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Use of Plastic Commercial Off-The-Shelf (COTS) Microcircuits for Space Applications

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Outline



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 - The Derating process
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Introduction



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

To fully understand and risk rate these concerns & issues, NASA is undertaking a *comprehensive* investigation and performing *extensive* evaluations of various COTS components from selected manufactures.



Introduction

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- Performance
 - Commercial – 90nm; GHz
 - Mil/Space – 0.25 μ m; MHz
 - Weight
 - Plastic
 - Ceramic
 - Costs
 - Volume, complexity, assembly cost, screening yield, qualification testing, die, package
 - Risks
 - Assumed vendor risk,
 - accelerated testing
 - lack of standards



Questions for NASA PEMS Evaluations **JPL**

- What is the inherent quality of COTS PEMS?
- What is the inherent reliability of COTS PEMS?
- What are the product variations expected with COTS PEMS?
- What Elements of COTS PEMS screening/qualifications add value (how should NASA upscreen and qualify COTS PEMS)?
- Which of the vendor's many claims are really true?
- What risks should be assigned to using COTS PEMS for typical and special unique Space applications/environments?
- Where is the optimal balance between risk and cost tradeoffs when using COTS PEMS? When does the end justify the means?
- When should derating be used?
- What is the optimum path to part procurements?
- What radiation performance precautions are necessary?



Requirements for Space



-
- NASA Grades
 - 1 (mil S,V,K)
 - 2 (mil B, Q, H)
 - 3 (MIL STD 883 compliant)
 - Upscreening Possible
 - for specific lots only – results cannot be extrapolated
 - Radiation hardness needs to be performed on every lot
 - PEMs generally not screened to same levels
 - Mission specific screening needs to be performed
 - Outgassing generally not considered in COTS



Packaging Evaluations

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- Lead Solder Heat Exposure
- Extended Temperature Cycle
- HAST (no preconditioning)
- HAST (with preconditioning)
- Moisture Level Sensitivity
- Experiments with Delaminated Packages



Reliability and Risks

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- Current State
 - Mission specific requirements
 - Devices
 - Improved commercial processes, better reliability
 - Reduced cycle time → less data
 - Packages
 - Significant commercial advances in the last 5-10 years
 - Better materials – fewer ionic impurities
 - High-rel hermetic packages are screened – PEMs are not
 - Risks Not Addressed
 - Traceability – date codes can represent many lots
 - Outgassing of molding compounds not characterized



Traceability

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- A single date code can represent many parts



