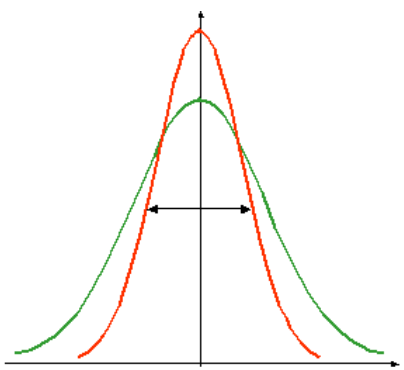
Space Parts Working Group
April 13 & 14 Hilton
Torrance, CA

One NASA

Review of COTS Plastic Encapsulated Microcircuits (PEMs) for Space Applications



In Pursuit of Excellence in Quality & Reliability

ACKNOWLEDGEMENT

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GTL

GENERAL TEST LABORATORY

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TEST & MEASUREMENT

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INTRODUCTION

NASA's use of COTS PEMS electronic components in Space applications has raised serious concerns and issues about their inherent reliability, quality, and design performance robustness.

To fully understand, and to assess and mitigate risks, NASA is undertaking a *thorough* investigation and performing *extensive* screening and package evaluations on various COTS components from selected manufactures.

The device screening/reliability evaluations have been completed. Additional package evaluations are currently underway.

GOALS & OBJECTIVES

1. *NASA started this characterization to validate which screens are necessary and value added in the usage of PEMs in Spaceflight, and which screens are not necessary. This also holds true for deciding what qualifications are most effective based on mission requirements.*

2. *From all of NASA's experiences gained with the COTS PEMs Q/R Evaluation program, a NASA guideline document will be written to aide NASA projects that will use COTS PEMs in future flight hardware.*

NASA EEE PARTS ORGANIZATIONS

The organizations listed below have played a major role in the peer review process for NASA.

- **NASA/ARC**
- **NASA/GRC**
- **NASA/GSFC**
- **NASA/JPL**
- **NASA/JSC**
- **NASA/KSC**
- **NASA/LaRC**
- **NASA/MSFC**
- **US AMCOM**
- **US NAVSEA**
- **USAF-SMC/Aerospace Corporation**
- **USAF/Northrop Grumman ICBM**
- **ESA**
- **JHU/APL**
- **JAXA**
- **CSA**

NEPAG
NASA EEE PARTS ASSURANCE GROUP

NEPP

PLAN AND TIMELINE

NASA's plan and timeline are designed to complete three major deliverables by FY05.

Deliverable	Year	Status
Part Selection/Criteria	FY02	✓
Test Lab Selections	FY02	✓
Procurements	FY02	✓
Screening Test/ Evaluations	FY03	✓
Die/Package Evaluations	FY04	
ONE-NASA Guidelines	FY05	

✓ - Completed

PLASTIC PART SELECTION

- **8 Bit High Speed, Ultra Low Power A/D; 24 ld SOIC -Vendor A**
- **16 Channel Analog Multiplexer; 28 ld SOIC-Vendor B**
- **High Speed Operational Amplifier; 8 ld SOIC -Vendor C**
- **High Precision Voltage Reference; 8 ld SOIC -Vendor D**
- **High Common Mode Voltage Difference Amplifier; 8 ld SOIC - Vendor E**

The selection criteria were based on NASA's needs, part complexity, testability, procurement cost, and part availability.

SCREENING/TEST EVALUATIONS

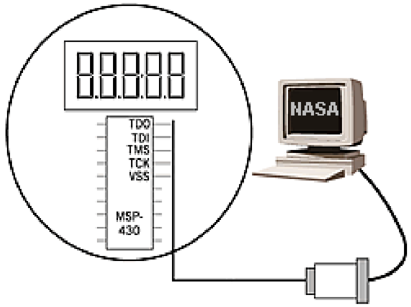
- ✓ DPA (completed)
- ✓ Serialization (completed)
- ✓ Electricals (completed)
- ✓ Static Burn-In FIT (completed)
- ✓ Temperature Cycle (completed)
- ✓ X-Ray (completed)
- ✓ CSAM (completed)
- ✓ Dynamic Burn-In (completed)
- ✓ Dynamic Operating Life Test (completed)

FY 03

DATA REVIEW PROCESS/METHODOLOGY

Conducting data reviews using established procedures is critical to finding and uncovering all part performance and reliability issues, especially those governed by time, temperature, and voltage. Below are the steps taken during the test/data review.

