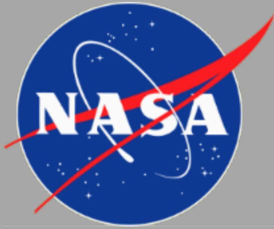

The NASA Electronic Parts and Packaging (NEPP) Program

NASA Items of Interest

Space Parts Working Group

April 4-5, 2017 Los Angeles, California

Kenneth A. LaBel — ken.label@nasa.gov — 301-286-9936

Michael J. Sampson — michael.j.sampson@nasa.gov — 301-614-6233

Co- Managers, NEPP Program

NASA/GSFC

http://nepp.nasa.gov

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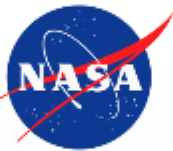
Open Access

To be presented at the Space Parts Working Group (SPWG) April 4, 2017

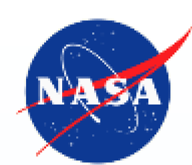


Acronyms

Acronym	Definition
3D	Three Dimensional
ADC	analog-to-digital converter
AES	Advanced Encryption Standard
AF SMC	Air Force Space & Missile Systems Center
AFRL	Air Force Research Laboratory
AMOLED	Active Matrix Organic Light Emitting Diode
AMS	Agile Mixed Signal
ARM	ARM Holdings Public Limited Company
CAN	Controller Area Network
CAN-FD	Controller Area Network Flexible Data-Rate
CBRAM	Conductive Bridging Random Access Memory
CCI	Correct Coding Initiative
CGA	Column Grid Array
CIGS	Copper Indium Gallium Selenide
CMOS	Complementary Metal Oxide Semiconductor
COTS	Commercial Off The Shelf
CPU	Computer Processing Unit
CRC	Cyclic Redundancy Check
CREME	Cosmic Ray Effects on Micro-Electronics
CSE	Computer Science and Engineering
CU	Cu alloy
D-Cache	Data Cache
DCU	Display Controller Unit
DDR	Double Data Rate
DDR2	Double Data Rate Two
DDR3	Double Data Rate Three
DDR4	Double Data Rate Four
DMA	Direct Memory Access
DNA	Deoxyribonucleic Acid
DoD	Department of Defense
DRAM	Dynamic Random Access Memory
DSP	Digital Signal Processing
dSPI	Dynamic Signal Processing Instrument
DTRA	Defense Threat Reduction Agency
Dual Ch	Dual Channel
ECC	Error-Correcting Code
EEE	Electrical, Electronic, and Electromechanical
EMAC	Equipment Monitor And Control
EPC	Efficient Power Conversion
ESL	Electronic System Level
eTimers	Event Timers
FCCU	Fluidized Catalytic Cracking Unit
FeRAM	Ferroelectric RAM
FinFET	Fin Field Effect Transistor (the conducting channel is wrapped by a thin silicon "fin")

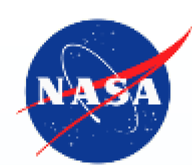
Acronym	Definition
FlexRay	FlexRay communications bus
FPGA	Field Programmable Gate Array
FY	Fiscal Year
GaN	Gallium Nitride
Gb/s	gigabyte per second
Gen	Generation
GIC	Global Industry Classification
GPU	Graphics Processing Unit
GSFC	Goddard Space Flight Center
HALT	Highly Accelerated Life Test
HAST	Highly Accelerated Stress Testing
HDIO	High Density Digital Input/Output
HDR	High-Dynamic-Range
HEMTs	High-electron-mobility transistors
HP Labs	Hewlett-Packard Laboratories
HPIO	High Performance Input/Output
HUPTI	Hampton University Proton Therapy Institute
HW	Hardware
I2C	Inter-Integrated Circuit
IBM	International Business Machines
IBM/GF	International Business Machines/GlobalFoundaries
IC	Integrated Circuit
I-Cache	Instruction Cache
IoT	Internet of Things
IP	Intellectual Property
IR	Infrared
IR/Infineon	International Rectifier/Infineon Technologies
IUCF	Indiana University Cyclotron Facility
JPEG	Joint Photographic Experts Group
KB	Kilobyte
L2 Cache	independent caches organized as a hierarchy (L1, L2, etc.)
LCoS	Liquid-Crystal-on-Silicon
LET	linear energy transfer
LinFlex	Local Interconnect Network Flexible
LLUMC	Slater Proton Treatment and Research Center at Loma Linda University Medical Center
L-mem	Long-Memory
LP	Low Power
M/L BIST	Memory/Logic Built-In Self-Test
MBSE	Model-Based Systems Engineering
MEMS	Micro Electrical-Mechanical System
MGH	Mass General Francis H. Burr Proton Therapy
MIPI	Mobile Industry Processor Interface
MOSFETS	Metal Oxide Semiconductor Field Effect Transistors
MPSoC	Multi-Processor System on a Chip
MRAM	Magnetoresistive Random Access Memory
Msg	Message

Acronym	Definition
NASA	National Aeronautics and Space Administration
NAVY Crane	Naval Surface Warfare Center, Crane, Indiana
NEPP	NASA Electronic Parts and Packaging
NGSP	Next Generation Space Processor
NOR	Not OR logic gate
NSRL	NASA Space Radiation Lab
Occam	Open Conditional Content Access Management
OKC	Oklahoma City
OLED	Organic Light Emitting Diode
PBGA	Plastic Ball Grid Array
PCIe	Peripheral Component Interconnect Express
PCIe Gen2	Peripheral Component Interconnect Express Generation 2
PCIe Gen4	Peripheral Component Interconnect Express Generation 4
PS-GTR	Global Regulation on Pedestrian Safety
R&D	Research and Development
RAM	Random Access Memory
ReRAM	Resistive Random Access Memory
RF	Radio Frequency
RGB	Red, Green, and Blue
RH	RAD-Hard
SAR	Successive-Approximation-Register
SATA	Serial Advanced Technology Attachment
SCU	Secondary Control Unit
SD/eMMC	Secure Digital embedded MultiMediaCard
SD-HC	Secure Digital High Capacity
SDRAM	Synchronous Dynamic Random Access Memory
SEE	Single Event Effect
SERDES	Serializer/Deserializer
SiC	Silicon Carbide
SMMU	System Memory Management Unit
SOC	System on a chip
SPI	Serial Peripheral Interface
SPU	Synergistic Processor Unit
TCM	Tightly Coupled Memory
TI	Texas Instruments
TRIUMF	Tri-University Meson Facility
TRL	Technology Readiness Level
T-Sensor	Temperature-Sensor
TSMC	Taiwan Semiconductor Manufacturing Company
UART	Universal Asynchronous Receiver/Transmitter
UFHPTI	University of Florida Health Proton Therapy Institute
USB	Universal Serial Bus
VNAND	Vertical NAND
WBG	Wide Band Gap
WDT	Watchdog Timer



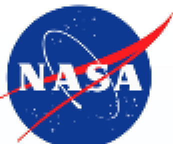
Outline

- NEPP Program Overview
- Mike’s Highlights and “Concerns”
- Electrostatic Discharge (ESD)
- Radiation Update
- Automotive Parts
- Parts Issues
- GIDEP and Counterfeits
- A Look Forward
- Summary



