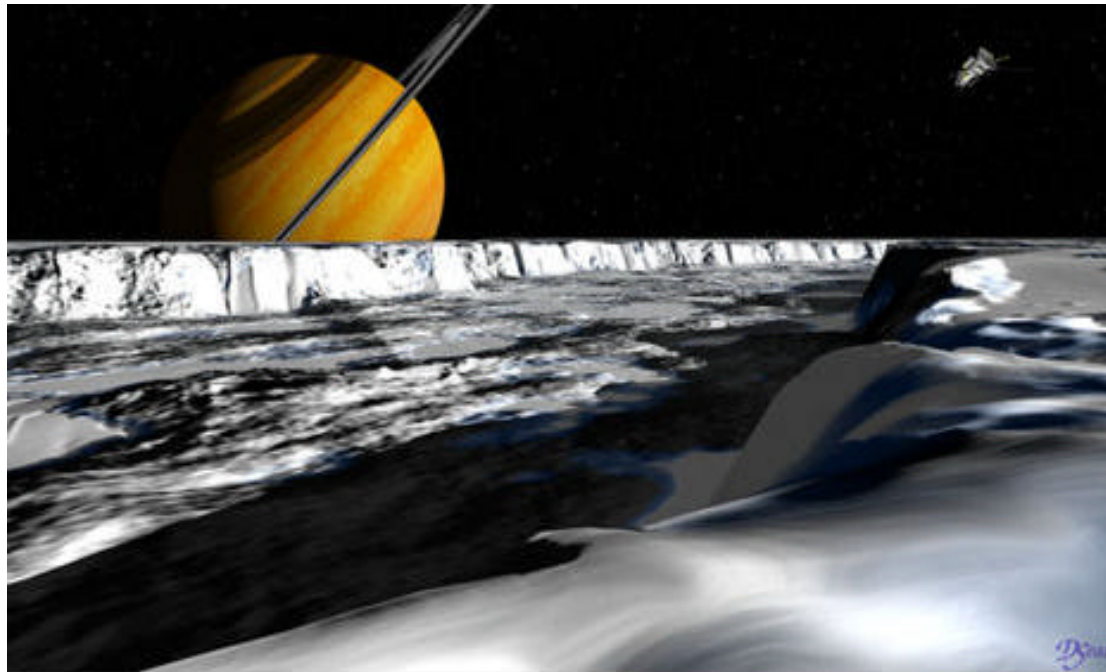
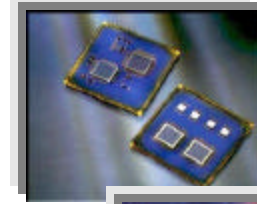




# Experience with Plastic Part Evaluations At Cold Temperatures

NASA Electronic Parts and Packaging Program

May 15-16, 2001



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**Electronic Parts Engineering – Office 514**



## Electronic Parts Engineering

# AGENDA

**Introduction**

**Cold Temperature Activities**

**Cold Temperature Capabilities**

**Test Results**

**Summary**

The work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration.



## INTRODUCTION



°C	°K	°F
0	273.2	32
-55	218.2	-67
-105	168.2	-157
-125	148.2	-193
-175	98.15	-283

- Missions to MARS/planets/asteroids require electronic parts to operate and survive at extreme cold conditions.
- At extreme cold temperatures many types of cold related failures can occur.
- Office 514 is currently evaluating plastic parts under various cold temperature conditions and applications.
- Evaluations, screens, and qualifications are ongoing on flight parts.