- ❑ Test procedures approval and data problem resolutions
- ❑ Raw test data extraction into workable analysis format
- ❑ Review of all test parameters by temperature and serial number
- ❑ Statistical summaries with reliability interpretation
- ❑ Data analysis of failures to vendor's specifications
- ❑ Correlation to vendor's lot and or date code
- ❑ Numerical analysis
- ❑ Peer review of data and interpretation of results

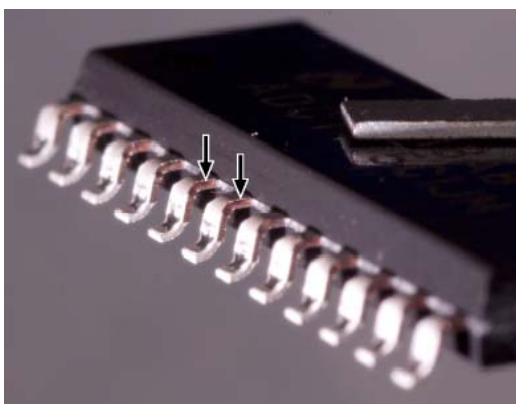


DPA SIGNIFICANT RESULTS

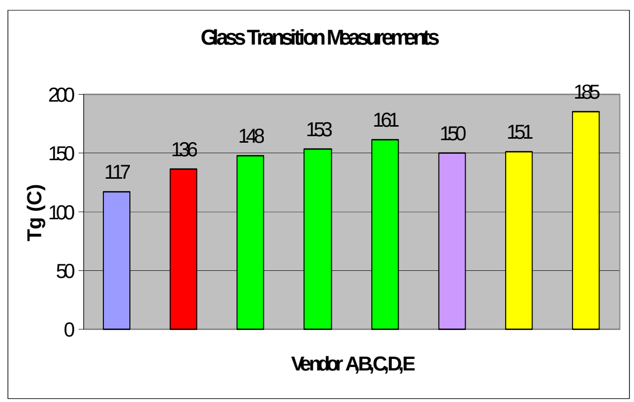
Part Type	Vendor	Ex Visual	Int Visual	X-Ray	Outgassing	Ld Finish	Die Attach	Tg	Bond Pull	Metallization
A/D	A	Pass	Pass	Pass	Pass	Pure Sn	Pass	Low	Pass	Pass
Multiplexer	B	Pass	Pass	Pass	Pass	Pb-Sn	Pass	High	Pass	Pass Marginally
Op Amp	C	Pass	Pass	Pass	Pass	Pb-Sn	Pass	Low	Pass	Pass
Reference	D	Pass	Pass	Pass	Pass	Pure Sn	Pass	High	Pass	Pass
Amplifier	E	Pass	Pass	Pass	Pass	Pb-Sn	Pass	High	Pass	Pass

Sample size was 22 pcs per part type. The number of date codes sampled varied from one to three per part type depending on the availability during part procurements.

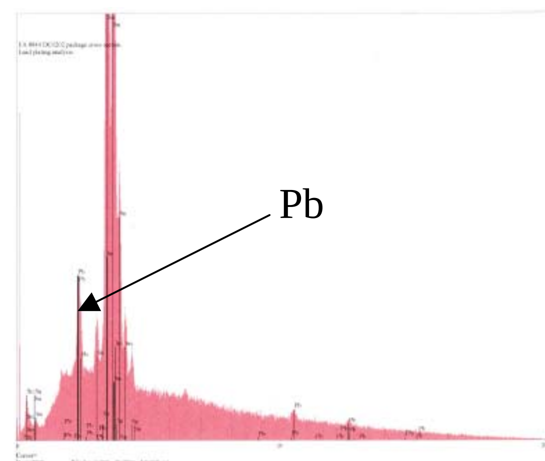
Based on the results:



1.Pre-tinning is recommended before any board assembly.



