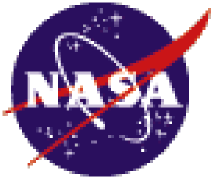
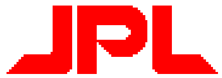
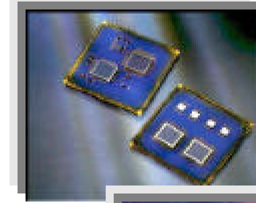
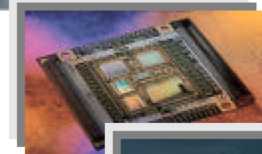




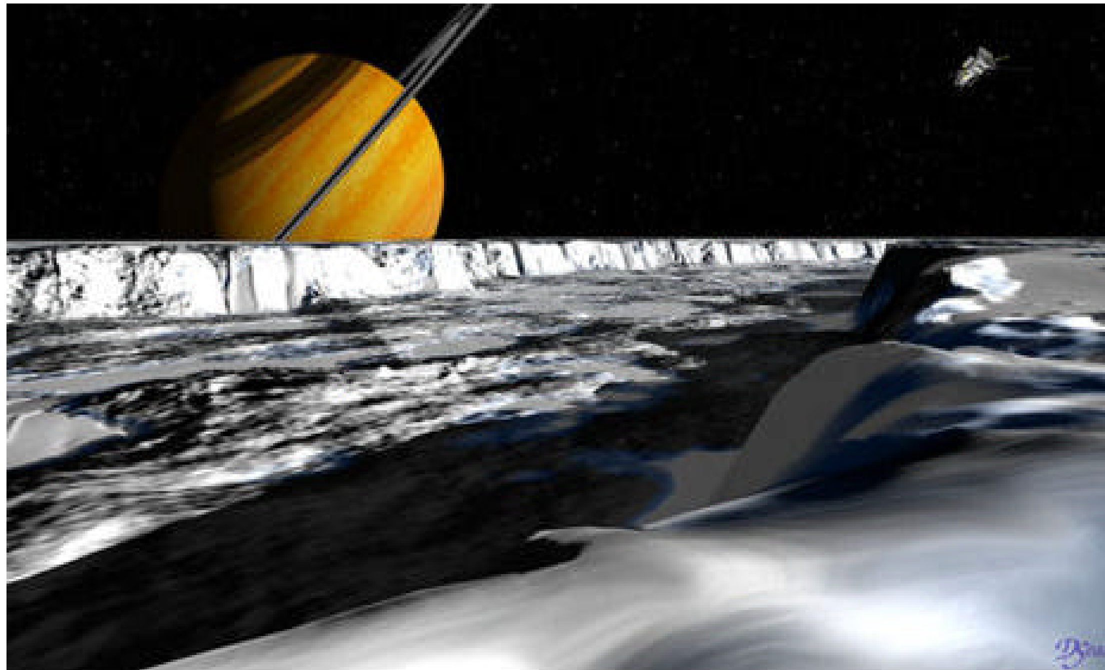




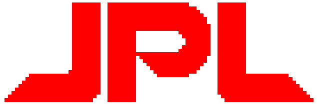
# Experience with Plastic Part Evaluations At Cold Temperatures

NASA Electronic Parts and Packaging Program

**May 15-16, 2001**



**Mike Sandor & Shri Agarwal**
**Electronic Parts Engineering – Office 514**

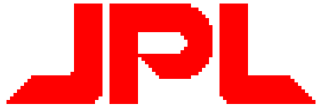




# AGENDA

- 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

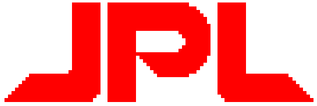
| °C | °K | °F |
|---|---|---|
| 0 | 273.2 | 32 |
| -55 | 218.2 | -67 |
| -105 | 168.2 | -157 |
| -125 | 148.2 | -193 |
| -175 | 98.15 | -283 |

- 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.

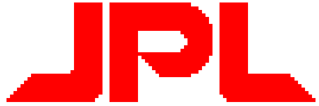
- Evaluations, screens, and qualifications are ongoing on flight parts.





