effort**
  - JESD 625B and S20.20 Harmonization telecons and face-to-face meetings
  - Participation by NASA and The Aerospace Corporation
- **Updated MIL-STD-883, Test Method 1014**
  - Added Para 2.2.1d. "ESD Protective Tubes shall be utilized to ensure the system is ESD safe…"
- **Continuing NASA ESD Surveys**
  - Conducted by NASA experts

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Electrostatic Discharge Special Issue (Part 1)

- NASA EEE Parts Bulletin (January – July 2016)

National Aeronautics and Space Administration

EEE Parts Bulletin

Electrical, Electronic, and Electromechanical

A periodic newsletter of the JPL/OSMS Assurance Technology Program Office (ATPO), NASA EEE Parts Assurance Group (NEPAG), and Section 514, of the Jet Propulsion Laboratory.

January–July, 2016 • Volume 8, Issue 1, Revision A, January 26, 2017
Special Edition on Electrostatic Discharge (ESD)
(The NASA *EEE Parts Bulletin* has been published since 2009)

Note: This revision adds a number of details and corrects ambiguities in the original issue that was released August 31, 2016 (the K. LaBel article on partnering and the back-page material were not changed).

Damage from ESD is a major cost to the microcircuit industry in terms of time, money, and mission risk. We plan to release two issues. This first special issue deals with the need to upgrade specifications related to ESD and suggestions for better ESD practices wherever parts are manufactured, stored, or prepared for shipment. This issue also includes an article about partnering in radiation and reliability testing. The second special issue will describe examples of ESD-related problems. Figure 1 is an example of damage caused by ESD.

(a) (b)

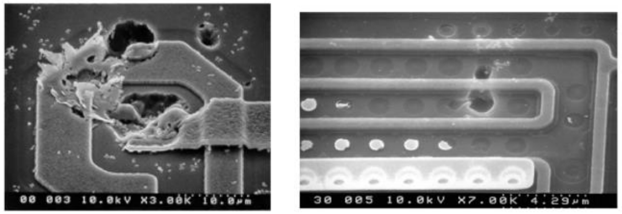

Figure 1. Examples of ESD damage to microcircuits (Images courtesy of JPL Analysis and Test Laboratory):
a) A static random access memory (SRAM) device with 5-micron features was deliberately exposed to an 8000-volt pulse from a 100-picofarad capacitor. This produced an approximately 5.3-ampere peak current pulse lasting just under one microsecond. Melting of conductive traces is typical of such ESD damage and creates an open circuit path.
b) An undefined microcircuit with 1-micron line widths that failed in service after being exposed to a pulse of approximately 500 volts. This caused a breakdown of the SiO_2 layer and a short circuit in the part.

Upgrading ESD Control: Its Importance and Possible Strategies

A. What Is ESD and How Are ESD Controls Applied?

Electrostatic discharge or ESD in electronic parts is an electrical sparking event that functions like a tiny version of lightning. When two objects with different potentials are brought sufficiently close, a current flows toward the ground equalizing the potential. These differences can be caused by friction of dissimilar materials (shoes on a carpet is a classic example), but even the difference in potential between a human body and an object may be enough to initiate an ESD event.

For electronic parts, built to carry minute amounts of current, tiny lightning bolts are a cause for concern. If such an errant current flow of an ESD goes along the outer case of a part or the outside of an ESD-resistant (anti-

tatic) bag or shipper, there may be no problem. However, such a current goes through the part, serious damage nay result. ESD damage can include catastrophic damge and/or latent damage. Catastrophic damage is immeiately detectable by the resulting loss of function and ofen visible damage. Latent damage is not immediately deectable because there is no loss of function and often no isible sign of damage. However, the part has been weakned and may fail in the field or (worse) in space.

his has always been a serious concern for electronic arts, but it has grown steadily more urgent.

he purpose of this article is to sensitize the entire space ommunity, and in particular, the standards-developingodies to the fact that the ESD requirements must be learly specified in such standards documents so that verybody handling microcircuits, from manufacture to fial use can minimize ESD damage. Furthermore, the tandards must be updated to reflect the present level of echnology.

n this context, the role of DLA (Defense Logistics gency) for the department of defense (DoD) becomes ital. The standardization branch of DLA develops and naintains the military (MIL) standards, which are used for naintaining high-reliability quality parts production for the DoD and for NASA. In addition, manufacturers and non-MIL standards organizations provide inputs to the standrds

hese standards are often enforced by periodic audits of arts manufacturers and their supply chains. The audit ranch of DLA officially conducts official enforcement. NASA actively supports DLA in both of these activities.