2. Glass transition measurement is recommended for each date code.



3. Measurement for Pb peak on lead plating is recommended.

STATIC BURN-IN RESULTS (FIT)

Part Type	ss	Vendor	Hours	BI Temp	Rejs(25C)	Functional	Parametric	Critical Parameters	[1] FIT
A/D	22	A	1500	+85C	0	0	0	Offset	1435
Multiplexer	24	B	1000	+125C	0	0	0	Ron	38
Op Amp	22	C	1500	+105C	1	0	1	VOS	TBD
Reference	22	D	1500	+125C	2	0	2	Vout	6153
Amplifier	22	E	1000	+125C	0	0	0	*None*	42

- Two device types were burned-in at a lower temperature to prevent the junction temperature from exceeding the glass transition temperature.
- There were no functional failures and three parametric failures. Devices were classified as parametric failures when they did not meet the vendor's specification at 25ºC after the burn-in.
- Parameters listed as **Critical** above, either failed the vendor's specification or showed > 10% degradation (still within spec) for some parts.

[1] NASA's FIT calculations (90%CL) were done using vendor's activation energy and/ or base temperature when available. These are different for each part type.

The purpose of this test is to determine the failure rate as a point estimate on a portion (sample) of the population using established confidence intervals and <u>without any lot preconditioning</u>.

DYNAMIC BURN-IN RESULTS

Part Type	ss	Vendor	Hours	BI Temp	Rejs(25C)	Functional	Parametric	Critical Parameters
A/D	254	A	440	+85C	1	0	1	ICCD
Multiplexer	250	B	168	+125C	7	0	7	Ron, I+VEN,IAL,IAH
Op Amp	253	C	400	+105C	1	0	1	VOS
Reference	252	D	168	+125C	TBD	TBD	TBD	TBD
Amplifier	230	E	168	+125C	1	1	0	Gain ERR,VOO

- Two device types were burned-in at a lower temperature to prevent the junction temperature from exceeding the glass transition temperature.
- There was one functional failure & nine parametric failures for four part types. Devices were classified as parametric failures when they did not meet the vendor's specification at 25ºC after the burn-in.
- Parameters listed as **Critical** above, either failed the vendor's specification or showed > 10% degradation (still within spec) for some parts.

A dynamic burn-in per the application is recommended and is a value added step when done in conjunction with a data review for part performance and reliability. It is more effective than a static burn-in for many part types.

The purpose of this test is to electrically and thermally stress 100% of the parts to identify/accelerate potential failure modes due to weak devices which can then be eliminated .

OPERATING LIFE RESULTS

Part Type	ss	Vendor	Hours	BI Temp	Rejs(25C)	Functional	Parametric	Critical Parameters
A/D	45	A	1000	+85C	0	0	0	Offset
Multiplexer	45	B	1000	+125C	0	0	0	Ron
Op Amp	45	C	1500	+105C	1	0	1	VOS
Reference	45	D	1000	+125C	3	0	3	Vout
Amplifier	45	E	1000	+125C	0	0	0	Gain ERR,VOO

- Test conditions identical to dynamic burn-in test.
- Two device types were burned-in at a lower temperature to prevent the junction temperature from exceeding the glass transition temperature.
- There were no functional failures and four parametric failures. Devices were classified as parametric failures when they did not meet the vendor's specification at 25ºC after the burn-in.
- Parameters listed as **Critical** above, either failed the vendor's specification or showed > 10% degradation (still within spec) for some parts.

The purpose of this test is to evaluate the reliability of the die and to generate defects resulting from manufacturing aberrations that are manifested as time and stress-dependent failures.