# 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**

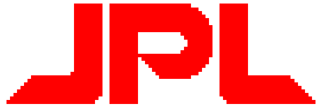




# COLD TEMPERATURE ACTIVITIES

**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**



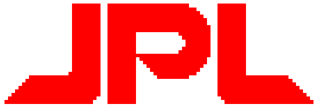


# TEMPERATURE REQUIREMENTS

(OP/NOP Example)

| Allowable Flight | Qualification | Flight Acceptance |
|---|---|---|
| -105°C minimum | -125°C minimum | -110°C minimum |

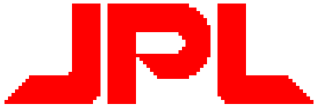
| Part Test/Eval | Part Test/Eval | Part Test/Eval |
|---|---|---|
| -115°C minimum | -135°C minimum | -120°C minimum |
| Part Accept | Part Accept | Part Accept |
| -110°C minimum | -130°C minimum | -115°C minimum |





# EXAMPLES OF PERFORMANCE IMPROVEMENTS NEAR $LN_2$ TEMPERATURES

- Copper is seven times more conductive
- Chip performance equates to reducing chip geometry by 2X
- Devices may operate faster because Cj decreases and mincreases
- 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

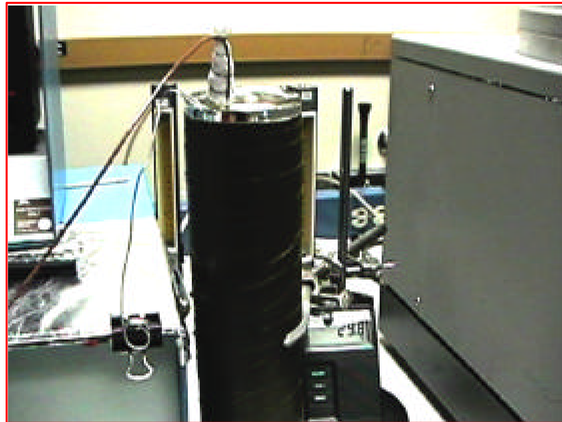




# Cold Temperature Capabilities/Developments

-195°C Cold Test Evaluation Chamber

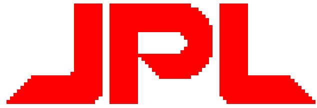
-125°C Cold ATE Digital Tester



-180°C Liquid Nitrogen Bath

IN DEVELOPMENT

-125°C Cold Linear/Mixed Signal Testers



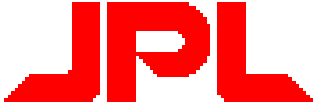


Performance

# SCREENING/QUALIFICATION METHODS USED AT COLD TEMPERATURES

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

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%.