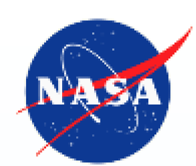
NEPP

- **Chartered in the 1980’s to ensure electronic commodities expertise supported the Agency.**
  - **The NASA Electronic Parts Assurance Group (NEPAG) was created in 2000, as a sub-element of NEPP for**
    - **Information sharing between NASA Centers and other agencies, and**
    - **Sufficient infrastructure to support Agency needs and leadership in EEE Parts Assurance**
- **NEPP evaluates new EEE parts technologies and develops insertion, test, screening, and qualification guidance.**
  - ***We do not qualify specific parts, but develop the knowledge on HOW to qualify/test the parts.***
- **NEPAG supports audits, specification and standard reviews failure investigations etc.**



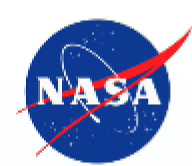
NEPAG "Extended Family"

To be presented by Mike Sampson at the Space Parts Working Group (SPWG) April 4, 2017



Program Highlights

- ***NEPAG has celebrated 16 years of stimulating, weekly discussions and knowledge interchange that is/has been Educational, Influential, Collaborative, and Current***
  - *New multi-agency Working Group established for coordinated disposition of proposed changes to specifications and standards*
- **New NASA Standard, "Electrical, Electronic, and Electromechanical (EEE) Parts Management and Control Requirements for Space Flight Hardware & Critical Ground Support Equipment" NASA-STD-8739.10**
  - **Standardizes NASA traditional practices for the selection, acquisition, traceability, testing, handling, packaging, storage, and application of EEE parts**
  - **Includes radiation, prohibited materials and counterfeit avoidance**
- **Working with Aerospace to develop an agreement to share support of MIL QPL/QML audits led by the Defense Logistics Agency Land and Maritime**



NASA Concern - ESD

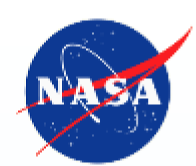
Electro Static Discharge (ESD)

- MIL-STD-883, Test Method 3015
  - Too old, long test times
  - Needs to be revisited for new technology
    - Smaller feature sizes, lots of contacts/pins, advanced packaging (2.5/3D)
  - 883 vs JEDEC (3 zaps/pin vs 1 zap/pin, for HBM test)
  - Equipment used to assemble /process parts/wafers need closer look – special talk at Space subcommittee meeting
  - Generic issue; applies to all parts military/space (and COTS)
- MIL-PRF-38535
  - Clarify requirements
    - No specific ESD requirements for wafer foundries
  - DLA is conducting their engineering practice (EP) study
- NASA EEE Parts Bulletin
  - Published a special edition on ESD, 2nd part published soon
- NASA ESD Surveys
  - Conducted to bring awareness

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)

Performed By?	Production Step
Company A	Die Design and Fabrication
Company B	Fabrication
Company C	Wafer Bumping
Company D	Package Design and Package Manufacturing
Company E	Package Design
Company F	Assembly
Company G	Column Attach and Solderability
Company H	Screening, Electrical and Package Tests
Company I	Radiation Testing



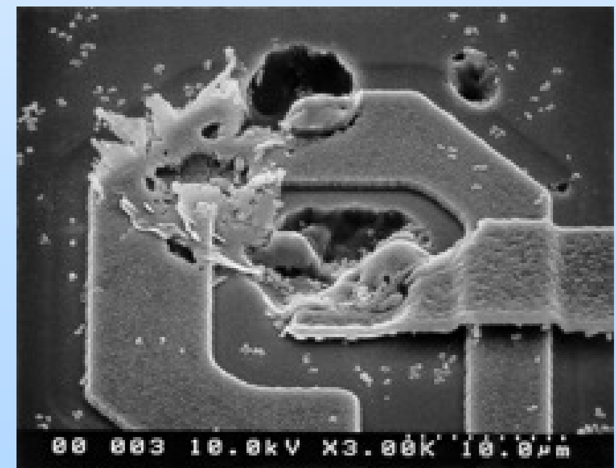
Some Standards for ESD Control

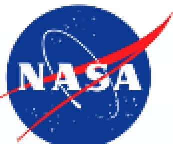
- MIL-STD-750, Test Method 1020, *Electrostatic Discharge Sensitivity (ESD) Classification*
- MIL-STD-883, Test Method 3015, *Electrostatic Discharge Sensitivity [ESDS] Classification*
- MIL-STD-1686, *Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)*, Rev. C, Oct. 25, 1995.
- MIL-PRF-38535, *Integrated Circuits (Microcircuits) Manufacturing, General Specification for*
- SEMI E78-0309, *Guide to Assess and Control Electrostatic Discharge (ESD) and Electrostatic Attraction (ESA) for Equipment*
- JESD22-A114F, JEDEC Standard For *Electrostatic Discharge Sensitivity Testing Human Body Model (HBM) - Component Level*
- ANSI/ESDA/JEDEC JS-001-2014, ESDA/JEDEC Joint Standard *Electrostatic Discharge Sensitivity Testing – Human Body Model (HBM) – Component Level*
- ESDA/JEDEC JS-002 2014, Electrostatic Discharge *Sensitivity Testing - Charged Device Model (CDM) - Device Level,*
- ANSI/ESD S20.20-2014, ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

Importance of ESD

- **Potentially affects everything, even mechanical parts, and there are major differences among the multiple ESD specs in use.**
- **There are ongoing efforts by various standards groups toward harmonizing the different standards.**
- **1686 is the original MIL document for ESD testing and control, and it could be built up into a major ESD spec. However, Office of Management and Budget (OMB) Circular A-119 favors Industry Standards over government ones.**

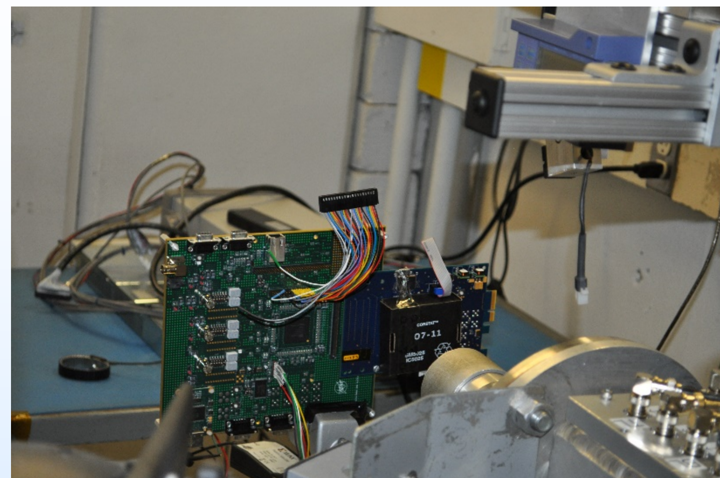
MIL-STD-750, MIL-STD-883, MIL-PRF-38535 and probably other MIL documents, call out MIL-STD-1686 Requirements