PACKAGE TEST RESULTS PART 1

Part Type	ss	Vendor	Precond	Moisture Sensitivity	HAST	T/C	Functional Rejs	Parametric Rejs
A/D	33	A	33	11	11	TBD	1 (MSL)	0
Multiplexer	33	B	33	11	11	11	0	0
Op Amp	33	C	33	11	11	11	0	11 (HAST)
Reference	33	D	33	11	11	11	0	10 (T/C)
Amplifier	33	E	33	11	11	11	0	0

- Devices were not screened by NASA prior to package testing except for initial electricals at 25°C.
- There was one functional failure and twenty one parametric failures.
- Preconditioning was performed in accordance with JESD22-A113-C.
- Moisture Sensitivity was performed in accordance with JEDEC J-STD-020B.
- HAST conditions were 96 hrs (130ºC, 85% RH) 2 atm, biased.
- Temp Cycle conditions were –65ºC to +150ºC for 1000 cycles.
- Acoustic microscopy and external visual examinations were also performed.

The purpose of this test is to evaluate the package, as received from the vendor, using industry standards and methods that could be compared to the vendor's published results.

C-SAM RESULTS

		TOPSIDE									BACKSIDE						THRUSCAN		
		(top of lf)			(top of die)			(space around die)			(die paddle area)			(back of lf)			(die attach area)		
Part Type	Vendor	LR	MR	HR	LR	MR	HR	LR	MR	HR	LR	MR	HR	LR	MR	HR	LR	MR	HR
A/D	A	250	0	0	250	0	0	0	35	215	109	126	15	237	8	5	11	74	165
Multiplexer	B	251	0	0	247	4	0	11	240	0	244	7	0	251	0	0	237	2	12
Op Amp	C	226	0	0	220	6	0	225	1	0	225	1	0	226	0	0	223	2	1
Reference	D	203	24	1	NA1	NA1	NA1	34	120	74	224	2	2	153	0	0	NA1	NA1	NA1
Amplifier	E	62	96	70	NA2	NA2	NA2	NA2	NA2	NA2	228	0	0	159	67	2	114	69	45
Total		**992**	**120**	**71**	**717**	**10**	**0**	**270**	**396**	**289**	**1030**	**136**	**17**	**1026**	**75**	**7**	**585**	**147**	**223**

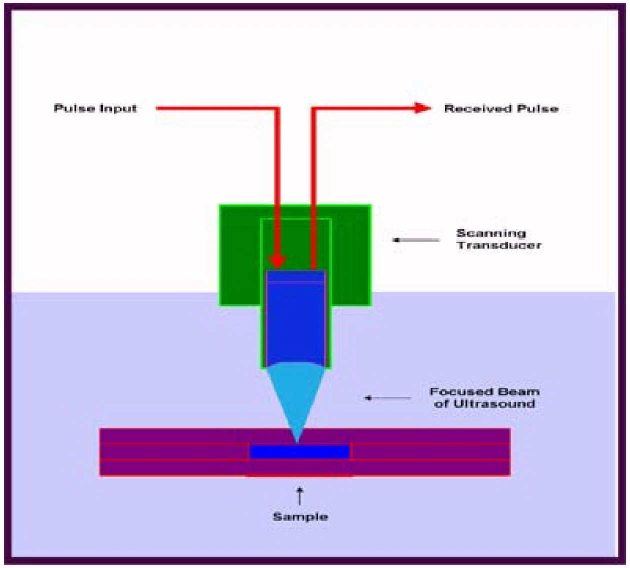
NOTES

LR- LOW RISK (NONE OR MINIMUM DELAMINATION <10% ON TOPSIDE, BACKSIDE, OR THRUSCAN)
MR- MEDIUM RISK (DELAMINATION >10% FOUND AT TOPSIDE, BACKSIDE, AND THRUSCAN)
HR- HIGH RISK (SIGNIFICANT DELAMINATION AT EITHER TOPSIDE, BACKSIDE, OR THRUSCAN - 50% TO 100%)

NA2-Could not distinguish die and risk assessment is not determined.
NA1-Die has topcoat(masked thruscan and top of die)

C-SAM Provides:

- Nondestructive Methodology
- Ultrasound Signal
- Ceramics, Plastics, Metals Inspections
- Voids, Cracks, Delamination, Anomalies, Defects, Disbonds Detection



C-SAM inspection (100%) should be considered as part of screening. Critical inspection points are after package thermal stresses.