CAUTION

ELECTRONIC SENSITIVE DEVICES

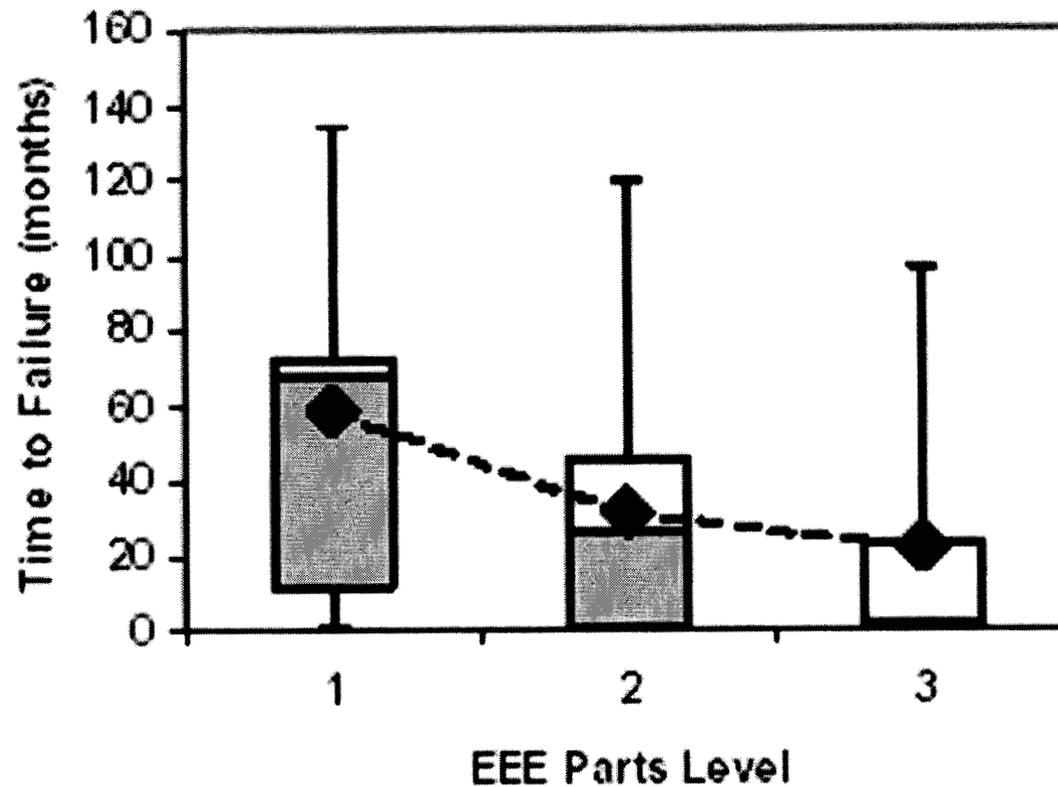
**USE PROPER ESD
HANDLING PROCEDURES**

S2X2A

Made in one or more of the following countries: China, Hong Kong, Indonesia, Japan, Taiwan, South Korea, Malaysia, Philippines, Singapore, Thailand, United Kingdom. The exact country of origin is unknown.



Screening Levels



- Lower screening levels are higher risk
- Significant costs are associated with upscreening



Package Failure Mechanisms **JPL**

- Ionic contamination - Any contaminant which exists as ions and when in solution increases electrical conductivity.
- Outgassing -Gaseous emission from a material when exposed to reduced pressure and /or heat.
- Popcorning - Expression that is used to describe a phenomenon that causes package cracking in PEMs (typically surface mount packages) during soldering to boards.
- Delamination - A separation between the laminated layers of a base material and/or base material and overlaying coating.
- Wire Sweep - Term used to describe the permanent movement or bending over of interconnection wires inside a PEM which can occur during the molding process.
- Electromigration - Migration of metal within interconnect lines which occurs when the momentum transfer of electrons is sufficient to move metal ions through the line. Factors such as high current density regions accentuate migration.
- Purple Plaque - An intermetallic compound between gold and aluminum (AuAl_2).



Device Failure Mechanisms



- ESD - (Electrostatic Discharge) Transfer of charge from one surface to another by static electricity.
- EOS – (Electrical Overstress) - *Infant Mortality* - Failures in a device population which occur early in the life of the population.
- Electromigration - Migration of metal within interconnect lines which occurs when the momentum transfer of electrons is sufficient to move metal ions through the line. Factors such as high current density regions accentuate migration.
- Purple Plaque - An intermetallic compound between gold and aluminum (AuAl_2).
- SEL (*Single Event Latchup*) - A loss of device functionality due to a single event typically the result of a parasitic SCR structure in an IC becoming energized by an ion strike.
- SEU (*Single Event Upset*) - A “soft error”, change of logic state, or a bit flip caused by alpha particles or cosmic rays as they pass through a device.
- TID - (Total Ionizing Dose), accumulation of absorbed ionizing radiation specified at a particular dose rate exposure at 25°C.
- TDDDB -(Time Dependent Dielectric Breakdown) typically refers to device oxide wearout



Manufacturing Variation/Defects **JPL**

- ❑ Electrical Outliers
- ❑ Electrical Failures
- ❑ Burn-in Failures
- ❑ Life Test Failures
- ❑ Package Evaluation Failures



Risk Mitigations and Methodology **JPL**

- Screening Tests
- Qualification Tests
- Derating
- Space Manufacturing Practices



Criteria for Evaluation



- Technology should be fairly mature,
- Moderate complexity
- Of interest to current NASA projects,
- Reasonably testable,
- Would not require exotic test fixturing
- Passed parts could be used on flight projects
- Robustness of design and process
- Reliability of device vs package type



Screening/Evaluation/Qualification Steps **JPL**

- DPA
- Electrical Testing
- Static Burn-In
- Temperature Cycle
- X-Ray
- CSAM
- Dynamic Life Test
- FA



Package Screening



- C-SAM

Scanning Acoustic Microscopy utilizing different modes such a "C", (CSAM), in assessing the reliability of PEMs. There is evidence that delamination at these surfaces can be a reliability concern.

