

JPL

Package Qualification and Verification for JPL/NASA Projects

Mass. (U) Technology Development Program

Extreme Temperature Thermal Cycling Tests and Results for Flight Qualification

Dr. Rajeshuni Ramesham “RAM”

Quality Assurance Engineering
Office of Safety and Mission Success
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA

Tel.: 818 354 7190

e-mail: rajeshuni.ramesham@jpl.nasa.gov

Package Qualification and Verification (PQV)

Thermal Cycle

PQV Team Members for Mars Exploration Rover

- Mark Boyles
- Christine Ferguson
- Linda Facto
- James Newell
- Reza Ghaffarian
- Mark Gibbel
- Rajeshuni Ramesham
- Ronald G. Ross-Jr
- Don Schatzel
- Etc.

Package Qualification and Verification for JPL/NASA Projects

Mars 10 Technology Development Program

ACKNOWLEDGEMENTS

- * PQV team members
- * MER Project Management (Barry Goldstein, Richard Brace, Richard Cook, Peter C. Theisinger, Tom Ramsey, Don Sevilla, etc)
- * Several PEMs, Cog Es, and Engineers (Mike Johnson, Don Noon, Edward C. Litty, Mark A. Schwochert, Eric Sunada, Andy Collins, Wayne Bosze, Saverio D'Agastino, Mike Sandor, Shri G. Agarwal, Yuanming Liu, Kalyani G. Sukhatme, etc of the Following Projects
 - Mars Exploration Rover (MER)
 - Herschel Plank (HP)
 - Microgravity Scaling Theory Experiment (MISTE)
 - MUSES CN
- * NASA Electronic Parts and Packaging (NEPP) Management (Dr. Charles Barnes and Phil Zulueta)
- * Carl DeSilviera for his Encouragement to support projects
- * Thomas R. Gavin provided us the lead for MUSES CN: Ross M. Jones, to address the packaging issues for MUSES CN project under NEPP Cold task

Package Qualification and Verification (PQV)

Thomas C. Kelly

Package Qualification and Verification for JPL/NASA Projects

Mars '09 Technology Development Projects

Projects

• Work Underway

- HP
- MISTE
- MER

• Planning for the following projects

- Mars'09
- Mars Technology Focus Plan
- Mars NetLander
- LTMPF
- MRO
- X2000

Package Qualification and Verification (P&V)

Thermal Cycling



- Temperatures below 100 K (-173°C) are generally referred to as the cryogenic range.
- Liquid nitrogen temperature: 77 K (-196°C)
- Temperatures typically attained by mechanical refrigerators: 20 K (-253°C)
- Liquid helium temperature 4.2 K (-269°C)

Kelvin $K = C + 273.15$

Celsius $C = 5/9 (F - 32)$

Fahrenheit $F = 9/5 C + 32$

Rankine $R = F + 459.67$

$$= 9/5 K$$

Energy $E = kT = 0.862 \times 10^{-4} \text{eV}$

Specific Environments

	Venus	Earth	Mars	Jupiter
Average temperature (°C)	467	15	-63	-144
Solar irradiance (W/m ²)	2660	1380	595	51
Surface pressure	92 bars	1014mb	6.1mb	>>100bars
Other considerations	H ₂ SO ₄	H ₂ O	Oxidant. dust	Aerosols NH ₃ Ice H ₂ O Ice NH ₄ SH

Package Qualification and Verification for JPL/NASA Projects

Multi-DB Technology Development Program

Technical Infrastructure

- Several liquid nitrogen chambers with variable ramp rates
- Thermal shock chamber
- Room temperature down to Liquid Helium chamber for electronic package qualification and connector qualification
- Optical microscopy facilities to handle large and small size electronic packages
- Accessible
 - Surface Acoustic Microscopy
 - X-ray imaging
 - Failure Analysis (Office 514)

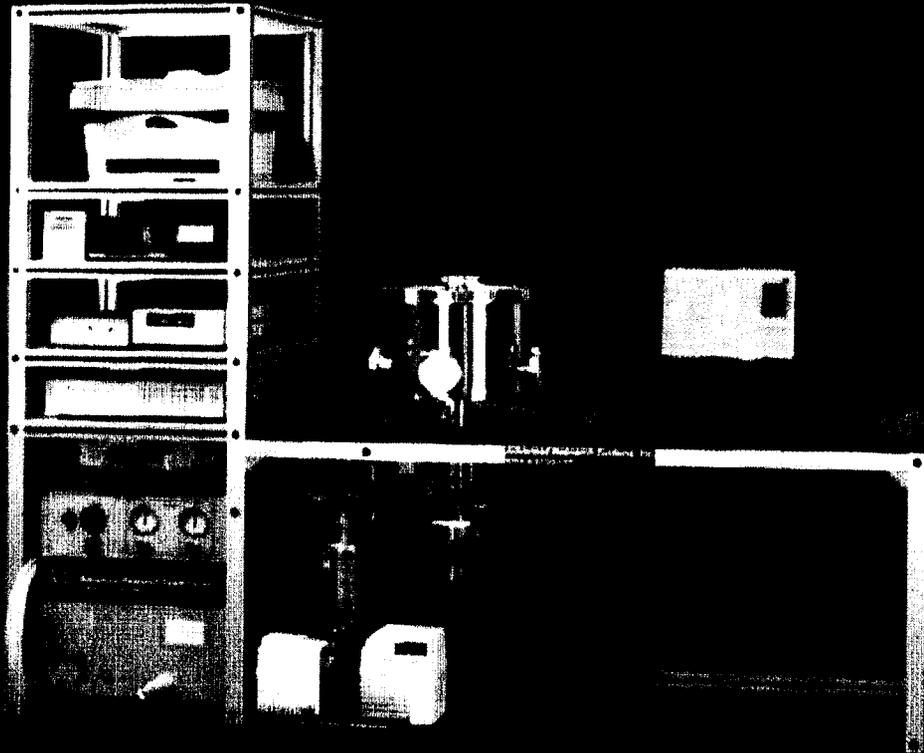
Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for JPL/NASA Projects