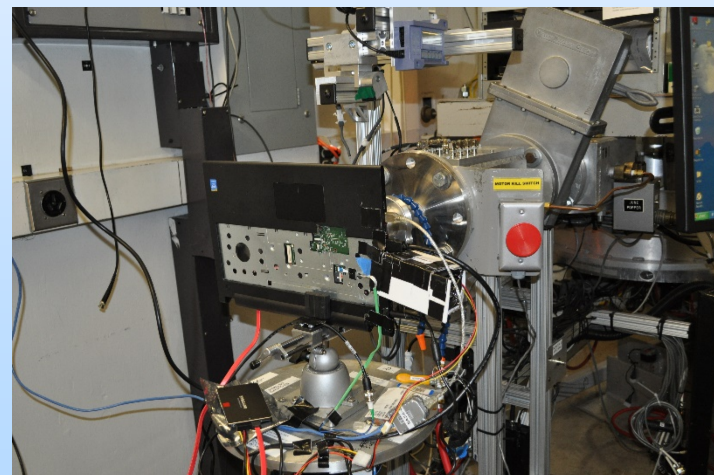


Radiation Highlights

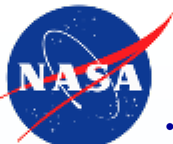
- **Independent heavy ion testing of Microsemi RTG4 FPGA**
  - **Collaboration with AF/The Aerospace Corp as well as Microsemi Corp**
    - **Nice to work with a manufacturer seeking improvement!**
- **Heavy ion single event safe operating area (SOA) for Schottky Diodes (and similar architecture devices)**
  - **Guideline planned by end of FY**
- **Processors**
  - **Collaboration with Navy Crane**
  - **State of the art technology (1x nm CMOS) evaluation**
- **Memories**
  - **Commercial RERAM and ST-MRAM samples under test**
- **Protons**
  - **Board level proton test guideline**
  - **Great proton search (next chart)**



Testing of RTG4 at Texas A&M Cyclotron (TAMU), Ken LaBel

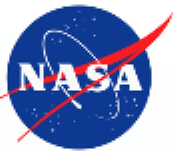


–Testing of Intel Broadwell Processor at TAMU, Ken LaBel



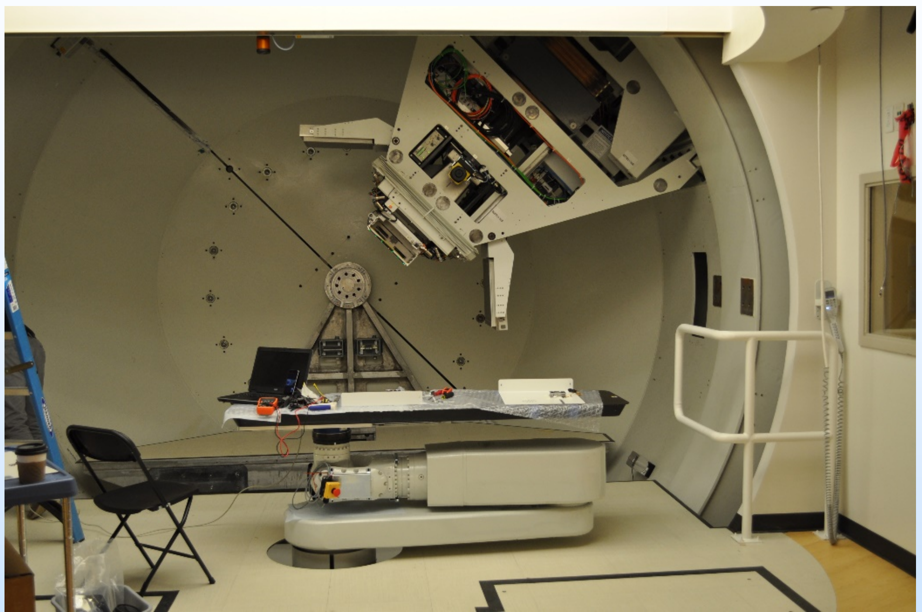
Proton Facilities Snapshot– 200 MeV regime

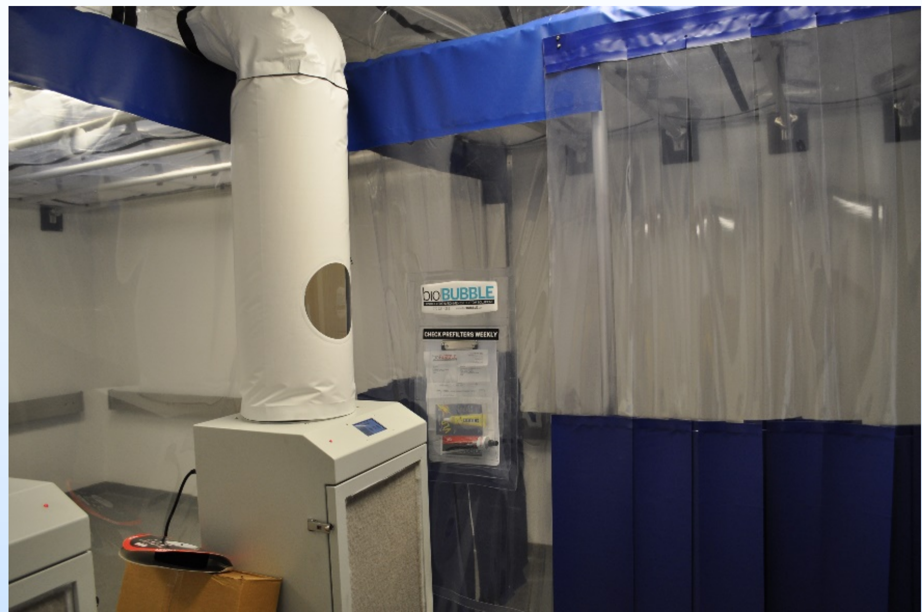
- Prime Proton Research Facilities
  - Massachusetts General Hospital (MGH) Francis H. Burr Proton Therapy Center
    - Provides 24 hours for 3 out 4 weekends a month
    - Highly used by industry and all Agencies
      - Overbooked already for CY17!
  - Tri-University Meson Facility (TRIUMF) – Vancouver, CAN
    - Runs 4 cycles a year
- Proton Cancer Therapy Facilities Taking Customers
  - Loma Linda University Medical Center (LLUMC)
    - Weekend usage with limited available time beyond current load
  - SCRIPPS Proton Therapy Center
    - Announced bankruptcy on March 2, 2017
    - Has 4 industry user contracts with no additional users (i.e., “large” users only – 100 hrs/yr)
  - Hampton University Proton Therapy Institute (HUPTI)
    - Planning to open research room in May-June 2017
      - NEPP and OneWeb supporting planning
    - Weekdays with beam interleaving w patients
    - Hourly costs - TBD
  - Northwestern Chicago Proton Center (former Cadence)
    - NASA biological dosimetry folks have gone there recently and NEPP has tentative 5/13/17 date
  - Cincinnati Children’s Proton Therapy Center
    - Nice separate research room with model similar to IU (interleaving weekdays with patients – no weekends)
    - Expect late summer opening for customers
- New to the Discussion (research rooms opening this year) – visits in April
  - U Penn Roberts Proton Therapy
- Proton Cancer Therapy Facilities – Pending Access
  - U MD Proton Therapy Center (Baltimore)
    - Planning on taking customers in summer’17 w/ NASA shakeout test prior
    - Planning similar mode to SCRIPPS
  - University of Florida Proton Health Therapy Institute (UFHPTI)
    - Completing medical commissioning
    - TBD yearly hours available to community but expect ~300 hours/year
    - Expect shakeout test in 4Q FY17
  - Case Western University Hospital Seidman Cancer Center
    - NASA GRC working a SAA with expected visit?
      - Waiting on lawyers
    - Small facility with expected limited hours (but great for GRC!)
  - Mayo Clinic
    - Two proton facilities (Rochester, MN and Phoenix, AZ) – synchrotron, but unique duty cycle
      - Visited in 1QFY17
      - Research room built and have experience with government contracts
      - Shakeout test expected in June FY17
  - ProVision (Knoxville)
    - TBD – 2 rooms opening with TBD excess capacity in TBD timeframe in 2017 – limited responsiveness
  - MD Anderson
    - NASA/JSC evaluating with The Aerospace Corp
- Proton Research Facilities – Proposals
  - Los Alamos Neutron Science Center (LANSCE)
    - Has 800 MeV proton source with white paper to modify for SEE test purposes
    - Visited in 1QFY17 – requested support and aid in obtaining funding
    - Question remains on beam structure



Sample Site Output

Proton Therapy Center – Cincinnati Children's Hospital





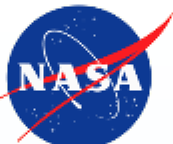
Research room is expected to be finished in Apr-May with customers late summer.