- Materials Characterization

A study of glass transition temperature (T_g) of the encapsulating materials was performed using Thermo-Mechanical Analysis (TMA) for each of the five parts and the results showed a wide spread with one value as low as 117°C , see Figure 2. A recommendation from the work would be to measure T_g for every lot until confidence in a manufacturer's process has been established. Even then, periodic testing for T_g would be advisable.

- Radiographic Examination

Radiographic examination (X-ray) should be performed, on a 100% basis, in accordance with MIL-STD-883, Method 2012, "Radiography."

- Visual & Mechanical Inspection

Visual inspection should be performed, on a 100% basis, in accordance to the nearest applicable standard (i.e., military, JEDEC, best commercial practices, etc.). Mechanical inspection should be performed, on a sample basis, in accordance to the same.



Device Screening



- Electrical Verification

To assure a part will function reliably in the intended flight application it is recommended that 100% electrical verification at the mission temperature profile extremes be performed.

- Burn-in

125°C for 168 hours. This varies significantly for different applications.



Package Qualification Testing **JPL**

- Destructive Physical Analysis (DPA)

DPA's can be performed by following the guidelines established in MIL-STD-1580, "Destructive Physical Analysis for Electronic, Electromagnetic, and Electromechanical Parts," where applicable.

- Outgassing

Outgassing testing is used to identify and quantify volatiles being emitted from PEM samples according to an accepted standard such as ASTM E595. Measured parameters are total mass loss (TML), collected volatile condensable materials (CVCM), and water vapor regained (WVR).

- Steady-State Temperature Humidity - Bias Life Test (85/85)

When 85/85 testing is performed, the guidelines established in JEDEC Standard JESD-22-A101, "Steady-State Temperature Humidity Bias Life Test" should be followed.

- Temperature Cycling (T/C)

JESD-22-A104 or Mil-Std-883 method 1010 Cond C, "Temperature Cycling" can be followed.



Device Qualification Testing **JPL**

- High Temperature Operating Life (HTOL) or Life Test
HTOL is concerned with infant mortality and the long-term reliability of devices to withstand temperature extremes. When performing HTOL, the guidelines established in JEDEC Standard JESD-22-A108, “Bias Life” can be followed.
- Radiation Hardness Assurance (RHA)
All parts, commercial and/or military must be evaluated for RHA. When required, total dose evaluation is conducted in accordance with MIL-STD-883, Method 5005, “Qualification and Quality Conformance Procedures,” Group E, or equivalent.