Mars 09 Technology Development Program

Technical Infrastructure



Courtesy of ARS

Experimental system that can go down to 4K Temperature

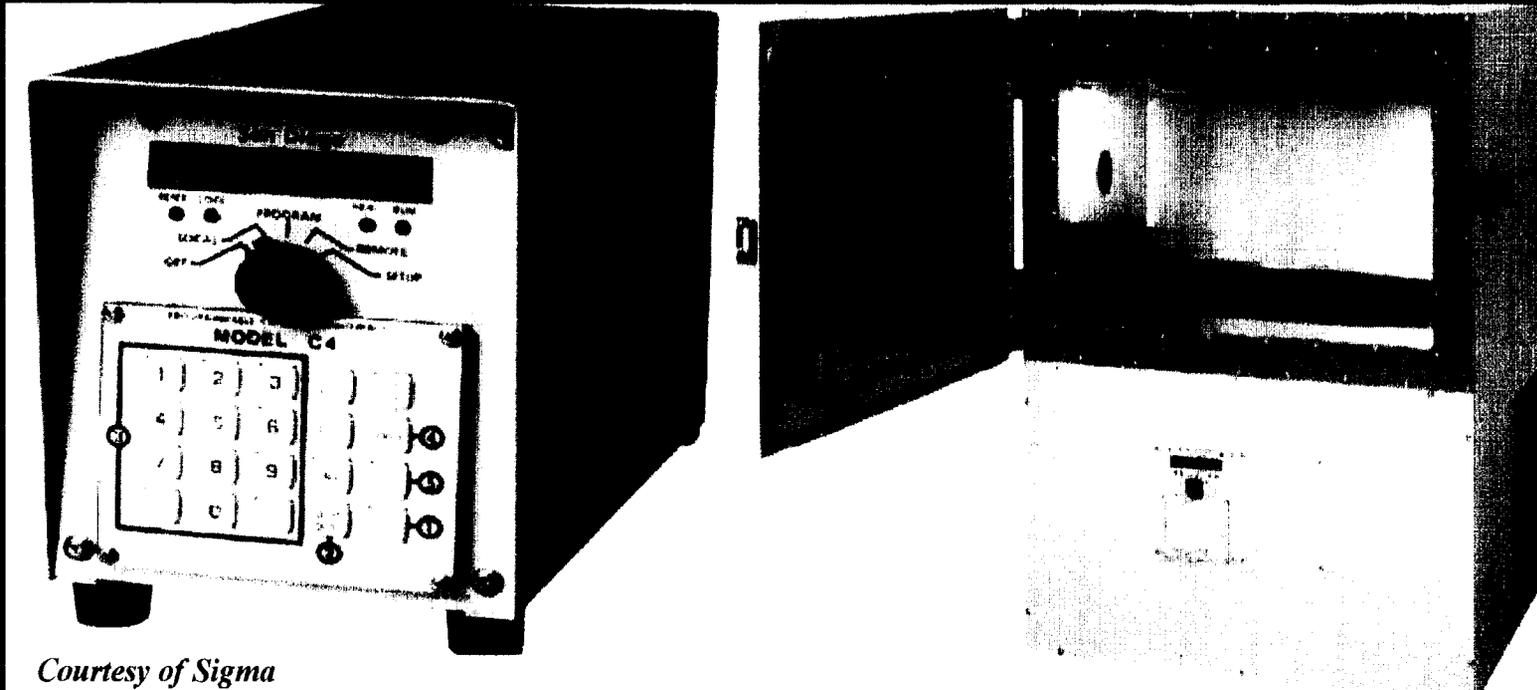
Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for JPL/NASA Projects

Advanced Technology Development Program

Technical Infrastructure



Courtesy of Sigma

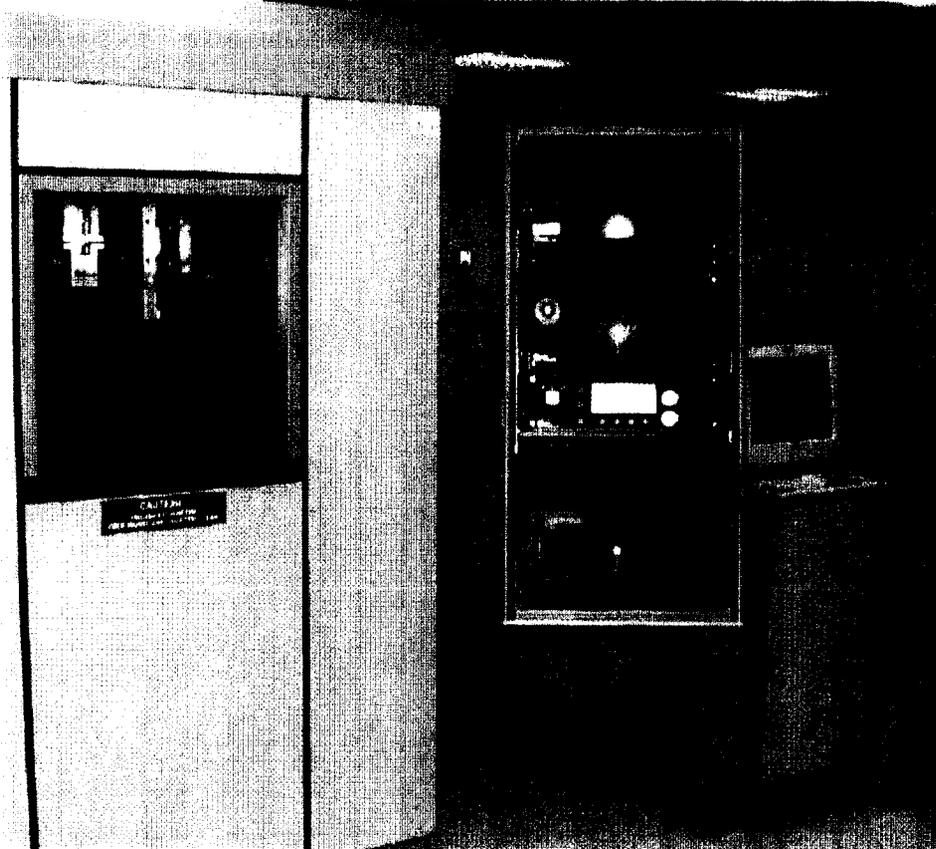
Thermal cycling chamber to assess the parts and packages for their reliability at various temperatures ranging from

-196°C (LN2) to 200°C

Package Qualification and Verification (PQV)