or the purposes of this article, we are focusing on monlithic microcircuits. The standard most commonly used y the U.S. space community for high-reliability microciruits is MIL-PRF-38535, *Integrated Circuits (Microcir-uits) Manufacturing, General Specification for*. Any mirocircuit parts produced under the military system must e in compliance with the requirements of this document.

he 38535 is the periodically changing overall document ontrolling microcircuit quality and reliability. The ESD asects of the document clearly need updating. For auditng, the requirements must be flowed down to the working udit, and it must be reflected in each manufacturer's uality management (QM) plan.

n addition, the ESD-related standards used by other oranizations may provide ideas for upgrades to the MIL tandards. Conversely, it would be highly beneficial if the MIL standard upgrades could be coordinated with those f the other standards bodies so that practices throughout he industry might be as similar and interchangeable as ossible.

B. Why Improved ESD Control Practices Are Crucial

Microcircuit densification has increased pin counts significantly in the last decade, particularly for communication and computing products. NASA and the space community are using 1752-pin counts, and higher counts are growing more common in the general market.

Current ESD rating methods were developed with typical pin counts in the twenties. Applying these old device testing standards to modern high-pin count products can cause severe problems. Testing times increase dramatically. Worse, wear caused by repeatedly stressing the same path and the increasing influence of tester parasitic losses (parasitics) can lead to false-positive failures.

The increased capabilities attained by increasing parts density has come at the cost of greater sensitivity to ESD. Thus, it becomes increasingly important to implement better methods of controlling potential damage from ESD. A wide assortment of books and journal papers provides information on methods for mitigating ESD.

For high-reliability microcircuits (where a part may cost as much as tens of thousands of dollars), organizations often develop and enforce required policies and procedures designed to mitigate ESD. These policies and procedures are codified in standards.

Furthermore, the landscape of microcircuit part production, handling, and shipping has changed radically. Because of the increased complexity of parts, the paradigm of a manufacturer shipping directly to a customer has largely given way to a highly dispersed production environment, which in turn, often requires highly dispersed ESD control among a number of organizations. Table 1 shows all the steps at which production or use of a microcircuit might be done by shipping to another facility. (The most extreme cases of maximum dispersion are more likely with new products such as flip chips.) Moreover, each of the steps involves at least one environment each for working on the part, storing the part, and shipping the part to the next step in the production.

Much as increased pin counts increase the susceptibility to ESD, increasing the number of shipping steps in the supply chain increases the number of points where ESD damage may occur.

It is important to recognize and fully address all the risk points to which ESD sensitive parts are subjected: from when they are fabricated and delivered from the original component manufacture's (OCM) site; through supply chain avenues to user inventories; then on to kitting and upper-level printed circuit board (PCB) level assembly, test and verification; and eventually to final box level assembly, test and final system level test. This is particularly important for handling, packaging, and shipping of ESD Class 0A devices (<125 volts in the Human Body Model).

- Are all three commonly used ESD models still valid or should the standards focus on one or two models?: Those models are 1) human body model (HBM) based on people accumulating electric charges; 2) charged device model (CDM) based on materials becoming charged after they rub against other materials; and 3) machine model (MM) [designed to simulate a machine discharging through a device to ground].
- Do we want a standard for reducing the number of pin combinations required for testing?
- Would statistical pin testing be a good approach?
- How can the testing time be reduced without losing useful information (and significantly impacting the test data)?
- Should the MIL standards be expanded to include charged device model (CDM) testing?
- How do the new 2.5D and 3D configurations affect ESD testing?

We need to consider future trends when revising test standards. This issue is growing more important because the unit cost of contemporary devices are very high (and are growing costlier as more functionality is added), on the order of several tens of thousands of dollars per unit. Poor ESD environment for such products creates possibility of damage/ latent damage to them, both of which could be very expensive. Costs for implementing an ESD-prevention program are miniscule compared to the overall cost incurred in dealing with ESD damage.

The above concerns were presented by NASA representative Michael Sampson at the June 2016 G12 Space Subcommittee meeting. He proposed that the military documents that control the ESD requirements for testing and rating ESD event severity be reviewed and updated as a first step. As part of this update process, he suggested that Defense Land and Maritime (DLA), which serves as the qualifying authority to maintain the MIL system of parts qualification, perform an engineering practice (EP) study on ESD to detail these issues and compare possible specification changes with those being implemented or proposed by other organizations, in particular the NASA Inter-Agency Working Group related to ESD (NASA IAWG-ESD). Ideally, coordination among the various standards-setting organizations would result in updated ESD standards with a great deal of commonality. DLA shared the results of their EP study at the JEDEC meeting held in January 2017. Based on the EP study and responses to it, JEDEC (JC-13) has opened a task group to resolve issues related to ESD.