Gantry position for electronics testing is variable but standard at either 0 or 90 degrees (vertical or horizontal board mounting on sled).

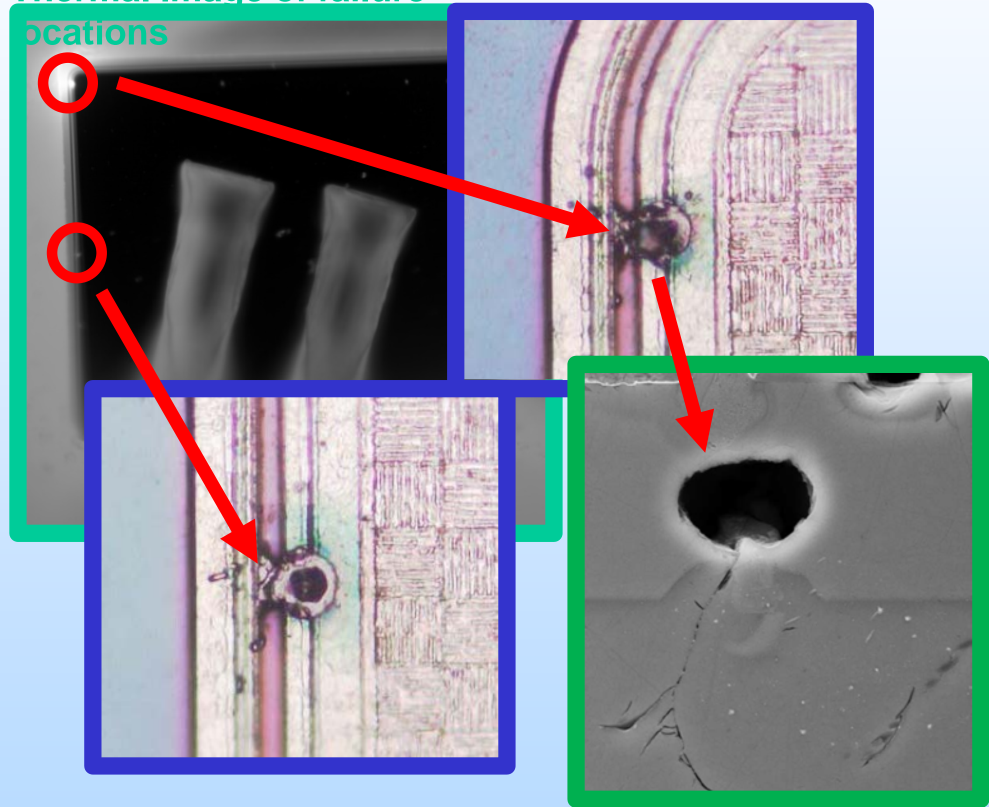
They plan on having "standard" positions with spot sizes, energies, fluxes available with custom options.

This is the planned wet lab area.

The research room is expected to be shared with biological and other research groups.

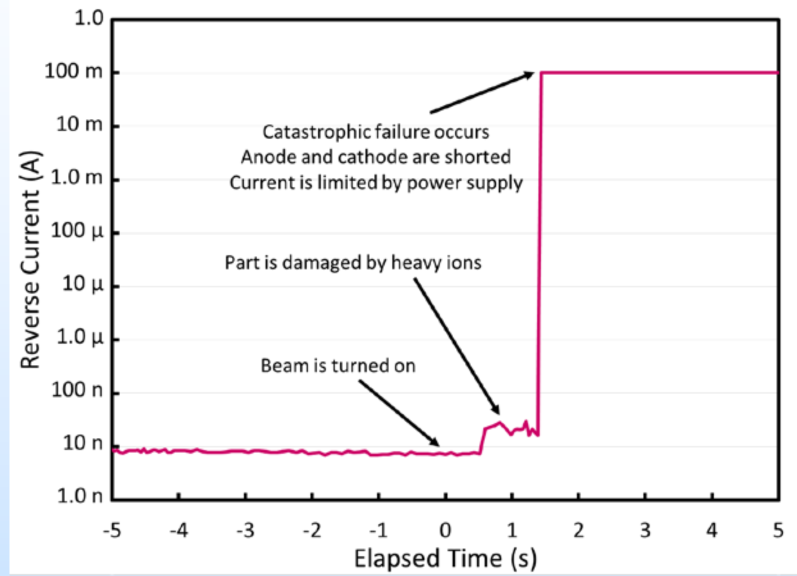


Failure Analysis of Heavy-Ion-Irradiated Diodes

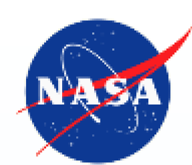


High magnitude optical images of failure locations

Cross-section of failure location

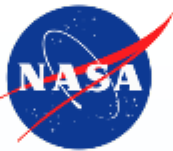


- **300 V, 20 A Super Barrier Diode**
- **Experienced catastrophic failure when reverse biased at 225 V and irradiated with 1233-MeV Xe (LET = 58.8 MeV-cm^2/mg) at LBNL**
- **After failure, breakdown voltage reduced from 331 V to 1 V and forward voltage reduced slightly**



Alternate Grade Electronics: Automotive

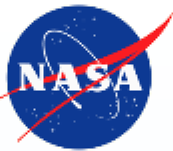
- NEPP has three goals for automotive electronics efforts
  - Determine exactly what :"automotive grade" does or does not entail.
    - Includes understanding:
      - Automotive Electronics Council (AEC) documents, and,
      - Manufacturer Production Part Approval Process (PPAP).
  - Perform "snapshot" screening and testing on representative automotive grade electronics.
  - Explore application of resilient automotive electronics system designs for space purposes.