Thermal Cycling

X-ray microscope



Sonix ultrasonic microscope



Package Qualification and Verification for JPL/NASA Projects

2002-2003 Technology Development Program

Test Articles Subjected to Extreme Temperature Thermal Cycling

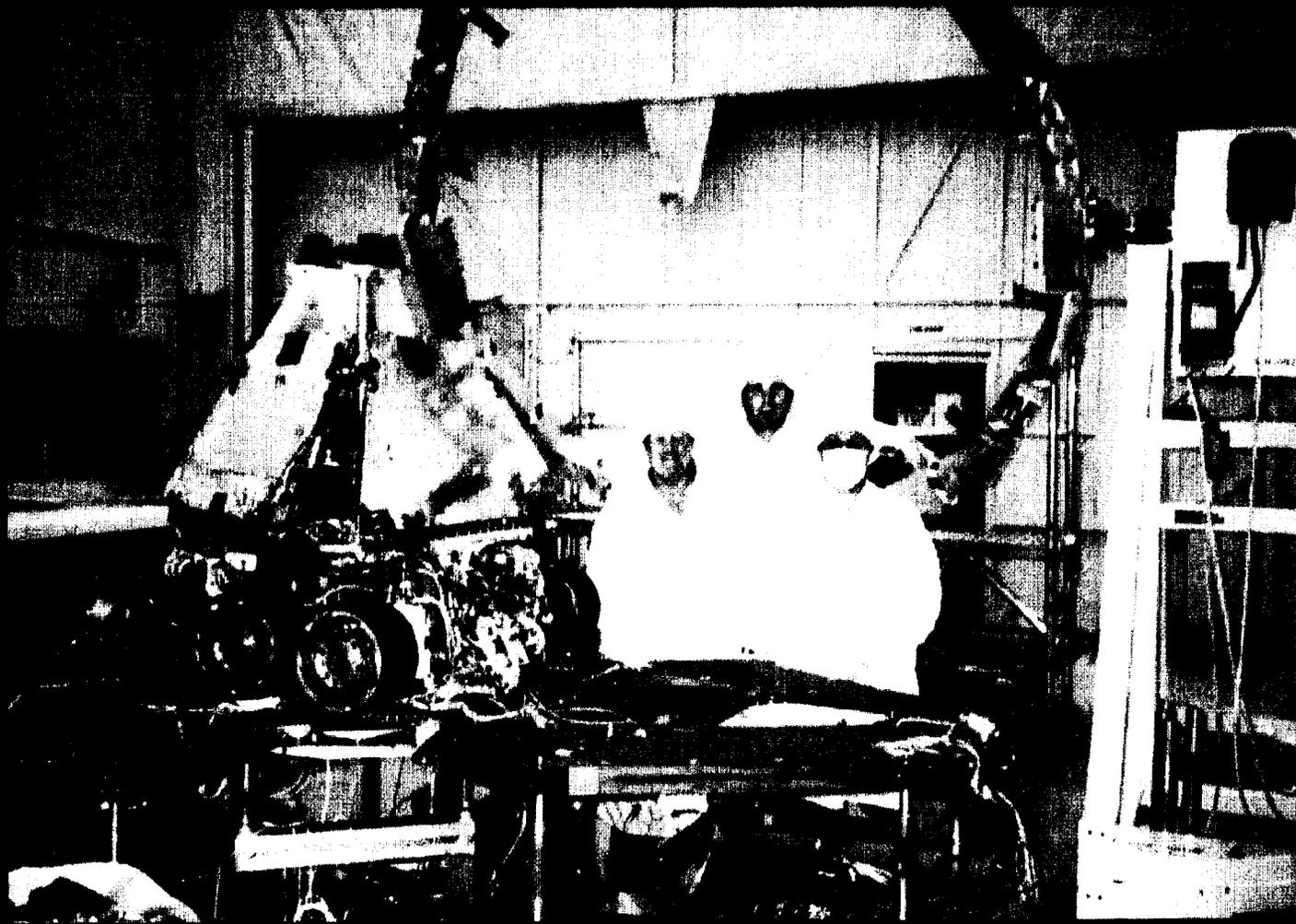
- ❖ Camera Electronics Assembly, Filter wheel assembly, diode assembly qual
- ❖ Leadless chip package in spectrometry electronics qual
- ❖ Leadless chip package in Camera Electronics Assembly qual
- ❖ Gyro and its assembly qual
- ❖ Brush Motors with Encoders qual
- ❖ Brush less motors
- ❖ LPAE, RPAE Electronics Assemblies qual
- ❖ Thin Film Heaters qual for motors
- ❖ Thin Film Heaters qual for solar array substrates qual
- ❖ RAT Butterfly switches qual
- ❖ Air-bag Retraction Actuator Acceptance test
- ❖ Potentiometers Acceptance test
- ❖ Indium Seals qual
- ❖ JFET Board with multiple Connectors
- ❖ Evaluation of epoxies for HP
- ❖ Connectors solder joints robustness
- ❖ UHF monopole antenna qual
- ❖ Aluminum foils for MER (EMI Test)

Package Qualification and Verification (PQV)