## **TIMELINE OF COLD TEMPERATURE TEST ACTIVITIES**

- **Part performance outside specifications - Now**
- **Temperature cycling – Now**
- **Thermal shock - Now**
- **Cold temperature startup - Future**
- **Extended low temperature operating life – Future**
- **Cold temperature device modeling – Future**
- **Power/temperature cycling – Future**
- **Long term cold storage – Future**



## COLD TEMPERATURE ACTIVITIES

Areas requiring further investigation that can impact part reliability under cold temperatures:

- **Material properties & characteristics**
- **Physics/operation of semiconductor devices**
- **Wafer Processing/Component Assembly**
- **Manufacturing/Lead Type**
- **Stress Induced Latent Damage**



# TEMPERATURE REQUIREMENTS

(OP/NOP Example)

**Allowable Flight**

-105°C minimum

**Qualification**

-125°C minimum

**Flight Acceptance**

-110°C minimum

**Part Test/Eval**

-115°C minimum

Part Accept

-110°C minimum

**Part Test/Eval**

-135°C minimum

Part Accept

-130°C minimum

**Part Test/Eval**

-120°C minimum

Part Accept

-115°C minimum



## EXAMPLES OF PERFORMANCE IMPROVEMENTS NEAR LN<sub>2</sub> TEMPERATURES

- **Copper is seven times more conductive**
- **Chip performance equates to reducing chip geometry by 2X**
- **Devices may operate faster because C<sub>j</sub> decreases and m increases**
- **Interconnection delays times are reduced**
- **Sharper signal transitions allow faster clock rates**
- **Memory chips consume less power & require fewer refresh cycles**
- **Thermal management is easier**



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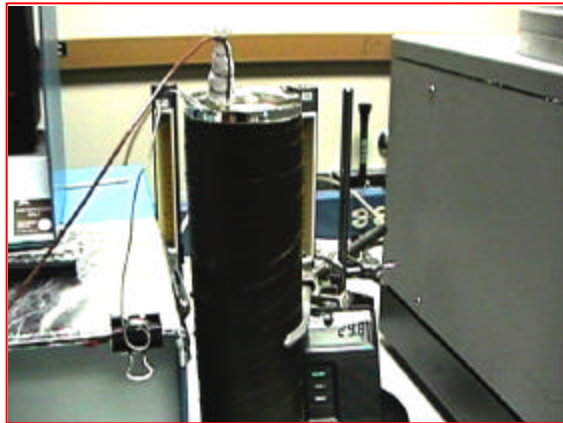
# Cold Temperature Capabilities/Developments



**-195°C Cold Test Evaluation Chamber**



**-125°C Cold ATE Digital Tester**



**-180°C Liquid Nitrogen Bath**

IN DEVELOPMENT

**-125°C Cold Linear/Mixed Signal Testers**





Performance

## SCREENING/QUALIFICATION METHODS USED AT COLD TEMPERATURES

GRADE EVALUATED	EXPECTED YIELD	EXPECTED OUTCOME
<b>Commercial</b> 0 to +70C	<b>Low</b>	<b>High No. of Outliers, Large Degradations</b>
<b>Industrial</b> -40C to +85C	<b>Medium</b>	<b>Medium No.of Outliers, Some Degradations</b>
<b>Military</b> -55C to +125C	<b>High</b>	<b>Few Outliers, Few Degradations</b>

Acceptable parts must be within 10-20% of lot parametric distributions at temperature, while accepted lots must yield at least 50% upon completed screening. Qual lots must pass 100%.



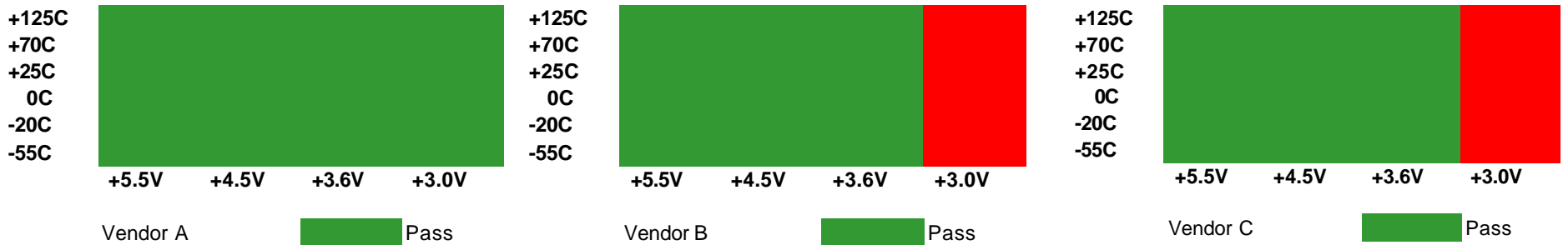
# COLD TEMPERATURE TEST RESULTS

## COTS SRAMS

### Case I

Performance

COTS SRAMS have been evaluated by JPL at military temperature range:



### Results:

Three different parts from three different vendors passed.