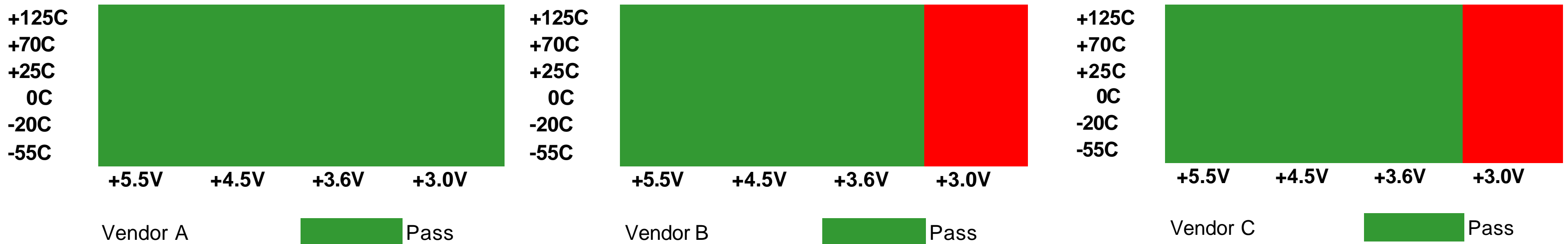
Electronic Parts Engineering

# COLD TEMPERATURE TEST RESULTS COTS SRAMS

## Case I

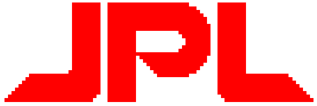
Performance

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




**Results:**

**Three different parts from three different vendors passed.**



Electronic Parts Engineering

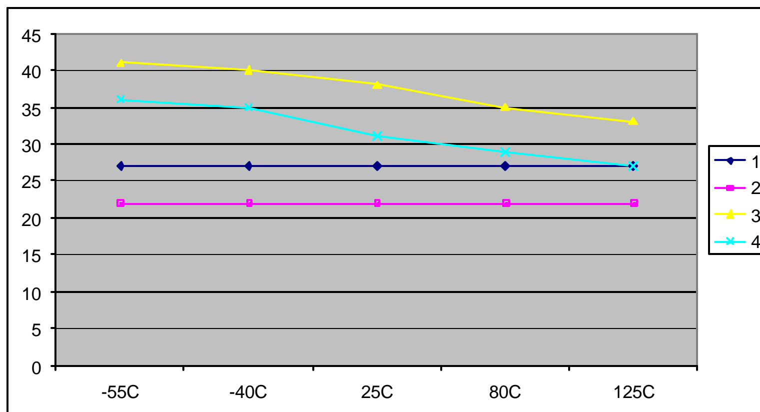
# COLD TEMPERATURE TEST RESULTS PROGRAMMABLE COTS OSCILLATORS

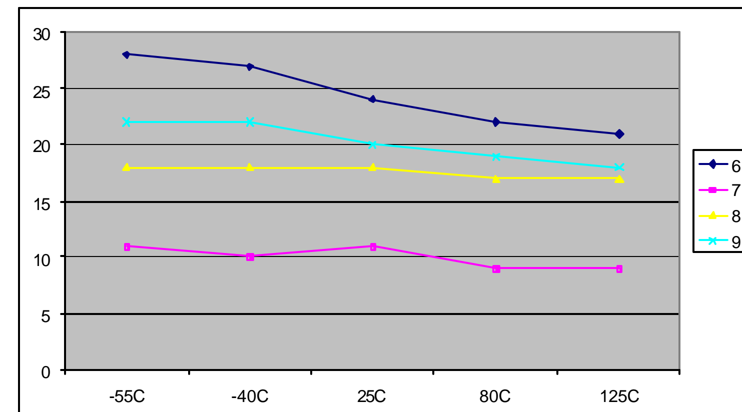
## Case I-A

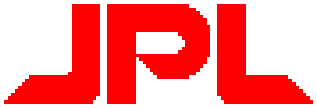
Performance

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 |





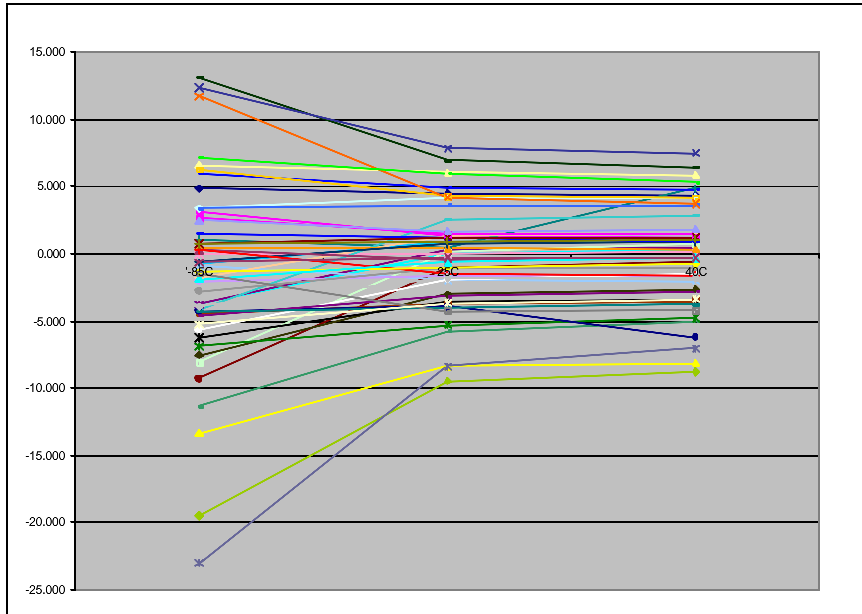
Electronic Parts Engineering

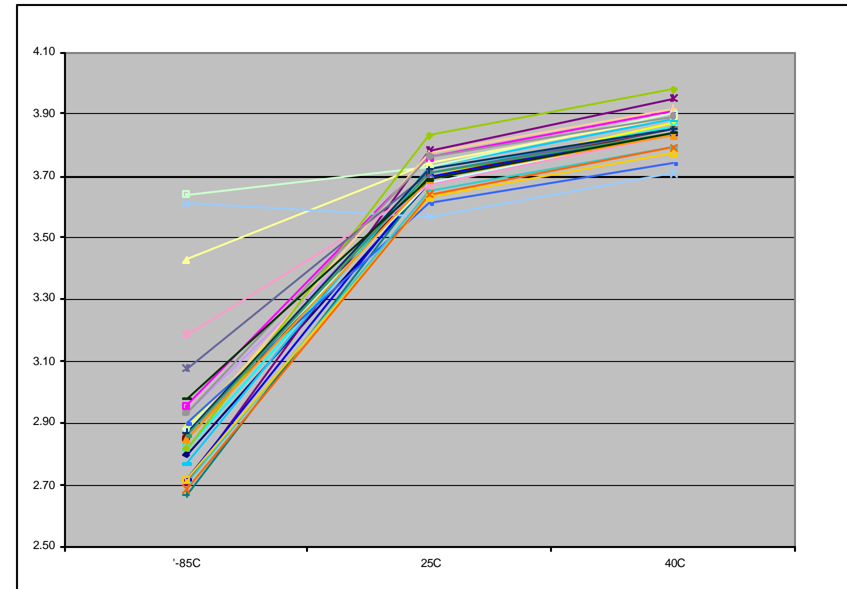
# COLD TEMPERATURE TEST RESULTS - COTS UPSCREEN

## Case I-B

(Examples)