X-RAY RESULTS (x-y horizontal plane)

X-Ray Inspection (Wire Sweep)

Part Type	Vendor	LR	MR	HR
A/D	A	249	1	0
Multiplexer	B	250	0	0
Op Amp	C	349	1	0
Reference	D	223	1	0
Amplifier	E	226	1	1
	Total	**1297**	**4**	**1**

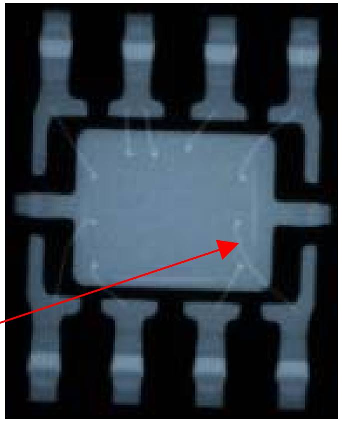


Fig A. Reject

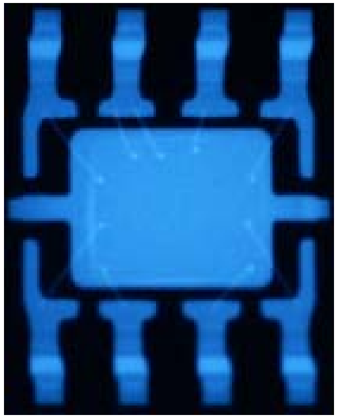


Fig B. Pass

NOTES

LOW RISK (distance between adjacent wires is >75% of nominal spacing)
MEDIUM RISK (distance between two adjacent wires is 10-25% of nominal spacing)
HIGH RISK (distance between two adjacent wires is <10% of nominal spacing)

Wire sweep is not typically an issue with low pin count packages because the wire pitch is large enough to compensate for minor wire sweep. However this is not always the case as seen in Fig A, which is not acceptable. X-Ray inspection (100%) is recommended during screening, especially for very high pin count packages exhibiting very fine wire pitch.

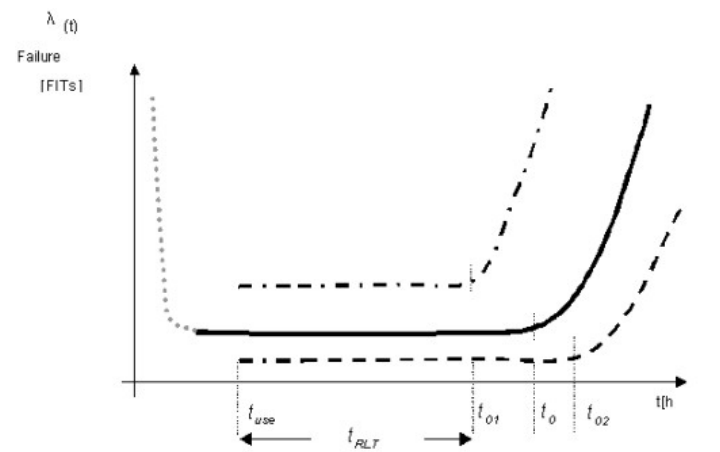
MULTIPLEXER FIT ANALYSIS EXAMPLE

NASA Multiplexer FIT Test Baseline:

Sample Size: 24
Test time: 1000 hrs
Burn-in temperature: 125°C
Burn-in condition: Static
Rejects: test lab reported zero functional

Manufacturer's Std FIT Parameters:

Activation Energy (Ea) used is 0.8eV
Base plate used is 25°C
Std outgoing lot FIT is 59 @ 60% CL



Typical Shape of the Failure Rate.
Dashed Lines Show the Basic Shifts of the Curve for Higher (1) or Lower (2) Stress.