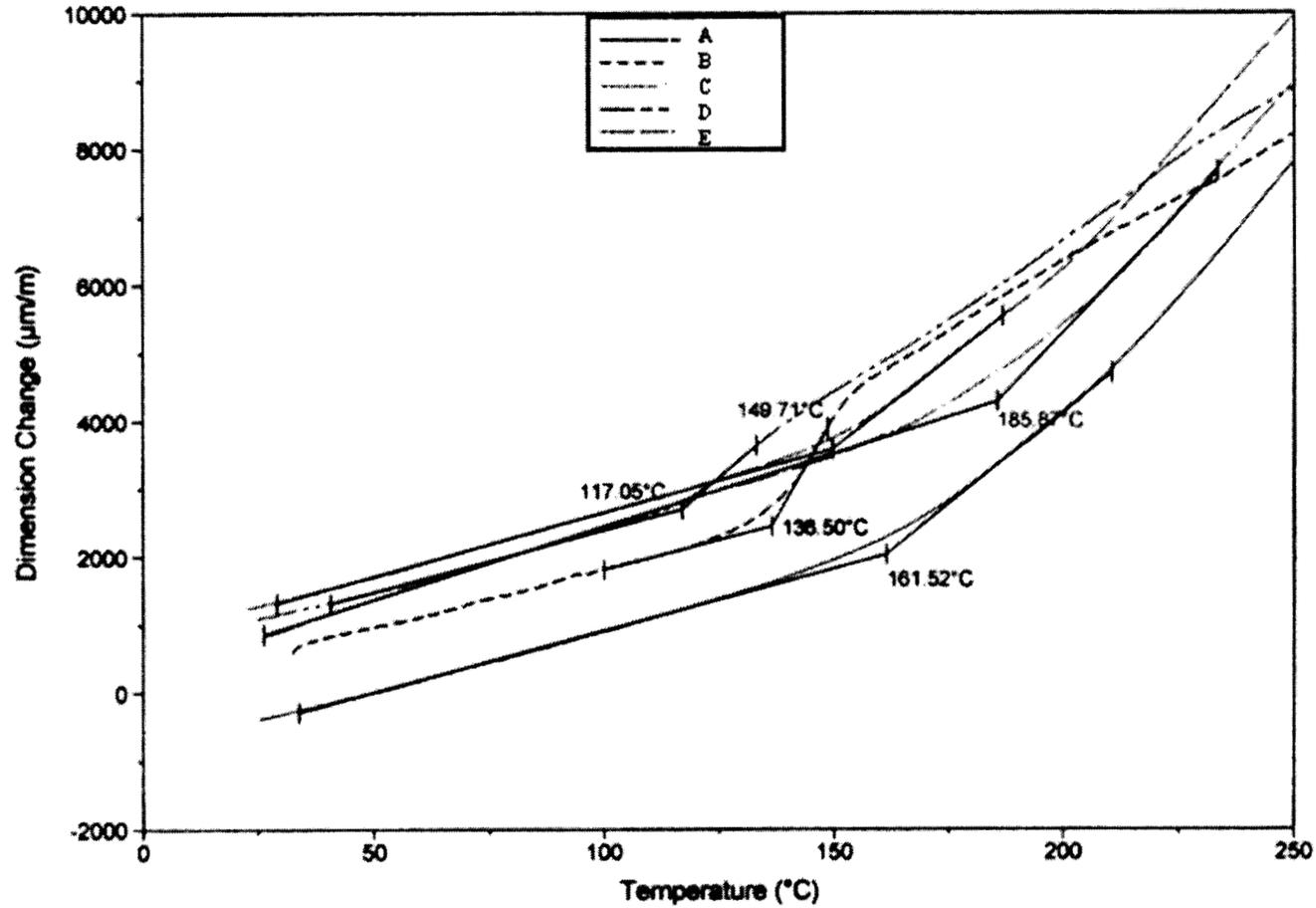


Data Process Review/Parameter Analysis **JPL**

- Test house raw data approval/review
- Test data extraction into analysis format
- Review of every parameter by temperature and serial number
- Statistical summaries with graphic formats
- Selection of parts for life test and package evaluation
- Correlation of failures to all tests performed
- FA if required
- Final SN compilation and report