These document changes will require review and coordination with associated reference documents from other organizations to bring consistency.

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Electrostatic Discharge Special Issue (Part 2)

- NASA EEE Parts Bulletin (August 2016 – May 2017)

National Aeronautics and Space Administration

NASA

EEE Parts Bulletin

Electrical, Electronic, and Electromechanical

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Second Special Edition on Electrostatic Discharge (ESD)

Damage from ESD is a major cost to the microcircuit industry in terms of time, money, and mission risk. The first issue dealt with the need to upgrade specifications related to ESD and suggestions for better ESD practices wherever parts are manufactured, stored, or prepared for shipment. This second ESD special issue focuses on a parts failure investigation that ultimately concluded that ESD was the most likely cause of the failure. The issue also includes an important reminder about regular ESD testing and a table of standard microcircuit drawings that were recently reviewed.

Figure 1 is an example of damage that was probably caused by ESD.

Oxide

Fig. 1. Detailed view of a damaged site on a metal oxide semiconductor field-effect transistor (MOSFET) probably caused by ESD.

ESD, the Silent Killer—

A. Background

There are several great points to consider with respect to ESD knowledge, practice, and compliance. However, the key for ESD program success is consistency. If we detect the results of an event, then, we [the operational group] should be able to ascertain and confirm that we never have any lapses in the program implementation. With systematic practices, we should be able to surmise that there is no way any events can occur on the organizational project watch.

ESD is the silent killer in electronics, and the resulting impacts are hidden project costs that are the motivator to address project risk cost and schedule impacts. When an ESD event occurs, one of three scenarios may play out.

1) There is no impact, and no detrimental result.

2) There is a catastrophic strike and the immediate

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and shipped off for failure analysis.

Figure 2 shows the PCB assembly with two noted non-functional parts circled in red. Although not conclusive, the corner location of damaged parts on the board was thought to be important to the forensics analysis. One theory implied that handling of the board (by the perimeter) allowed for the ESD event to contact these parts directly. During transport, the board is handled only inside an ESD-approved materials bag. There were questions as to the integrity of these transport bags. Due to bag traceability and reuse issues, there was no definite conclusion on this concern.

Figures 3 thru Figure 7 Show the die and damage areas from various photographic and radiographic perspectives. During upper-level assembly circuit troubleshooting, the potential for design or operational damaging voltages to the MOSFET gates were conclusively ruled out. The circuit was incapable of generating the necessary damaging voltages that would have the effect observed.

C. Investigation Conclusion

The conclusion of this ESD failure investigation was that failure was attributed to user error but review of all ESD compliance logs showed that all precautions were taken during operator handling. Due to lack of further evidence, the OCM and the PCB assembly operation were not ruled out as possible culprits, but neither could be confirmed.

Under these circumstances the team was advised of the event and warned of the total cost for repair and the need to double check all future handling procedures. The board was repaired with same lot date code parts, and there were never any repeat operational issues with that PCB assembly nor at the box operational level. The "Silent Killer" only struck once on that program. At least as far as can be determined at this time.

Figures 1 through 7 (provided courtesy of NASA Langley Research Center) were generated by Hi-Rel Labs as part of a project Component Failure Investigation at Langley.

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Fig. 3. Optical micrograph of the die in the failed device. The red arrows indicate the damage sites.

Fig. 5. SEM image of one of the damage sites. The arrow indicates the area where the damage originated

GATE

Oxide

Fig. 7. SEM image of another damaged area on the die. Note that the gate polysilicon fused during the failure, which is why the oxide is visible.

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A Changing Landscape (Shipping/Handling/ESD Challenge)

A New Trend – Supply Chain Management
Ensuring gap-free alignment for each qualified product
(All entities in the supply chain must be certified/approved)

Manufacturer A	Die design
Manufacturer B	Fabrication
Manufacturer C	Wafer bumping
Manufacturer D	Package design and package manufacturing
Manufacturer E	Assembly
Manufacturer F	Column attach and solderability
Manufacturer G	Screening, electrical and package tests
Manufacturer H	Radiation testing

More Stops — More Places with ESD Risk

NASA ESD Surveys of Microcircuit Supply Chain

- **NASA ESD Surveys**
  - Candidate companies are identified during DLA audits—but not a DLA activity
  - Conducted by NASA ESD experts
    - ❖ The survey findings and corrective actions are merely suggestions for improvements (but, in all cases, were implemented by the vendors)
  - Benefits the whole community
    - ❖ Especially vendors processing very expensive new technology parts (where the per unit price could approach $200k)
  - Very well received
    - ❖ Some vendors have requested re-surveys every two years
  - Working with Suppliers and DLA to incorporate NASA ESD Surveys into DLA audit agendas
    - ❖ Will save resources