NASA Test Results:

Device	Test	Test temp	ss	Rejs(1000 hr)
Multiplexer	BI	+125°C	24	0

FIT CALCULATION:

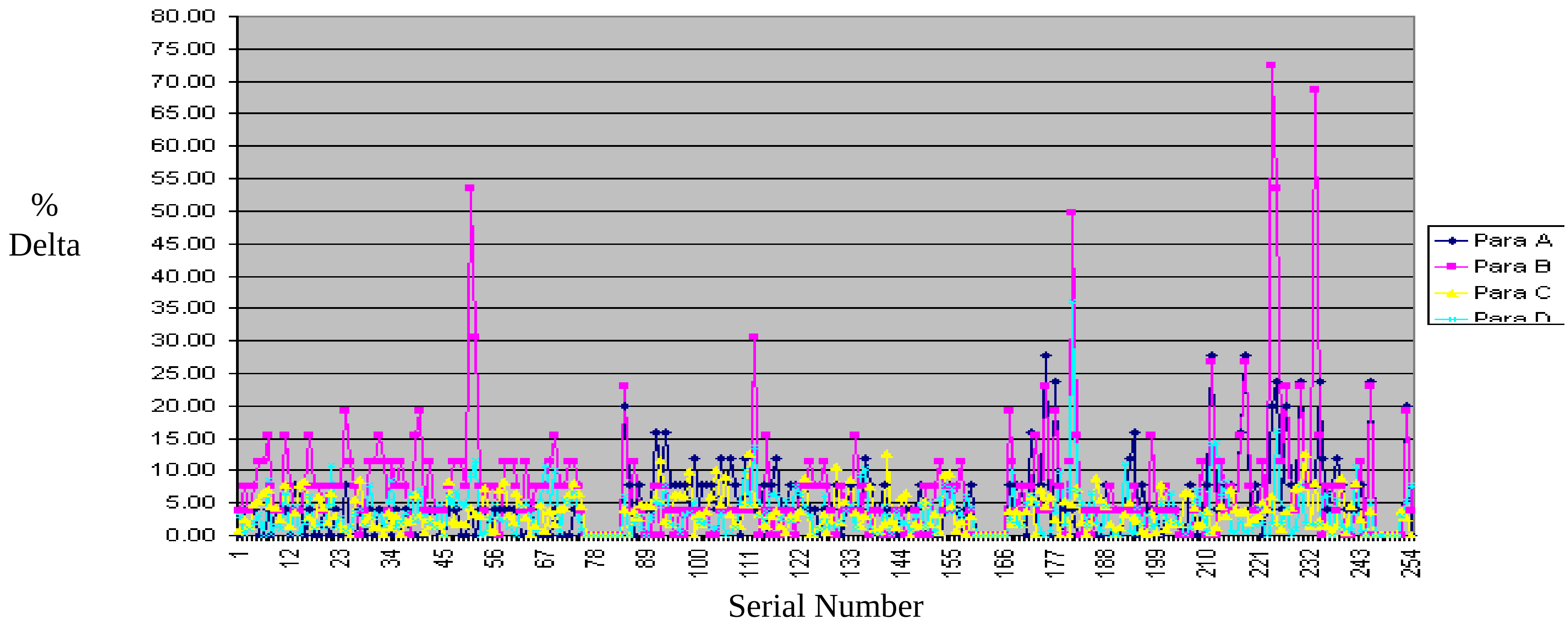
Fr=Nf/Ndt
Nf=number of failures=0
Ndt=number of device hrs at test temperature of 125°C
Ndt= Nd x Nh x At
Nd=number of devices tested=24
Nh=number of hrs of testing = 1000
At=acceleration factor between 125°C and 25°C=2502
Using Chi squared table, Fr=χ2(x,v)/2Ndt where χ2=1.83(60%CL) and χ2=4.61(90%CL)
x=(1-CL) and v=(2N+2) where N is the number of rejects
At 60% Fr=1.52 x 10-8 and at 90 % Fr=3.84 x 10-8