Materials Properties





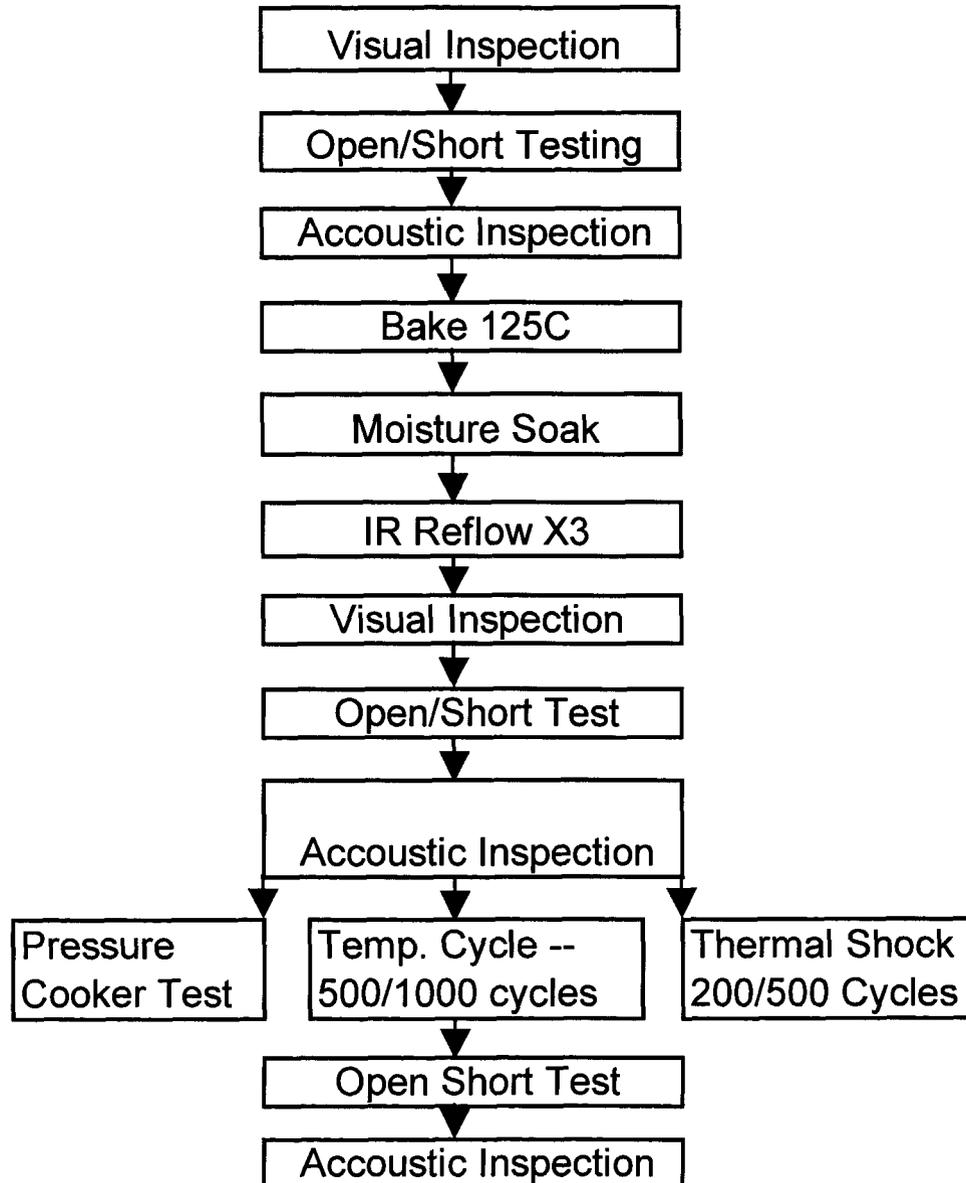
COTS Screening Flow



- DPA -SEM 2.Tg
- Serialization -Laser Serialization or other means for traceability
- 1st Electricals -Data sheet @ +25°C, 70°C, OC
- FITS Verification Sample Static Burn-in - BI @ 125°C with readouts @ 168hrs., 500hrs. and 1000hrs
- Temp Cycle -Ta = -65°C to +150°C
- X-Ray - Mil-Std-883 method 20-12, Inspect for wire sweep
- C-SAM - Inspect for delamination and or cracks
- Electricals - Test to data sheet @ +125°C, -55°C, (with functionality)
- Dynamic Burn-in - Circuit per application 168hrs. at +125°C, Vcc=max rating
- Electricals - Data sheet @ +25°C, +70°C, OC, +125°C, -55°C
- Dynamic Life Test (BI)
- Circuit is per application (+125°C)
- End Point Electricals
- Test to data sheet @ +25°C, +70°C, OC, +125°C, -55°C
- Post screening DPA
- Die visual inspection/Bonding inspection
- Cold Startup (optional)
- Per application requirements