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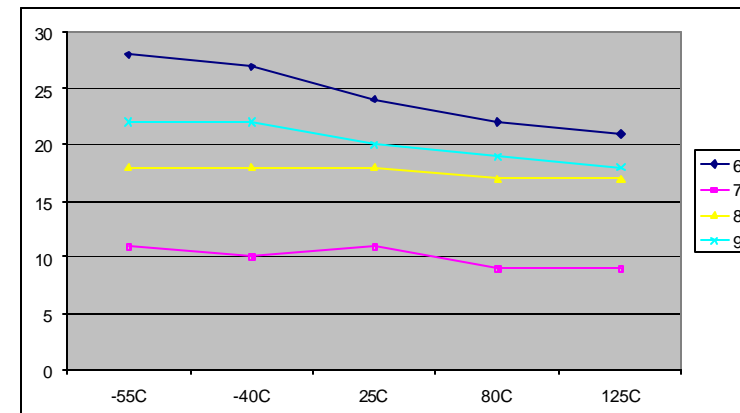
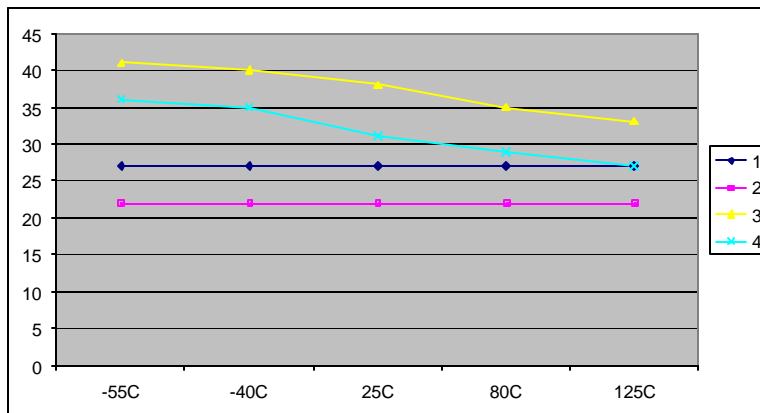
# COLD TEMPERATURE TEST RESULTS PROGRAMMABLE COTS OSCILLATORS

## Case I-A

Performance

Hermetic Package

			Powered and Measured by the HP E3612A DC Power Supply. All current readings are in mA.				
Voltage	Part No	Programmed Frequency (MHz)	-55C	-40C	25C	80C	125C
5.0	1	32.0000	27	27	27	27	27
5.0	2	66.0000	22	22	22	22	22
5.0	3	99.0000	41	40	38	35	33
5.0	4	133.0000	36	35	31	29	27
3.3	6	25.0000	28	27	24	22	21
3.3	7	50.0000	11	10	11	9	9
3.3	8	75.0000	18	18	18	17	17
3.3	9	100.0000	22	22	20	19	18