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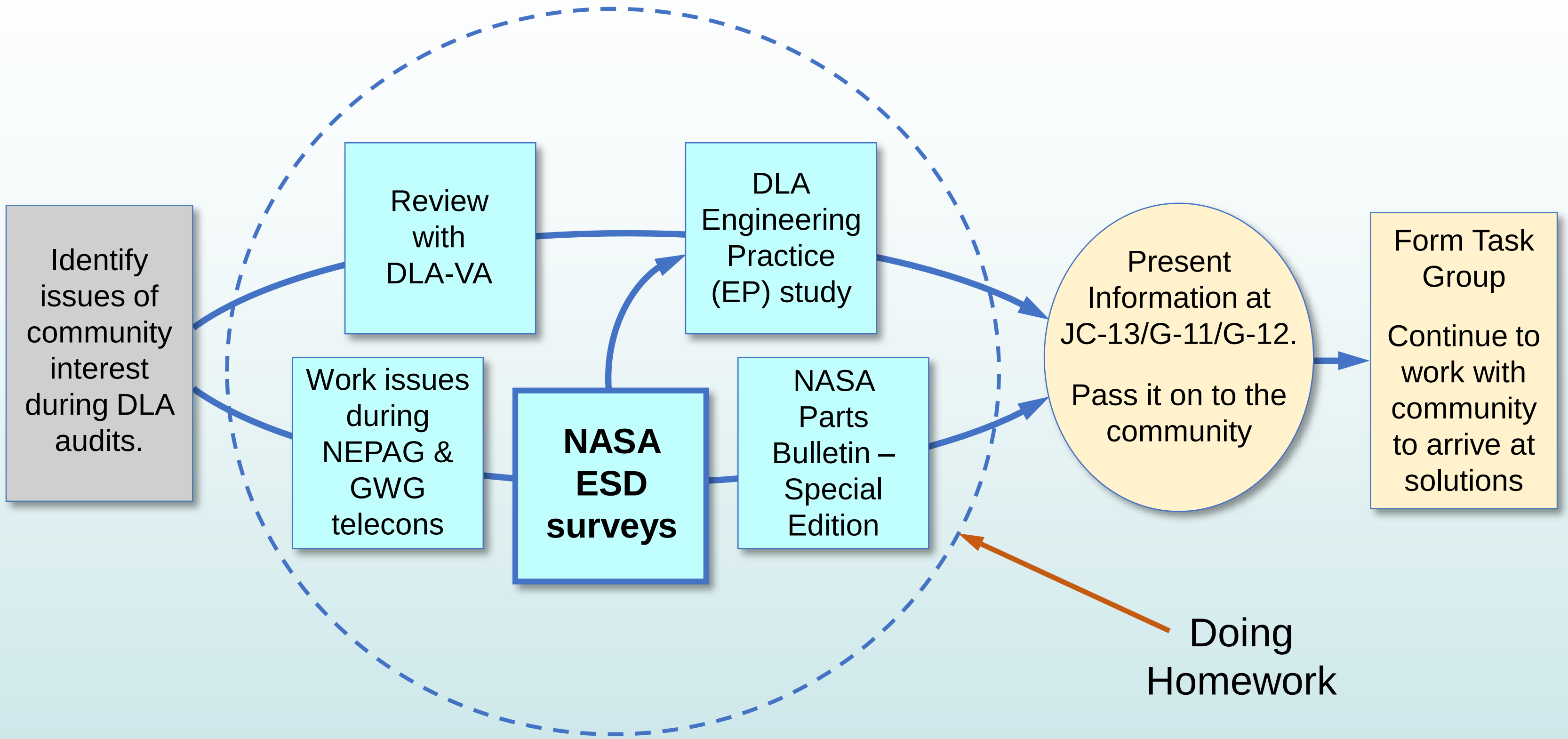
How NASA ESD Surveys Have Been a Key Part of the Process



- Bring general awareness (Via NASA Bulletins, Surveys)
- Work with DLA to help them conduct an engineering practice (EP) study
- Generate a basic proposal and related information so the potential task group (TG) has a strong starting point.
- This path has **saved time** in resolving major issues found during audits.

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Summary

- NASA brought many ESD concerns to the attention of the parts community
- All types of commodities affected for both military and commercial parts
- COTS hardware could be affected more severely
- New JC-13 Task Group was started to address ESD issues
- Monthly telecons are held on harmonization of 625 and 20.20
- NASA is continuing to conduct ESD Surveys
- 38535 Rev. L to update ESD requirements
- Parts community must promote ESD safe environment!
- Be mindful of ESD when shipping / handling parts and hardware!

http://nepp.nasa.gov

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