NASA FIT Findings:
FIT = 15 for 60%
FIT = 38 for 90%

REFERENCE BURN-IN ANALYSIS EXAMPLE

Parametric Degradation With Dynamic Burn-In

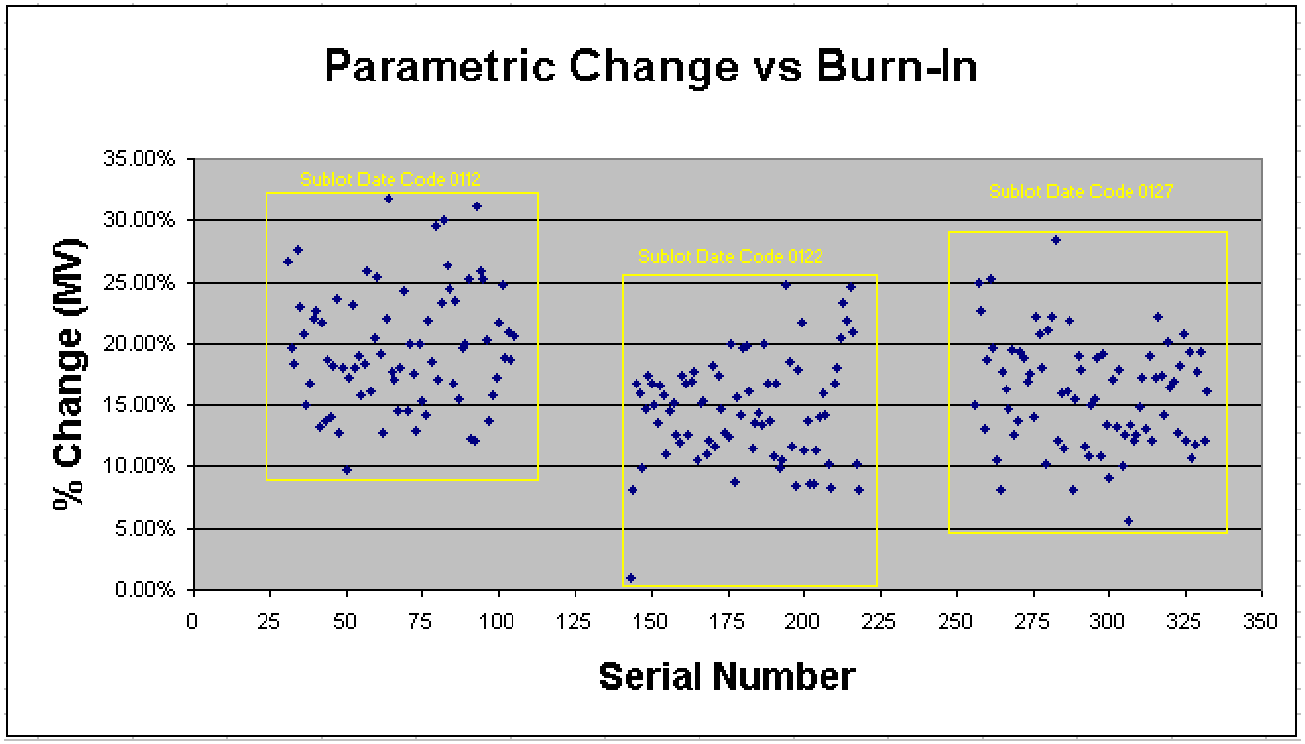
The part is advertised as a high precision reference device with an ultra low drift specification of 3 ppm/°C max. It is designed using precision thin film resistors and drift trimming. The graph below depicts some of the parameter changes measured at 25°C after burn-in. Some parts show significant change but the change does not always indicate the part did not meet specification. It is important that all designs be evaluated (*using a worst case analysis*) for tolerance to degradation and performance. Screening can eliminate unwanted devices.