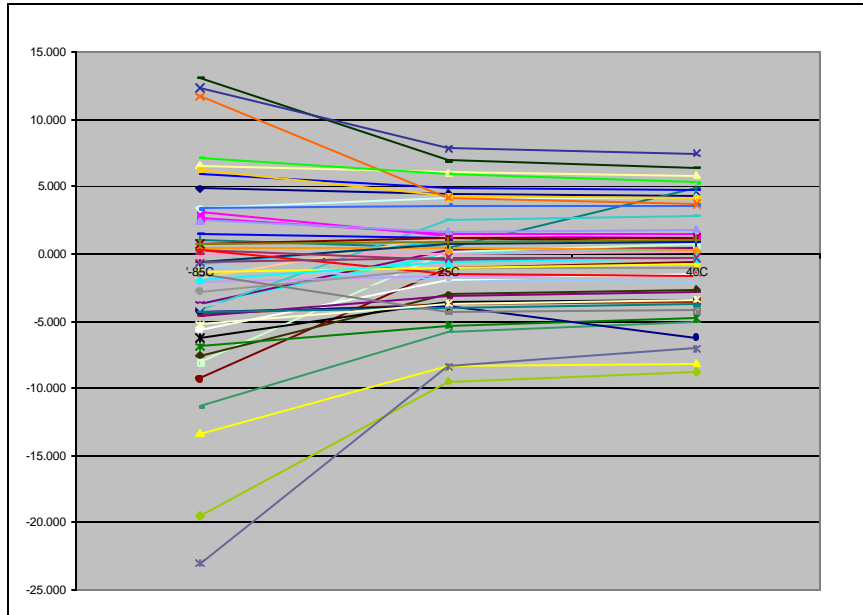
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# COLD TEMPERATURE TEST RESULTS - COTS UPSCREEN

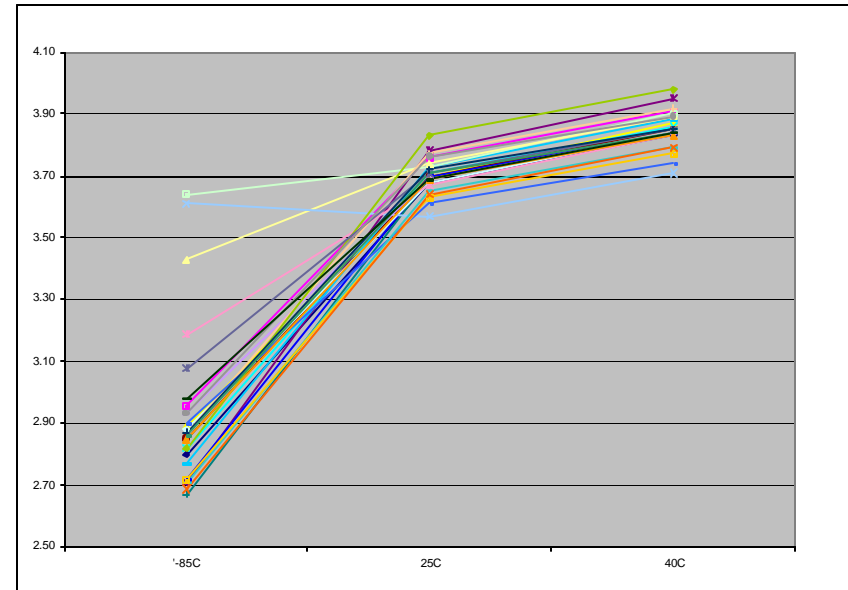
## Case I-B

(Examples)