Thermal Cycling

JPL
Package Qualification and Verification for JPL/NASA Projects

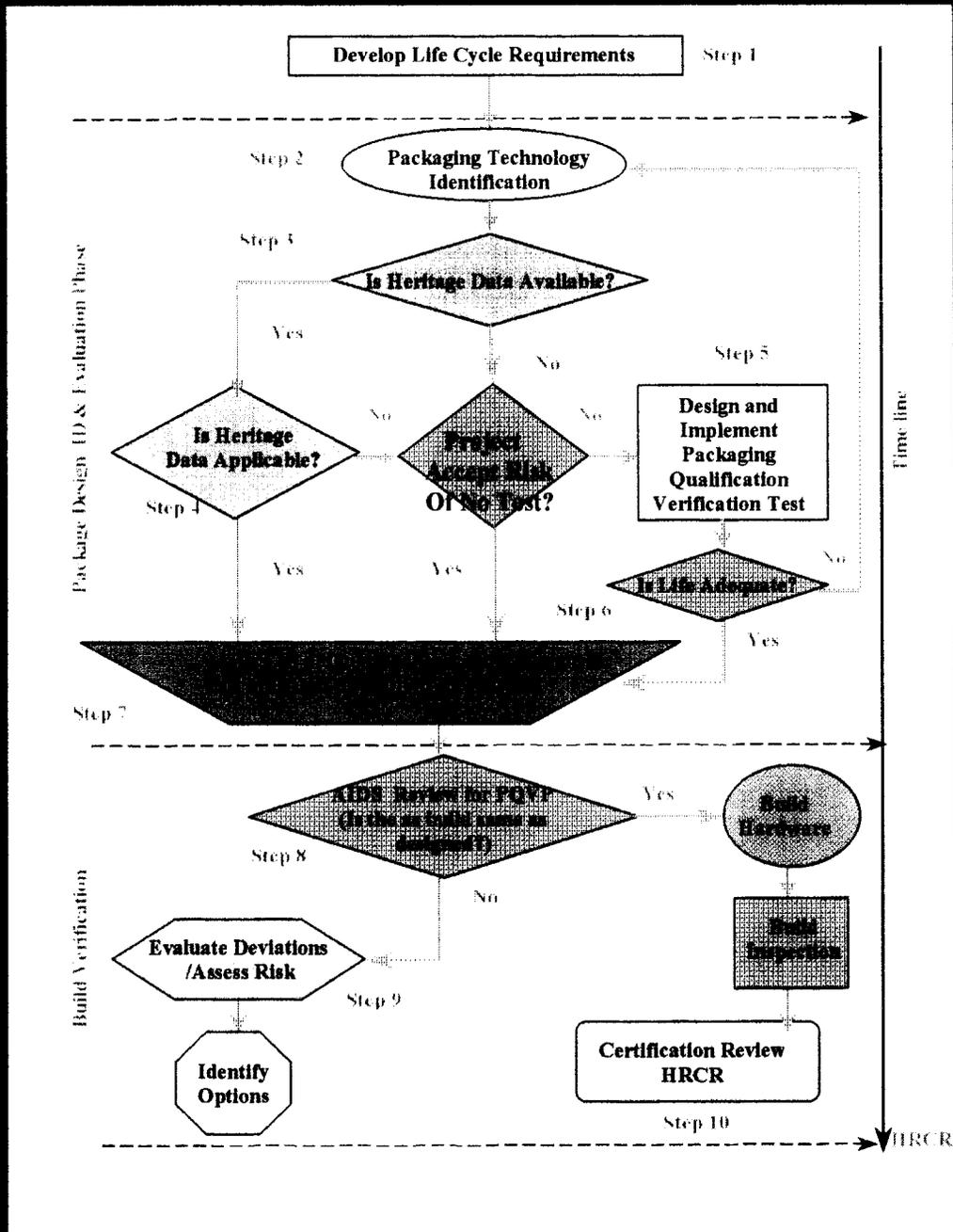
Mars '02 Electrical Development System



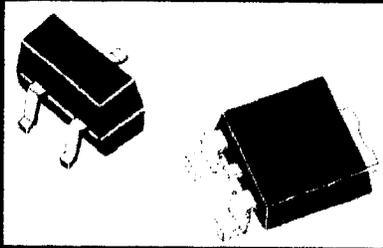
Courtesy of Mike Johnson

Package Qualification and Verification (PQV)

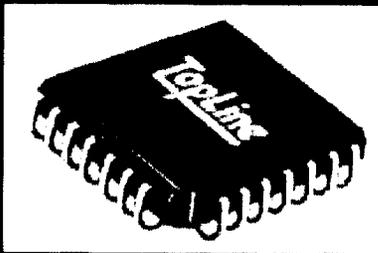
Thermal Cycling



Package Types



SOT

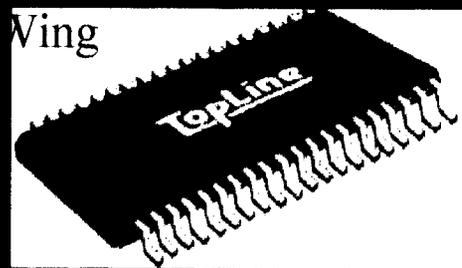


PLCC

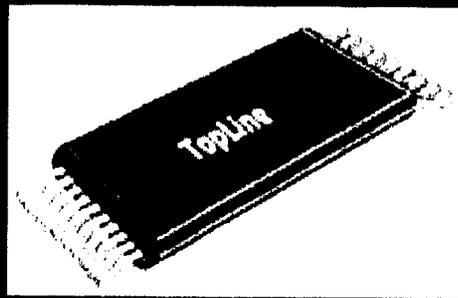


SO J-Lead

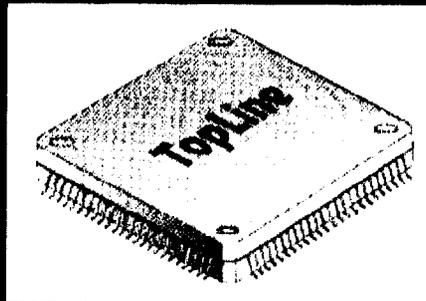
SO Gull Wing



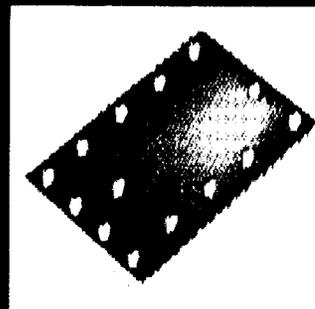
TSSOP



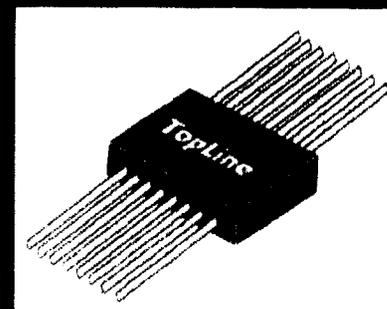
TSOP



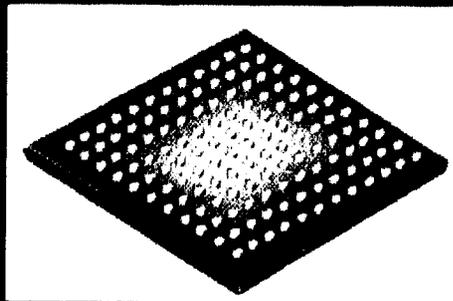
QFP



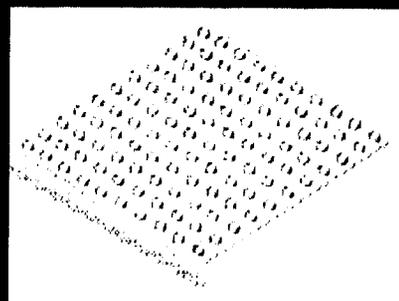
Flip-chip



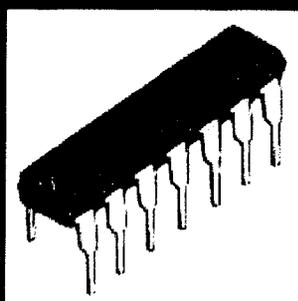
Flat Pack



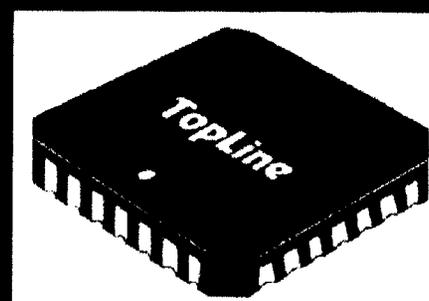
BGA



CBGA



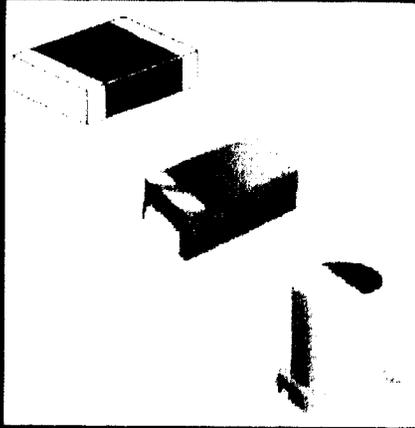
DIP



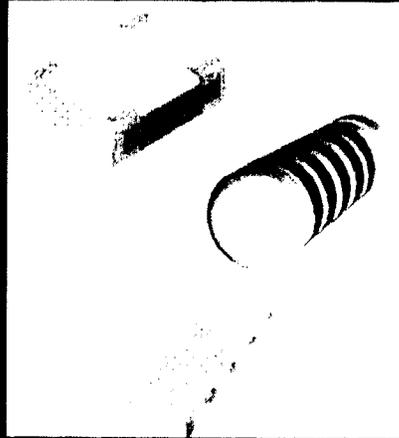
LCC

Stacked BGAs, Flip-chip BGAs, μ BGAs, CSPs, etc.....