LOT VARIATIONS EXAMPLE

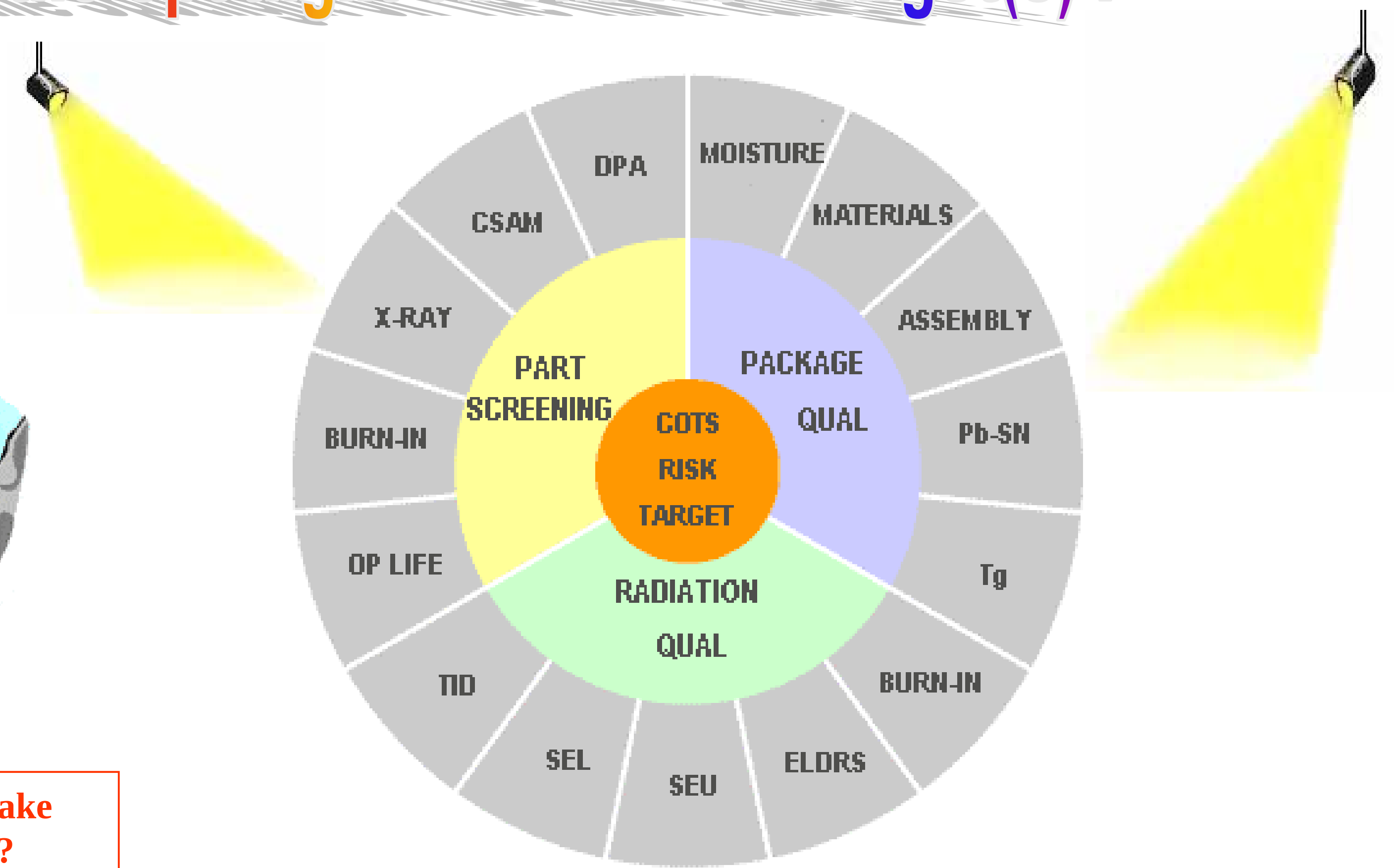
Parametric Degradation by Lot With Dynamic Burn-In

Three date codes of one tested part type were observed to have different degradation characteristics after burn-in. There is a statistical difference between date codes 0112 and 0122 with a 95% confidence level. These results support the concern of manufacturer's lot to lot variation associated with COTS products. It is therefore recommended that the user sample equally all date codes procured to determine acceptability for Space applications. This would also allow for individual part selection(s) to an acceptable delta criteria.



COTS RISK ELEMENTS

Keep the Spotlight on The Risk Target(s) !



Are you willing to take unnecessary risk?

CONCLUSION

NASA has concluded that the manufacturers COTS data can not be totally relied upon, therefore: Characterization of your lot of PEMS over your total space flight environment is paramount in the reduction of risk when PEMS are used outside of their intended environment.