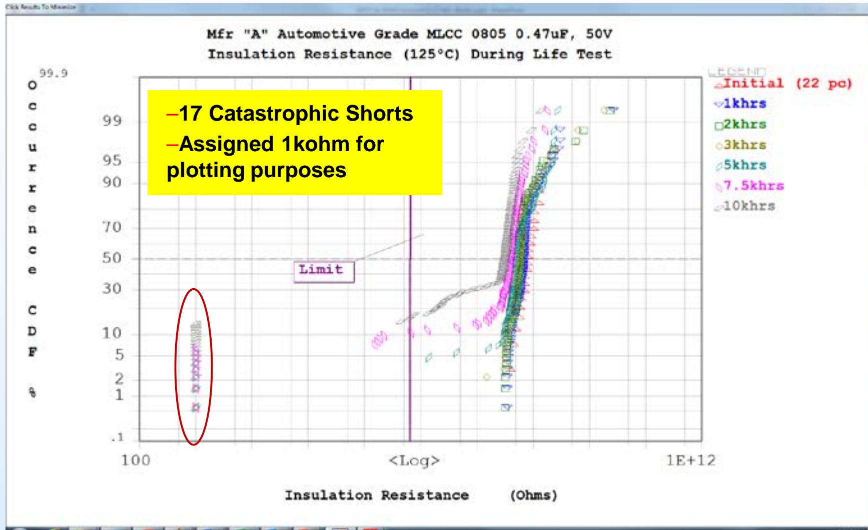
NEPP Evaluation of Automotive Grade EEE Parts

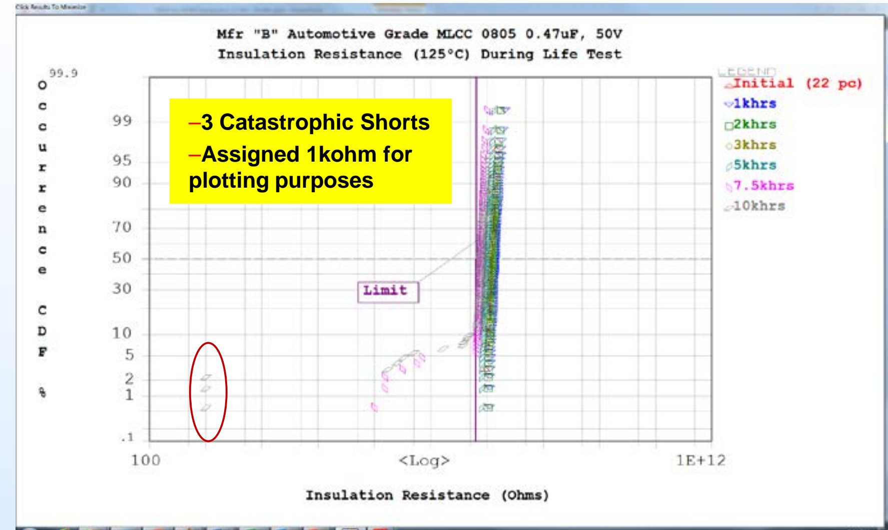
20-Mar-17

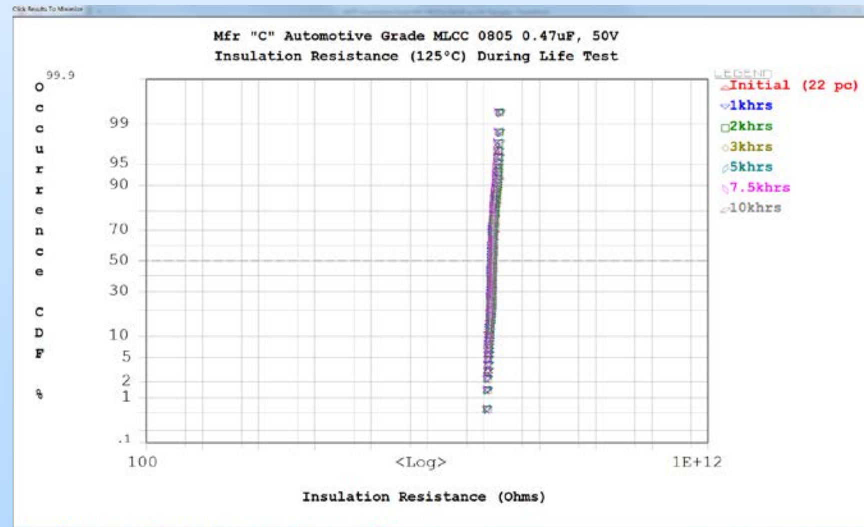
Manufacturer	Lot Code	Description	Quantity on Test	Life Testing Status	Comments
A	1302	Ceramic Chip Capacitor, 0805, 0.47uF, 50V	120	10khrs	120 pcs on test. 17 catastophic life test failures with first occurring ~3.1khrs
B	1304		120	10khrs	120 pcs on test. IR degradation noticed @7.5khrs; 3 catastrophic failures beyond 8khrs of test
C	1131		120	10khrs	120 pcs on test. No Catastrophic Life Test Failures
D	201028	Ceramic Chip Capacitor, 0402, 0.01uF, 16V	78	8k Hrs	few devices exhibit reduced IR (non-catastrophic)
E	TBD		80	8k Hrs	few devices exhibit reduced IR (non-catastrophic)
F	1247		79	8k Hrs	Stable IR Note: Precious Metal Electrode
AA	N/A	Tantalum Chip Capacitor, 22uF, 35V	80	2k Hrs	No Catastrophic Failures; ~10% show hot DCL above spec limit
AA	1301	Tantalum Chip Capacitor, 220uF, 10V	80	2k Hrs	No Catastrophic Failures;
G	TBD	Microcircuit, Transceiver	50	Not yet started	sent boards for fabrication
H	1152	Microcircuit, Comparator	90	2k hrs	Two setups, 45 units each. No failures.
I	1341	Microcircuit, comparator	50	Not yet started	Test Program in Development
J	unknown	Dual small signal NPN Bipolar transistor (similar to 2N2919 and 2N2920 MIL-PRF-19500/355)	20	>5k Hrs	No failures to Date Second batch of 20 devices in process to start life
K	1339	Switching diode (similar to 1N4148, MIL-PRF-19500/116)	20	100 hrs life test	No Failures to Date Parametric Degradation Observed beginning TA ~ 40°C behaves like short circuit >105°C
L	unknown	Transient Voltage Suppressor, 36V minimum breakdown voltage, 400 watt peak pulse power	20	Not yet started	Test plan and test boards being validated Testing to commence 3QFY17

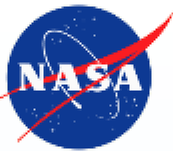


AEC-Q200: 0805 Ceramic Chip Capacitors, Insulation Resistance at 125^{0}C During Life Test