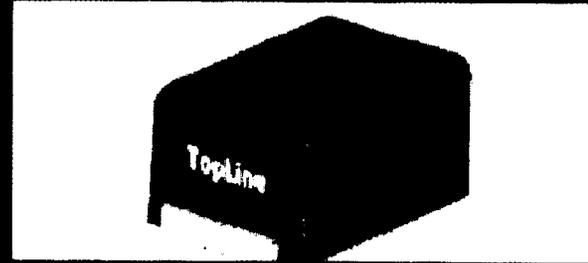
Passive Components



Capacitors



Resistors



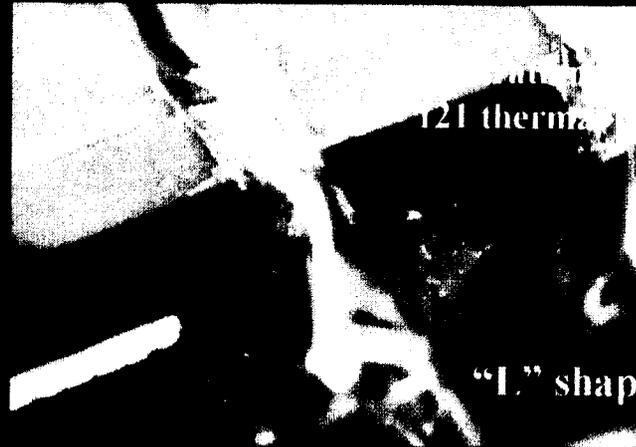
Inductors

Embedded passives ...