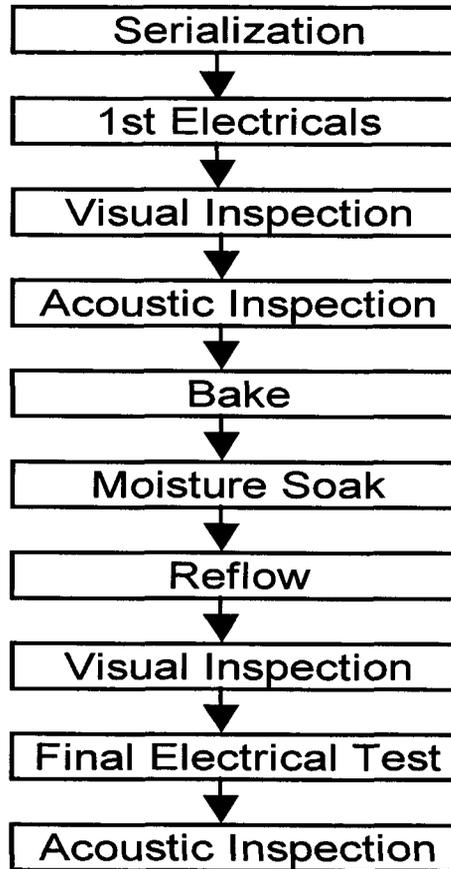


Typical Commercial Flow



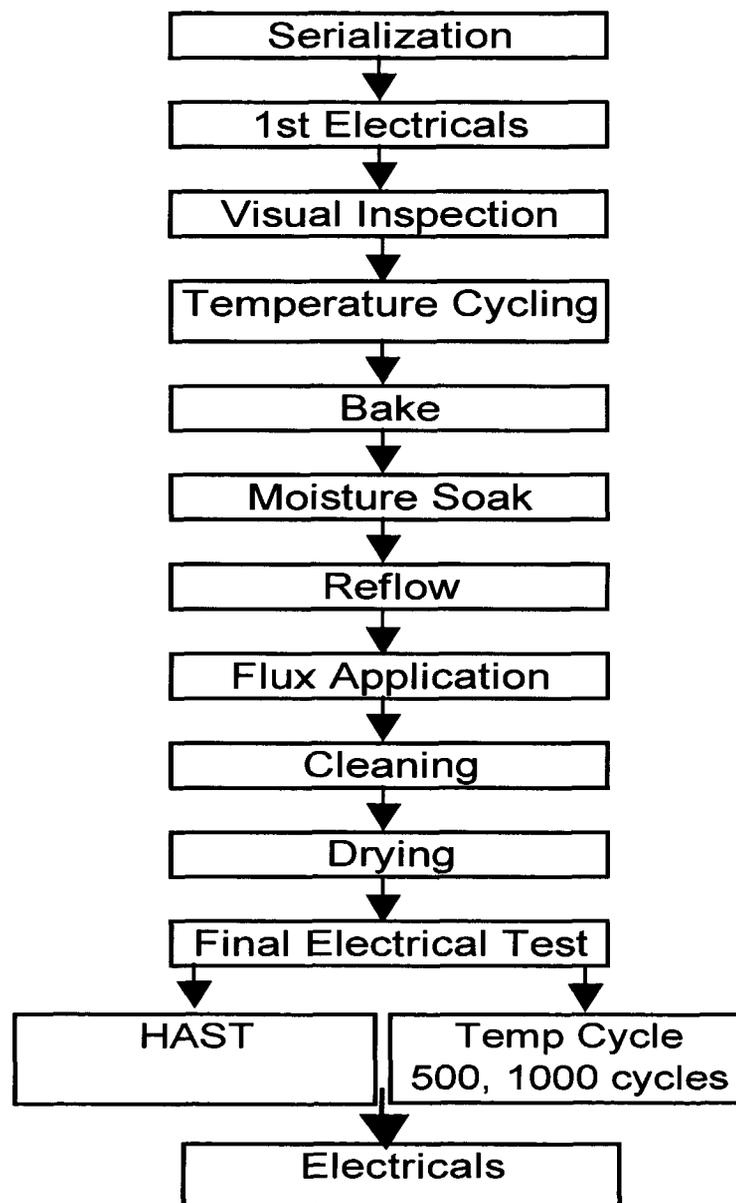


Validation Flow





Recommended Flow





Conclusions and Recommendations **JPL**

- Pros for use of COTS
 - Significant statistics
 - Stable processes
 - Established rules and methodologies
- Cons for use of COTS
 - Lack of traceability
 - Use outside intended application
 - Legal issues
 - Arbitrary changes in processes including splits
 - Outliers



Conclusions and Recommendations **JPL**

- For use of COTS
 - User needs to determine true screening history
 - Determine differences between screening history and NASA requirements
 - Perform additional testing per specific mission requirements
 - Work closely with manufacturers
 - Understand changes in processes
 - Review qualification data for each change
 - Follow given flows