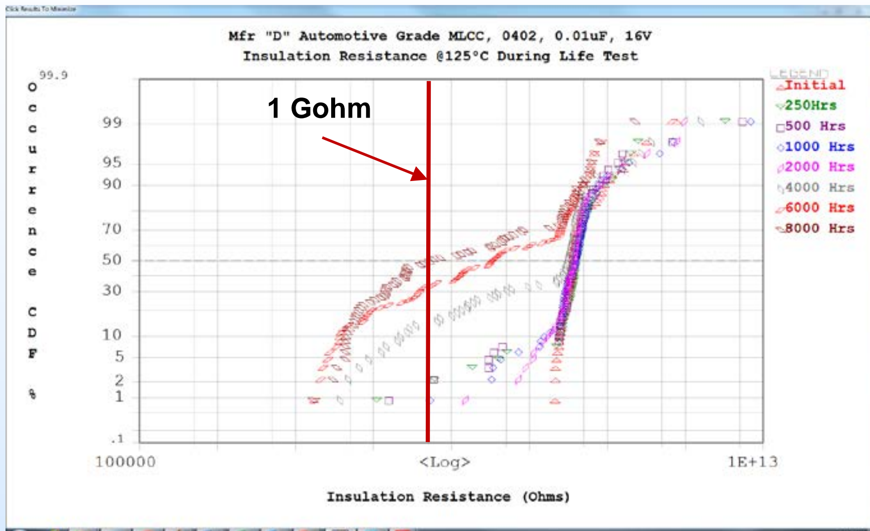


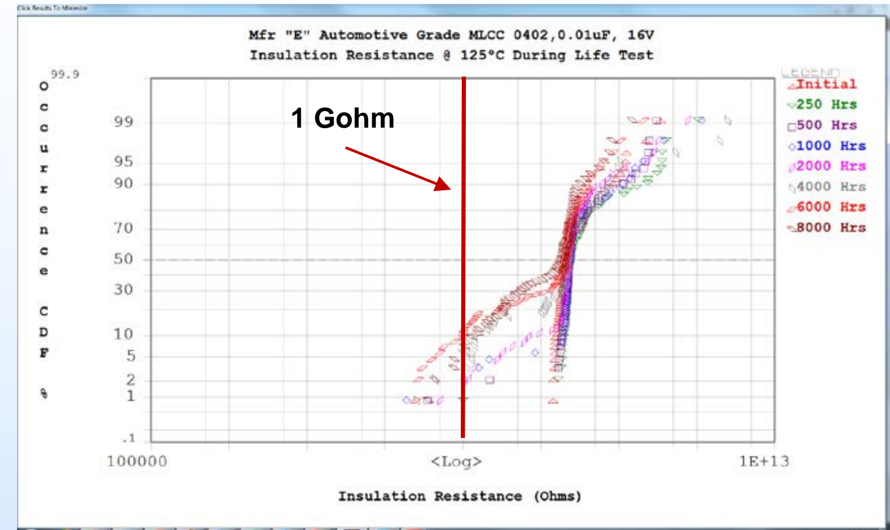


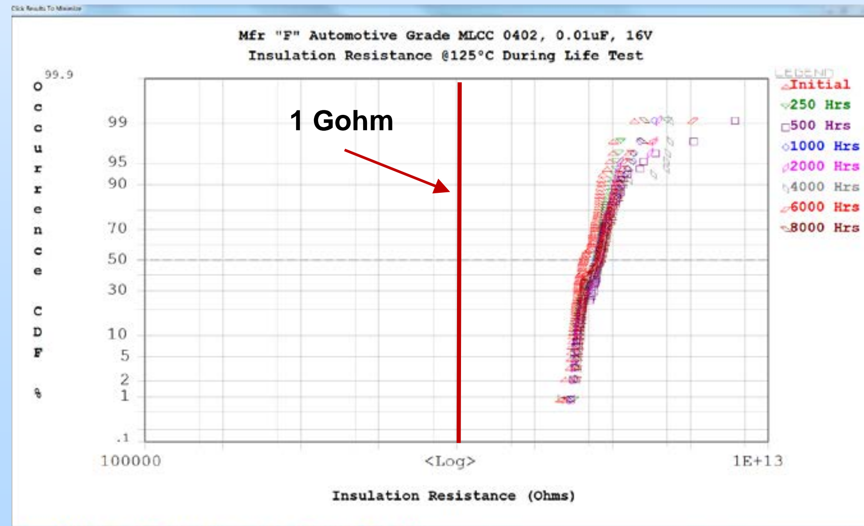


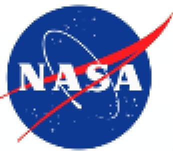


AEC-Q200: 0402 Ceramic Chip Capacitors, Insulation Resistance at 125^{0}C During Life Test

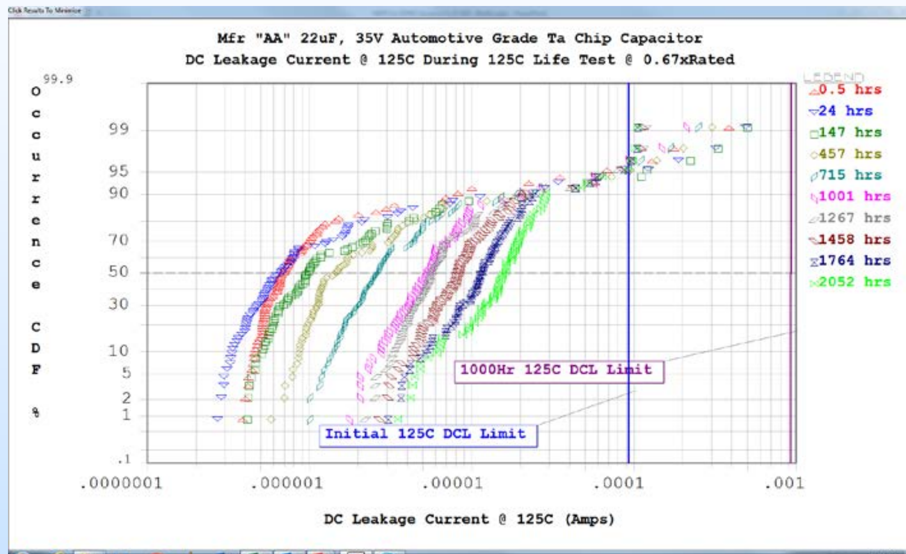


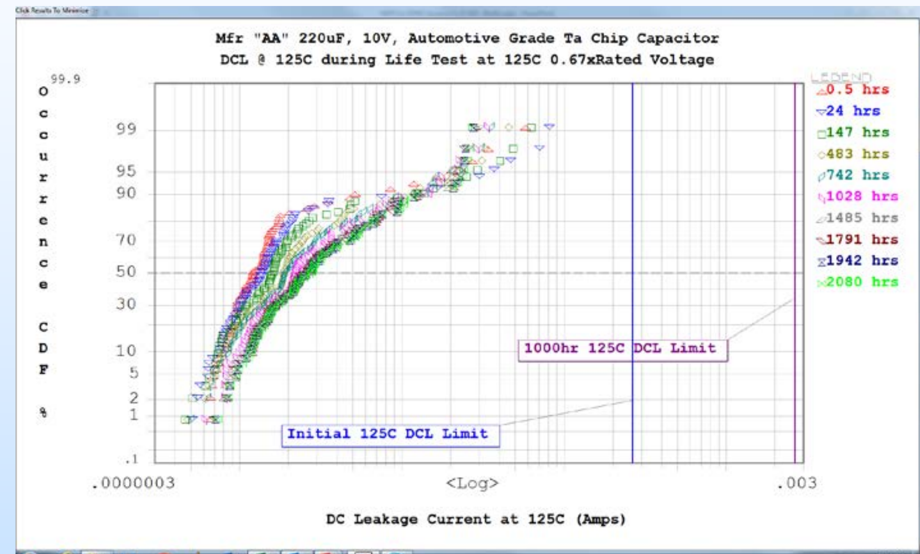


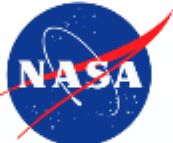




AEC-Q200: D-Case Tantalum Chip Capacitors, DC Leakage Current at 125^{0}C During Life Test







Switching Diode Testing

Forward Current, I_F (A)

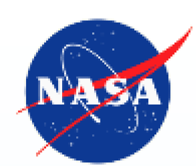
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6

Forward Voltage, V_F (V)

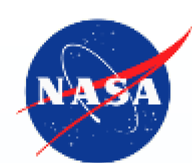
@ 25 ºC
@+50 ºC
@+100 ºC
@-50 ºC
@-75 ºC
@-150 ºC
@-100 ºC
@+150 ºC
@-192 ºC

- **Forward V/I characteristics of switching diode versus temperature**



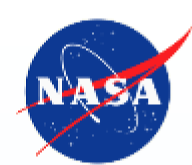
Switching Diode Temperature Testing Summary

- Temperature cycling and short extreme temperature exposures caused no effect on the plastic packaging.
- Diodes maintained operation between -192C and +150C with minimal characteristic changes
- Temperature Changes observed:
  - Increase in leakage current at high temperature
  - Decrease in breakdown voltage at extremely high and low temperatures
  - Further investigation needed to determine whether switching diode function and packaging would function in extended temperature ranges (-192C) for long periods of time.