Package Qualification and Verification for JPL/NASA Projects

Mars '09 Technology Development Program

Camera Electronics
Assembly for
MER qualified
under extreme temperatures



Microscopic view of solder joint after
121 thermal cycles

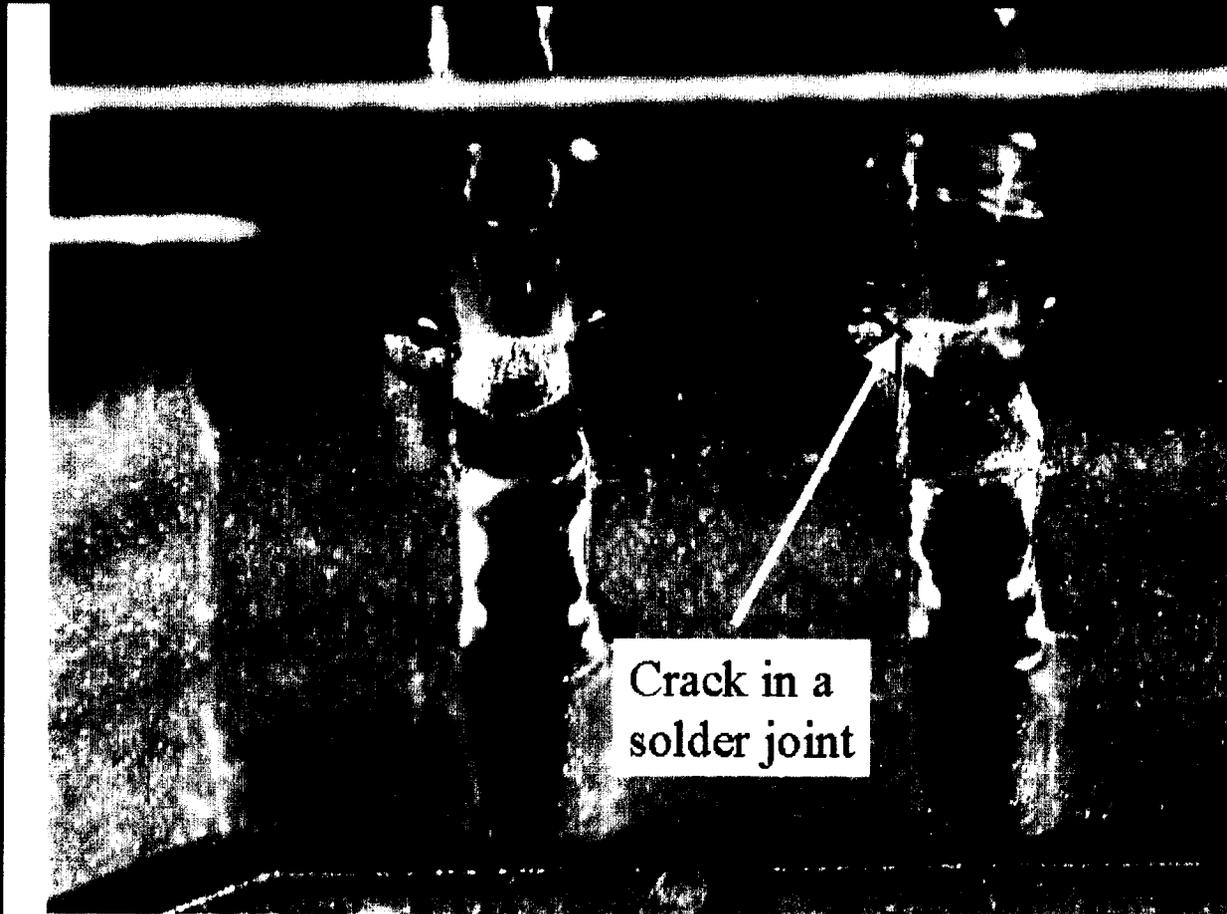
"I." shaped haywire

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for JPL/NASA Projects

Mass (00) Technology Development Program



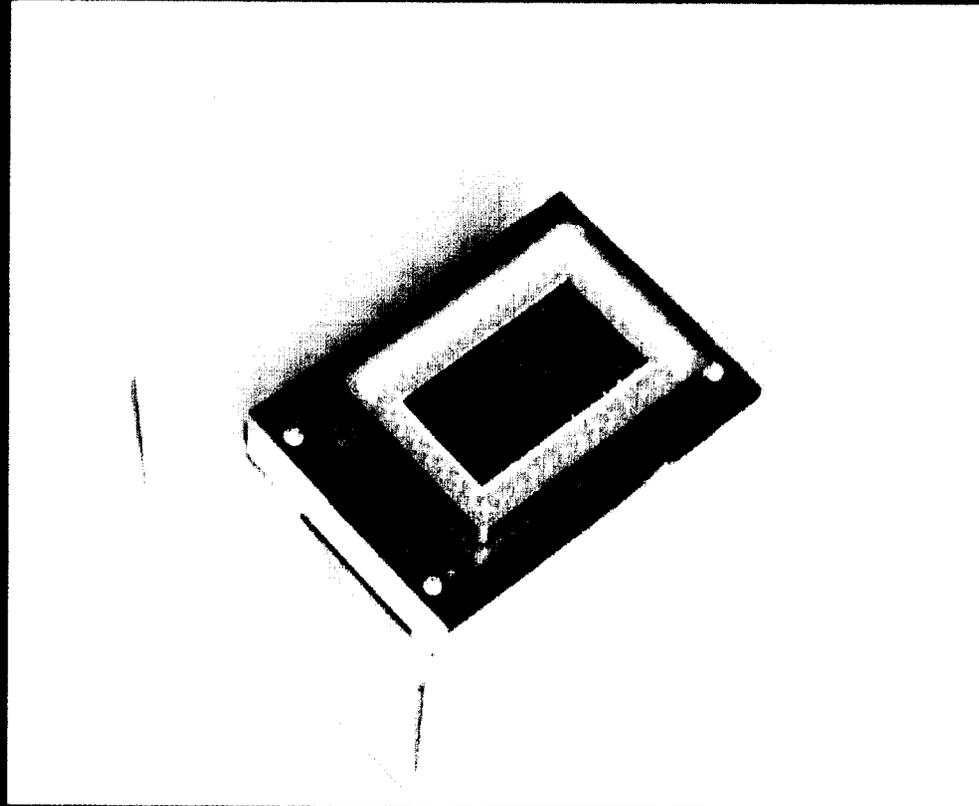
Crack in a solder joint

Optical photograph of a cracked interconnect in Leadless assembly after 50 thermal cycles (-120°C to 115°C)

Package Qualification and Verification (PQV)

Thermal Cycling

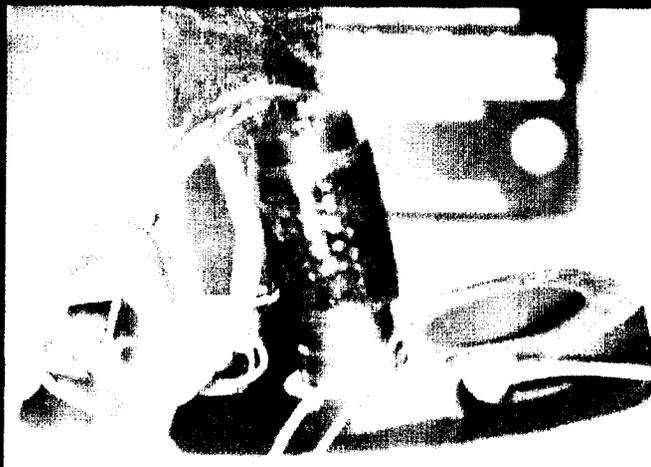
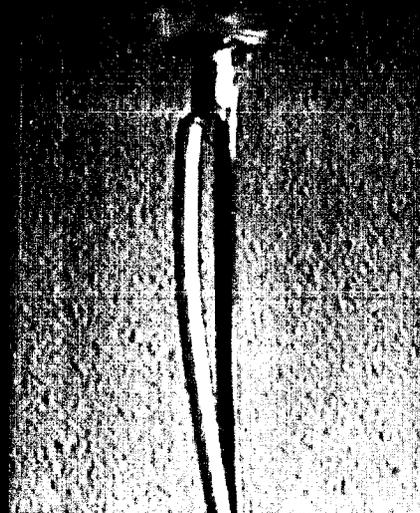
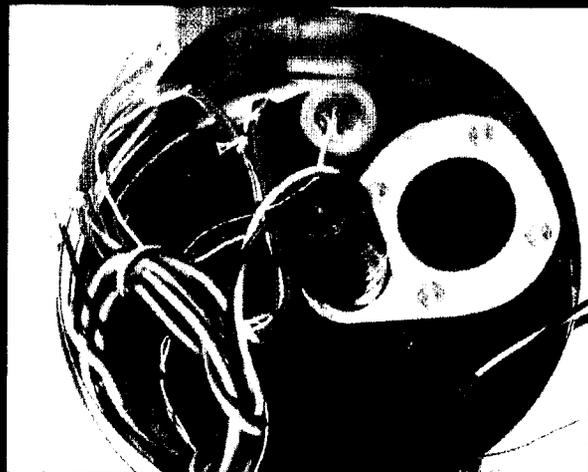
Package Qualification and Verification for NASA Projects



CCDs for Camera Assembly of MER
(10 thermal cycles performed in Extreme temperature range)

Package Qualification and Verification for NASA Projects

Package Qualification and Verification (PQV)



Camera
Components
for MER
Qualified under
extreme
temperatures

Package Qualification and Verification (PQV) Thermal Cycling

JPL

Package Qualification and Verification for NASA Projects

Mars '09 Technology Development Program



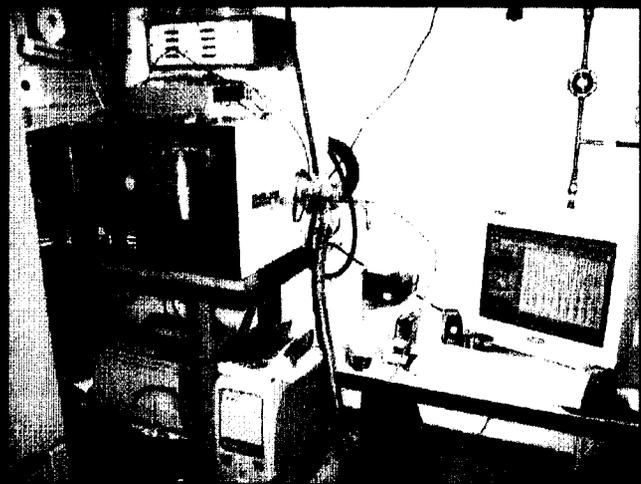
Spectrometry electronic package for MER - 55 to 100C; 200 cycles

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Microelectronics Development Program