Performance



Part A Ios Range @ -65C



Part A Isc Range @ -65C

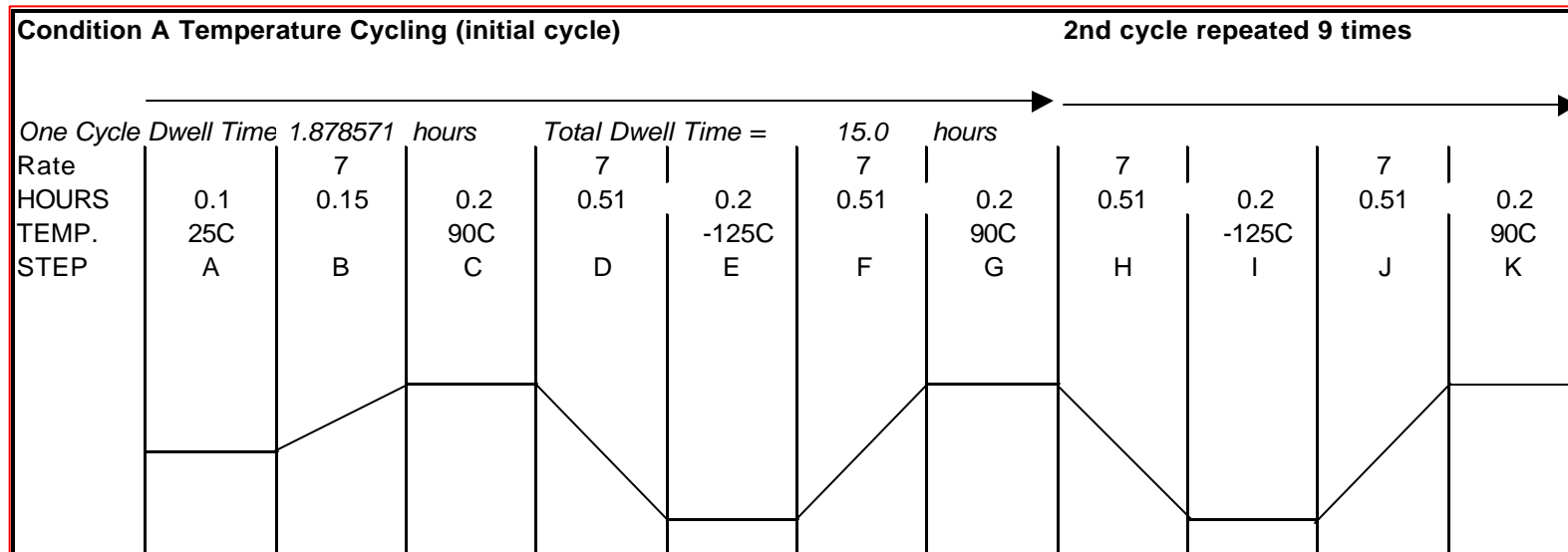
**Note: Some devices exhibit more variations and divergence at cold temperatures. Devices >10% from norm are rejected.**



# TEST RESULTS COTS UPSCREEN

## Case II

Temperature  
Cycle



**Part A Summary: 627 flight parts (PEMs) passed 10 cycles to the above requirement. 20 samples are being qualified to 300 cycles using the same T/C profile.**