Reverse-bias Tantalum Chips

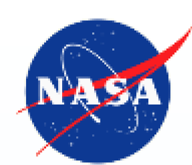
- Capacitors in International Space Station experiment pallets known as Express Logistics Carriers (ELCs) were found installed backwards
- They have so far functioned satisfactorily for 6 years on orbit
- The risk of failure needs to be understood to avoid a workaround including a space walk
- Why are the capacitors not failing and what performance envelope must they occupy to avoid failure for as long as possible?
- Experiments in progress to look at effects of voltage, temperature and humidity



Multi-layer Ceramic Capacitors (MLCCs)

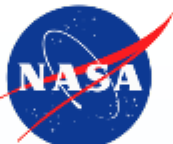
- **NASA has recently experienced 2 on-orbit MLCC anomalies**
  - Characteristics duplicated on engineering model
- **Both came from same 2010 lot**
- **Investigation has found previous indications of similar anomalies going back to at least 2004**
- **Anomalies are major increase in leakage currents and are associated with delaminations and cross dielectric cracks**
- **Too early in our investigation to identify the problem as manufacturer or part type specific.**
- **Handling and soldering stresses may be causing a sub-population to crack they passed all MIL specification tests**
  - Exploratory experiments have begun
- **Indications are this problem was recognized years ago but not communicated in a way NASA could hear**

To be presented by Mike Sampson at the Space Parts Working Group (SPWG) April 4, 2017



RNR 75 Resistors

- The sole source for this style resistor, Vishay Dale in Nebraska is suggesting changes to the test method in MIL-PRF-55182, for reduced barometric pressure
- The resistor type is axial-leaded, glass-bodied, hermetically-sealed thin film
- RNR75 has the highest power rating and test voltage in the specification (450 V AC, which is 600 V peak).
- The part is used by the Navy.
- Vishay experienced failures during a recent test. The test requires simulation of 100,000 ft (8 torr) in a bell jar, and voltage is applied to the insulated external case of the resistor. Tests the voltage withstanding across the glass tube and metal end cap
- The requested relaxation of the test requirement is either by dropping the test voltage to 300 V or by introducing water vapor into the chamber.
- More study will be done, but the vendor will probably be allowed to lower the requirement.



Quantity of Counterfeit EEE Parts Alerts per Year

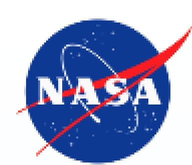
Counterfeiting does not seem to be going away

y = 3.5x - 1.0294

Alert Quantity: 0, 20, 40, 60, 80, 100, 120

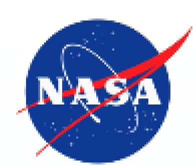
Calendar Year	Alert Quantity
2001	0
2002	2
2003	4
2004	3
2005	14
2006	15
2007	27
2008	9
2009	25
2010	30
2011	83
2012	109
2013	43
2014	46
2015	43
2016	58
2017	7

Calendar Year



Upcoming NEPP Challenges

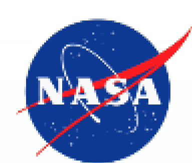
- **Complexity issues for inspection, screening, device preparation, and test**
  - **2.5/3D Packages/ICs**
  - **Package on Package (PoP) Commercial Devices**
  - **An FPGA combined with an SOC (MPSOC+ from Xilinx)**
  - **Cu Wirebonds**
- **Assurance**
  - **Automotive and catalog commercial EEE parts?**
  - **Increasing risk with a worldwide supplier base**
    - **Traceability**
    - **Change control**
    - **Screening?**
  - **Consolidation.**
    - ***What if the only source left is in an inhospitable or unauditable part of the world?***



Summary and Comments

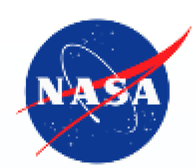
- **NEPP Roadmaps and Tasks are constantly evolving as technology and products become available.**
  - **Like all technology roadmaps, NEPP's is limited to funding and resource availability.**
  - **Not shown are TBD passives and connector roadmaps under development.**
  - **Partnering is the key:**
    - **Government,**
    - **Industry, and,**
    - **University.**
- **We look forward to further opportunities to partner.**

https://nepp.nasa.gov

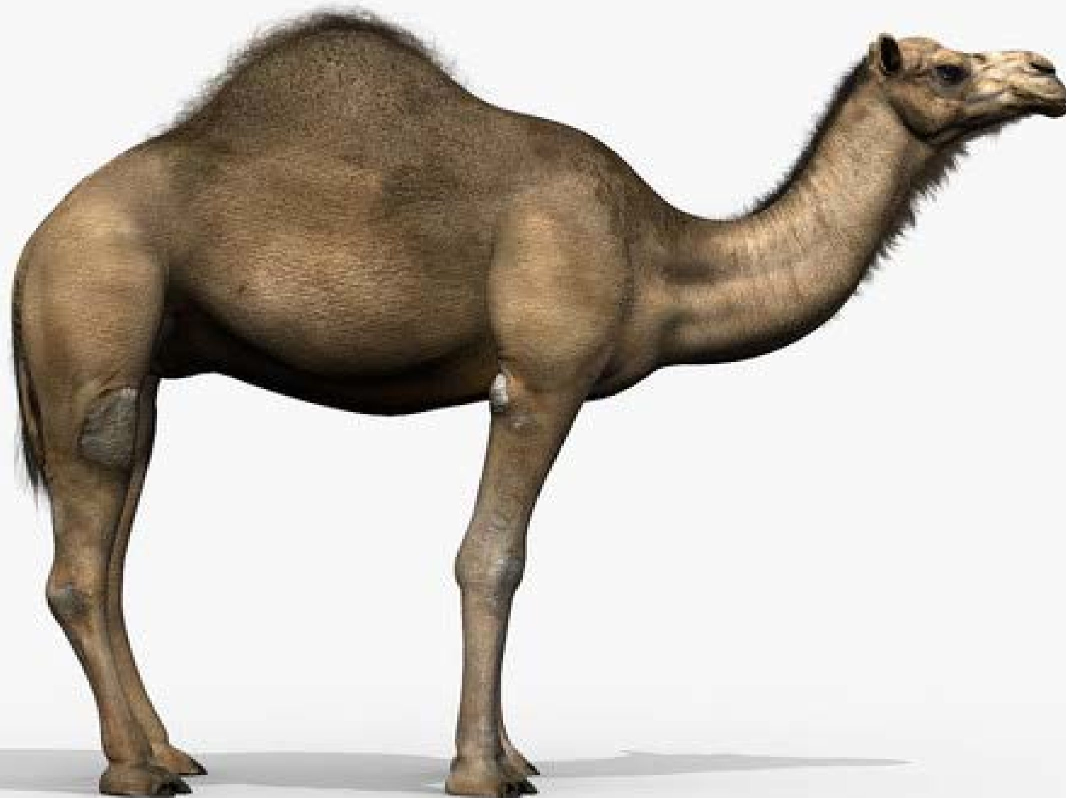


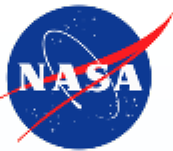
Upcoming

- 8th Annual NEPP Electronics Technology Workshop
  - June 26-29, 2017
  - NASA/GSFC (on-site) plus web access available
  - Highlights of NEPP tasks
  - HiREV day
  - Special topics include:
    - Automotive electronics and SiC power devices
    - 2.5/3D ICs and proton testing splinter groups