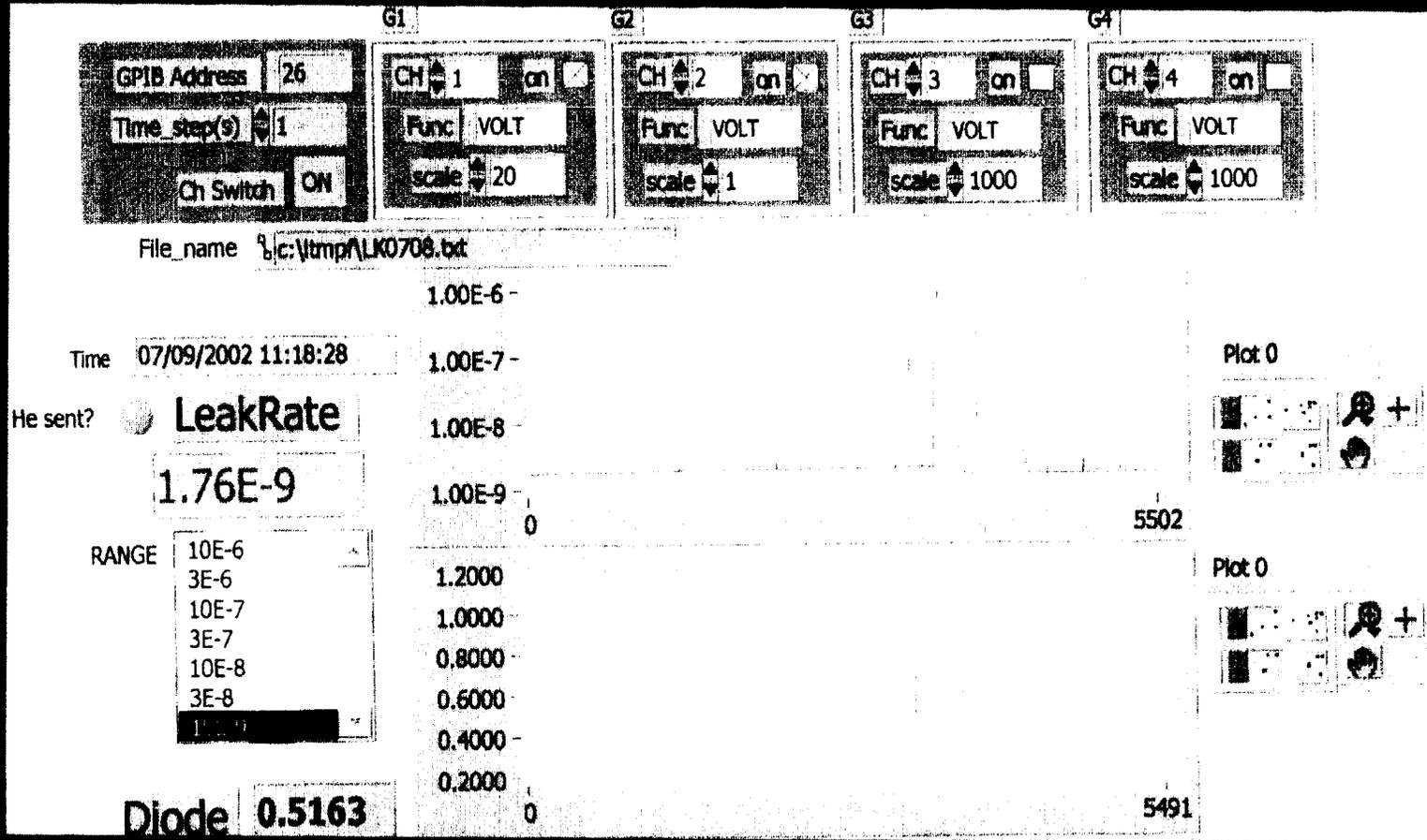
Extreme temperature qualification test of Indium Seals under Cryogenic Temperatures

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Package Qualification and Verification (PQV) - Thermal Cycling



Package Qualification and Verification (PQV) - Thermal Cycling

Package Qualification and Verification for NASA Projects

Mars09 Technology Development Program



Potentiometers
Tested for
MER
Under
Extreme
Temperatures

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for JPL/NASA Projects

Mars '09 Technology Development Program



Rock Abrasion Tool's Butterfly Switch qualified under extreme temperatures for MER

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Mars 09 Technology Development Program



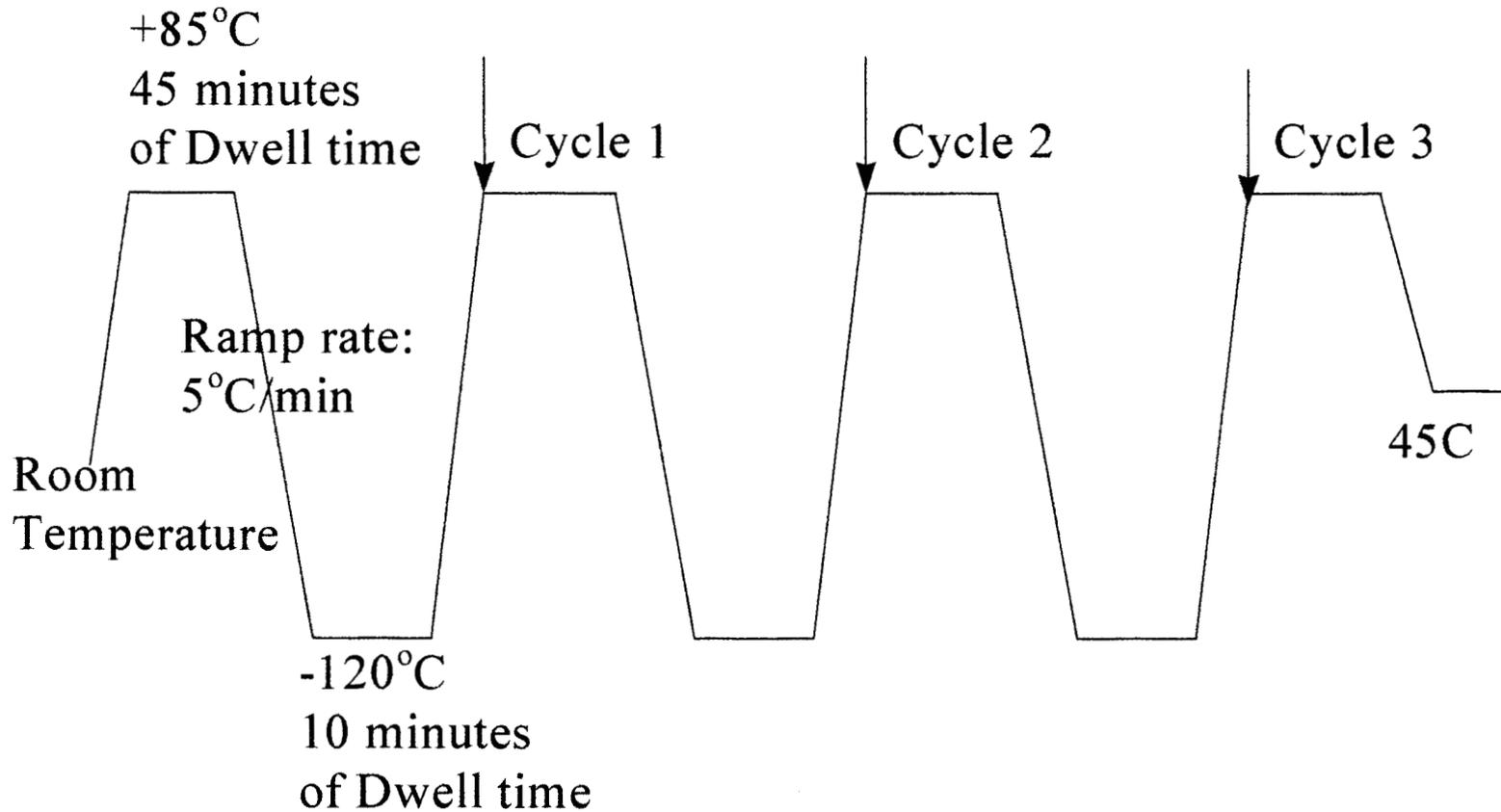
Air bag retraction actuator tested under extreme temperatures for MER