Performance

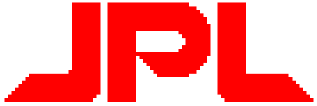



**Part A Ios Range @ -65C**

**Part A Isc Range @ -65C**

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

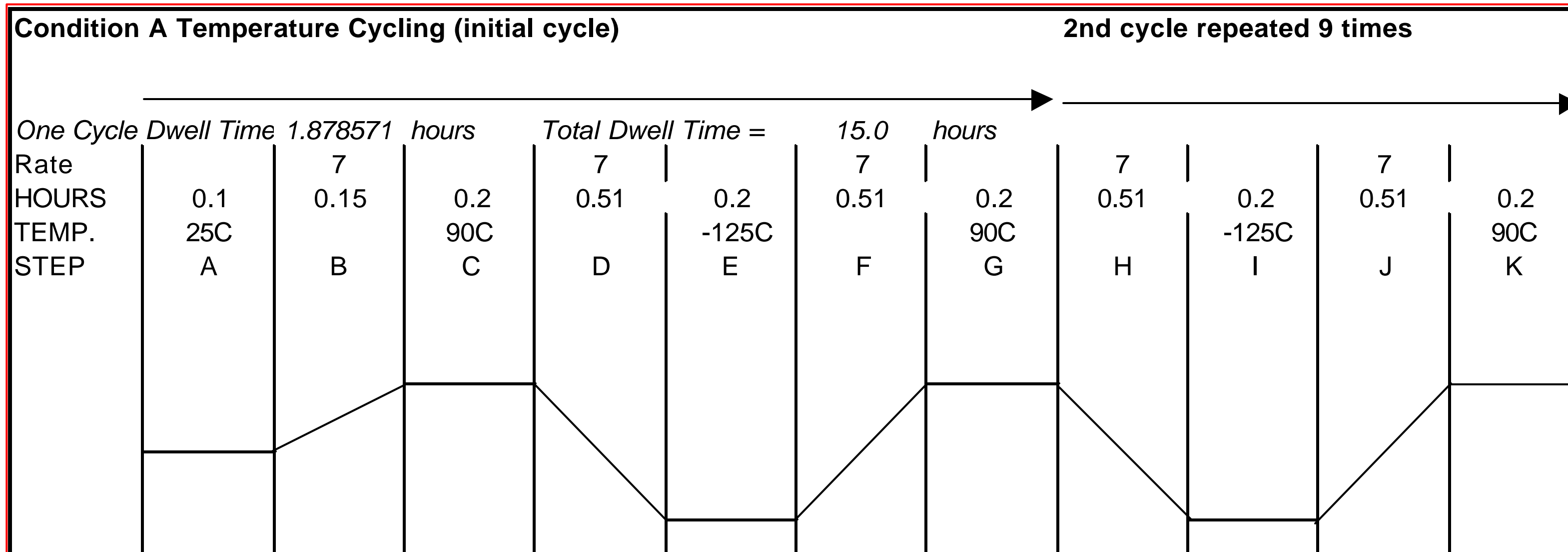


Electronic Parts Engineering

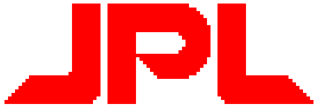
# TEST RESULTS
# COTS UPSCREEN

## 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.**



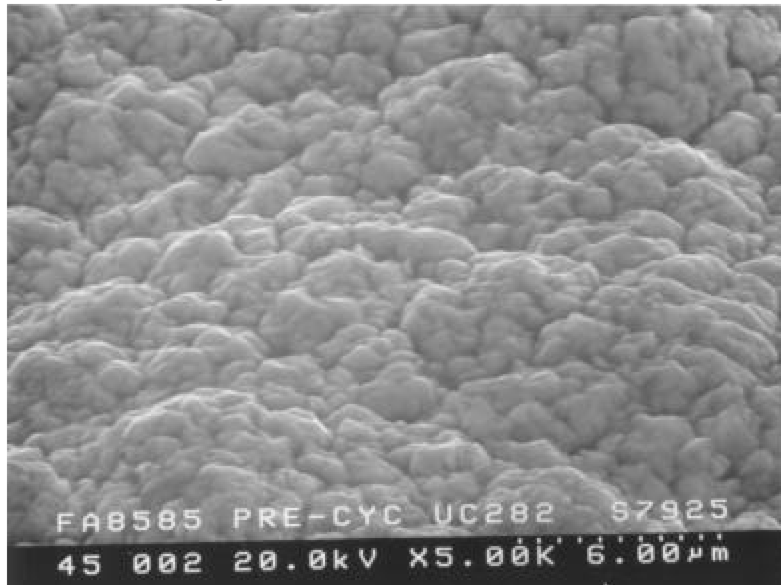


# FAILURE ANALYSIS

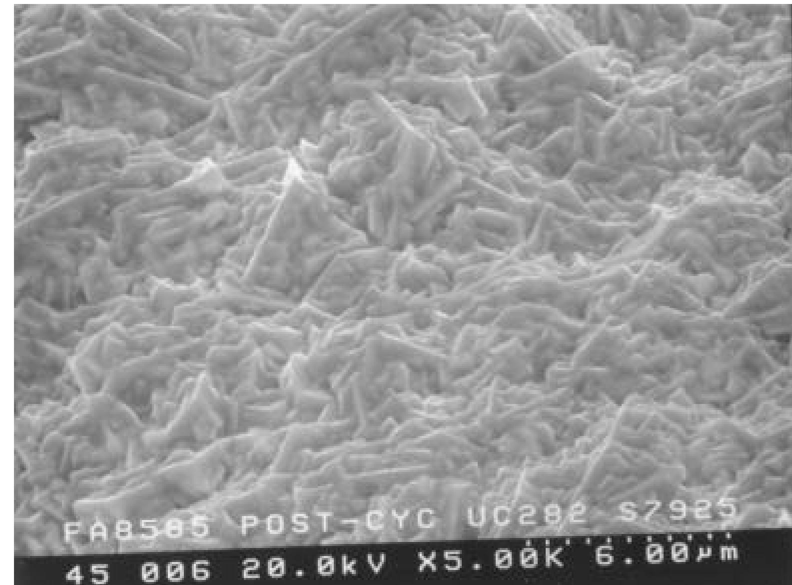
Temperature Cycle

## Case II-A

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

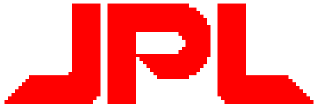