BACK-UP





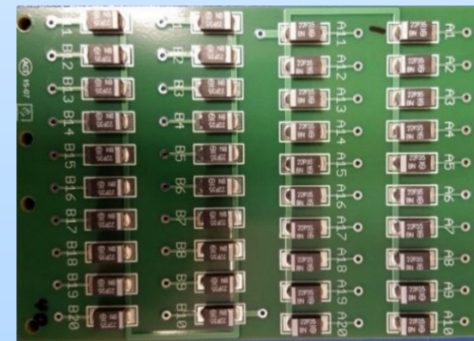
NEPP Automotive EEE Parts Evaluation Status

–Automotive Parts Task Team met with NSWC Crane test personnel 10/31 to 11/2, to resolve technical and funding issues. Very productive meeting.

Integrated Circuits
- Comparator:
  - Burn-In 2k hrs Life Test Complete. Continuing to 5k hrs
  - Used two setups, maximum and typical drive currents. 45 units each setup.
  - No Failures to Date.
- Differential Bus Transceiver:
  - Life Test RESTART Pending.
  - Testing at NSWC Crane re-started, boards being built – funding restored
- Comparator from another manufacturer:
  - Test to be started. Minor changes to be made to existing software for another comparator.

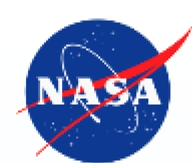
Discrete Semiconductors
- Bipolar transistor:
  - Burn-In + 5k hrs of life test completed.
  - No Failures to Date
  - Second batch of 20 devices in process to start life testing.
- Switching diode:
  - Parametric Degradation Observed beginning T_A ~ 40°C behaves like short circuit at temperatures above 105C. Under investigation
  - Burn-In and 100 hrs life test completed.
  - No Failures to Date
- Transient suppressor:
  - Test plan and test boards being validated (testing to commence 3QFY17)

Passives
- Ceramic Chip Capacitors
  - 10k hour life test on 3 lots of BME 0805 chip caps (0.47uF, 50V)
    - Mfr "A" – 17 catastrophic failures;
    - Mfr "B" – 3 catastrophic failures;
    - Mfr "C" – No failures
  - Completed 8k hour life test on 3 lots (2 BME and 1 PME) of 0402 chip caps (0.01uF, 16V)
    - Both BME lots show hot IR degradation beginning ~500 hours
- Tantalum Chip Capacitors
  - 125°C 2/3 rated voltage life testing at GSFC (22uF, 35V ; 220uF, 10V)
  - 2000 hour life test complete
  - No Catastrophic Failures
  - ~10% of parts show non-catastrophic parametric shift (125°C DC Leakage)



Life Test Board for Tantalum Chip Capacitor Evaluation

To be presented by Mike Sampson at the Space Parts Working Group (SPWG) April 4, 2017



Switching Diode Testing

Forward Voltage, V_F (V)

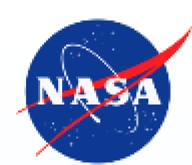
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4

-200 -160 -120 -80 -40 0 40 80 120 160

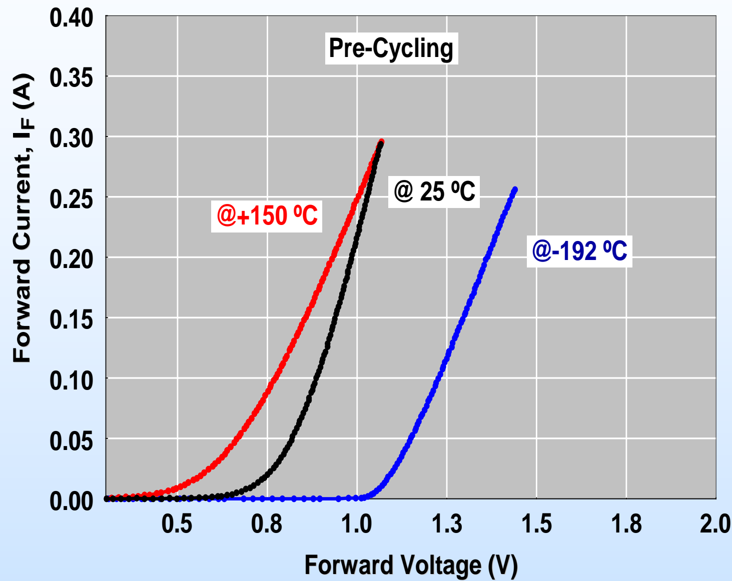
Temperature (ºC)

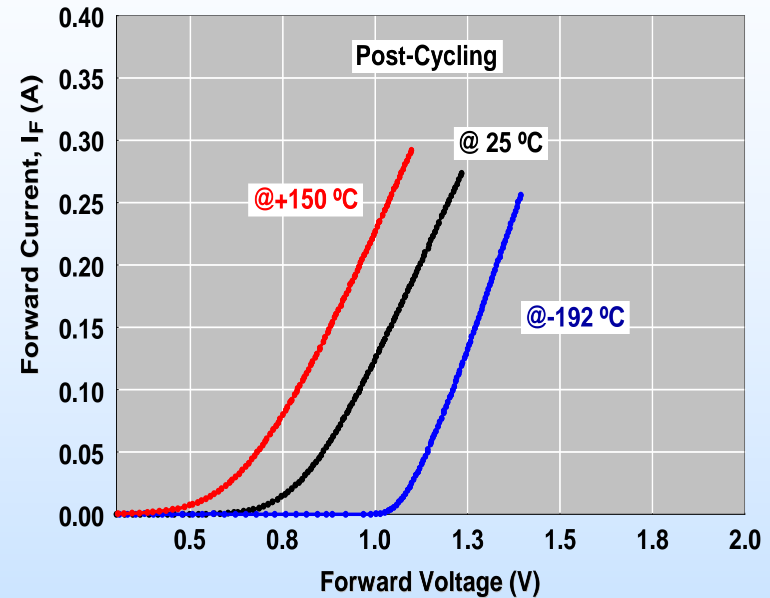
@ I_F 5 mA

- Forward Voltage as function of temperature

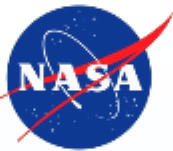


Switching Diode Testing





- **Pre- and post temperature cycling forward V/I characteristics of switching diode at selected temperatures**



Switching Diode Testing

Voltage (V)

200 150 100 50 0

Current (A)

0.000000 0.000005 0.000010 0.000015 0.000020 0.000025

@ 25 ºC
@+100 ºC
@-192 ºC
@+50 ºC
@-50 ºC
@-150 ºC
@-75 ºC
@-100 ºC
@+150 ºC

- **Reverse VI Characteristics as function of temperature**