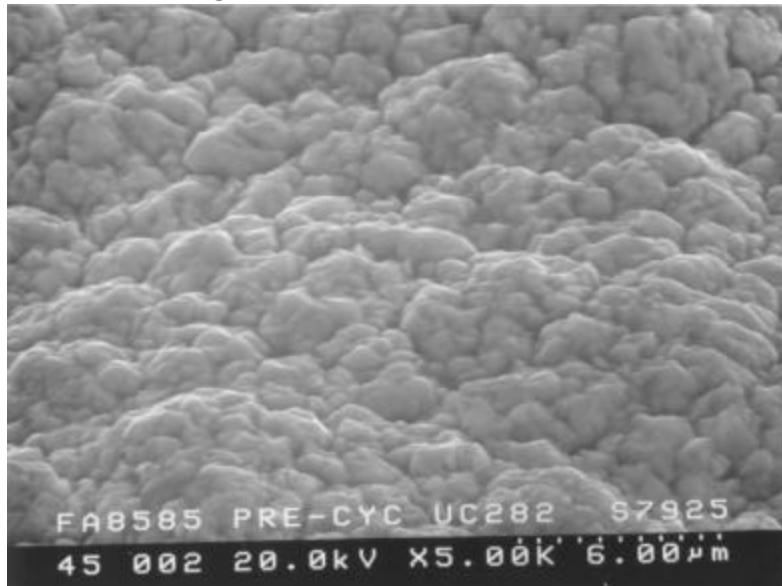


## FAILURE ANALYSIS

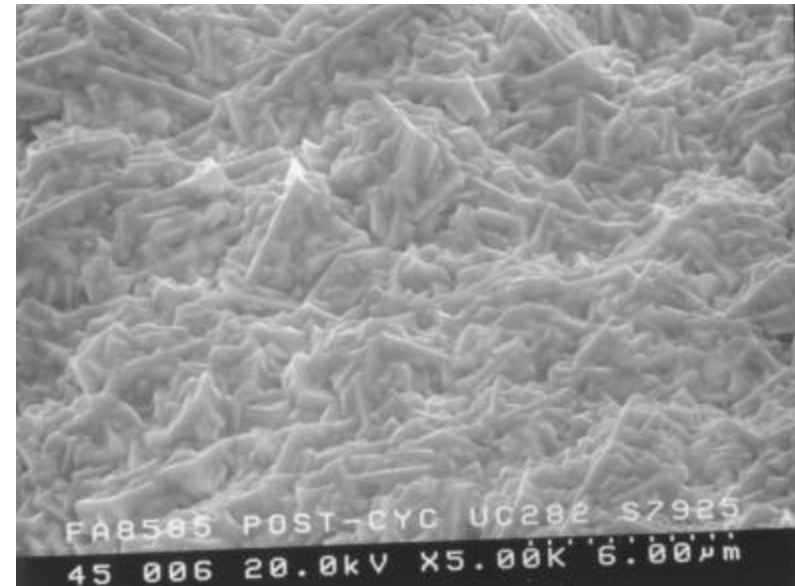
Temperature  
Cycle

### Case II-A

Oxidation of soldered leads were suspect since the lead surface became dull after T/C and bright after burnishing.



BEFORE



AFTER

5,000X SEM micrograph showing a closeup of the Pb/Sn solder coating on a lead in S/N A. The solder appears to have recrystallized after 10 cycles, resulting a roughening of the surface. Energy dispersive x-ray spectroscopy analysis of the surface revealed only the presence of Pb and Sn. Similar analysis of the pre-temperature cycled device also found only Pb and Sn. There is no apparent solderability problem.



# TEST RESULTS for COTS PEMS

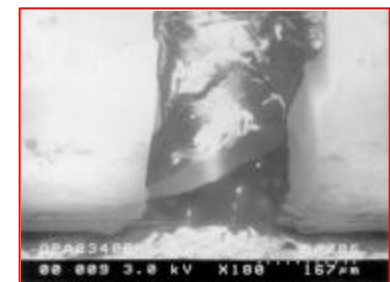
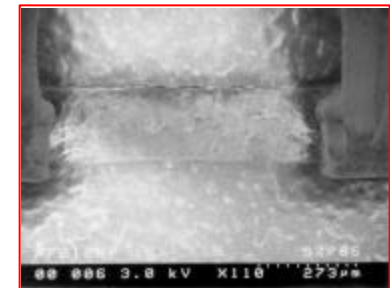
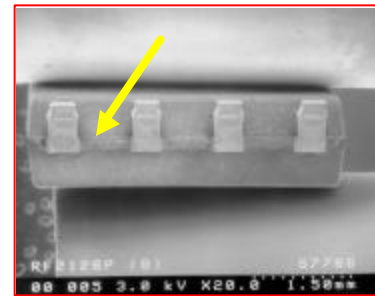
Thermal Shock

## Case III

Test Conditions: 30 cycles from  
-185° C to +135° C liquid bath

Miniature Cracks Found

Sample 1	PASSED
Sample 2	<b>FAILED</b> →
Sample 3	PASSED
Sample 4	PASSED
Sample 5	PASSED
Sample 6	<b>FAILED</b> →
Sample 7	PASSED





## SUMMARY

- Many CMOS commercial devices evaluated beyond their low-end rated temperature ranges have done quite well.**
- Plastic packages have held up under low temperature cycling but show signs of cracking under low temperature shock conditions.**
- Future work is planned to examine long term cold environmental effects such as cold start and operating life degradation.**
- Additional cold temperature test equipment is under development and evaluation.**
- Various part types are planned for reliability evaluation near LN<sub>2</sub> conditions under very long test times.**