BEFORE




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

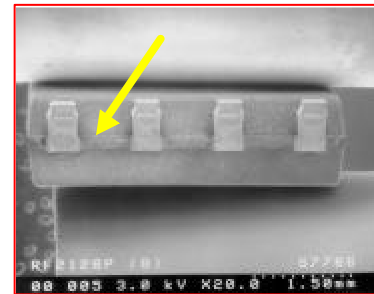
**Thermal Shock**

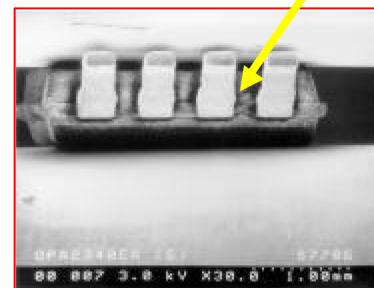
## Case III

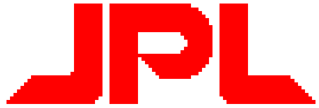
**Test Conditions: 30 cycles from –185° C to +135° C liquid bath**

| Sample | Result |
|---|---|
| Sample 1 | PASSED |
| Sample 2 | **FAILED** |
| Sample 3 | PASSED |
| Sample 4 | PASSED |
| Sample 5 | PASSED |
| Sample 6 | **FAILED** |
| Sample 7 | PASSED |

**Miniature Cracks Found**









# 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 $LN_2$ conditions under very long test times.