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

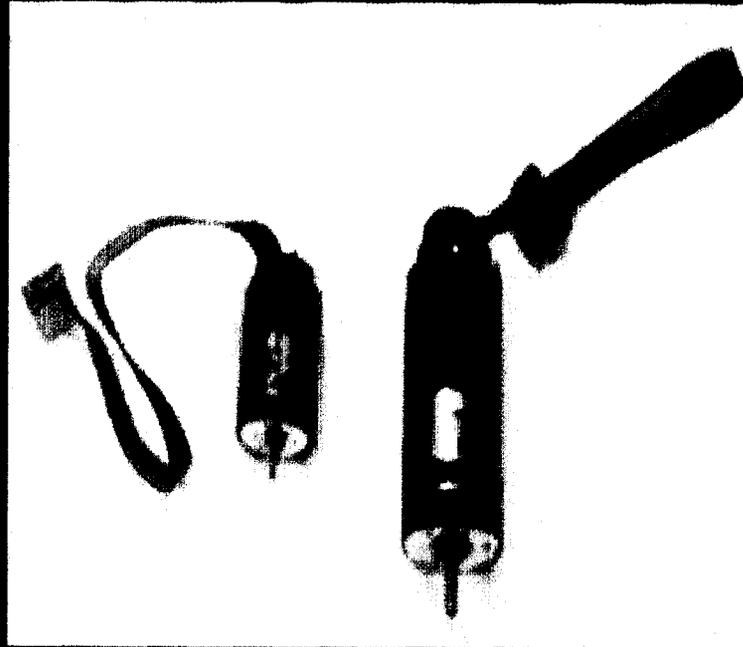
Mars'09 Technology Development Program



Temperature Profile 1: 270 cycles only

Package Qualification and Verification for NASA Projects

MER (09) Technology Development Program



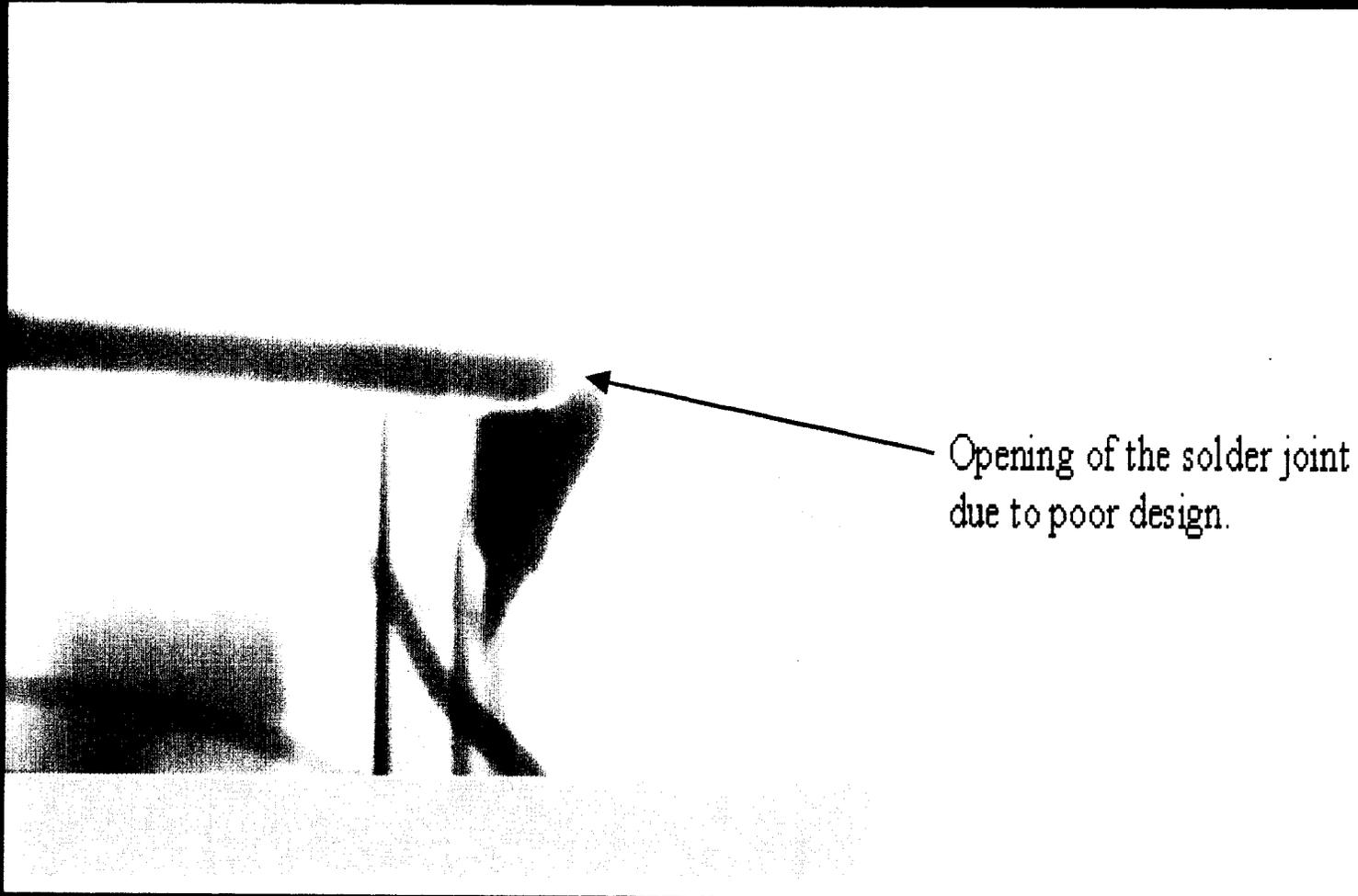
Brush motors and encoders qualification tested under extreme temperatures for MER

Package Qualification and Verification (P&V)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Package Qualification and Verification (PQV)



Opening of the solder joint due to poor design.

Package Qualification and Verification (PQV)

Package Qualification and Verification for NASA Projects

Mar 02 Technology Development Program



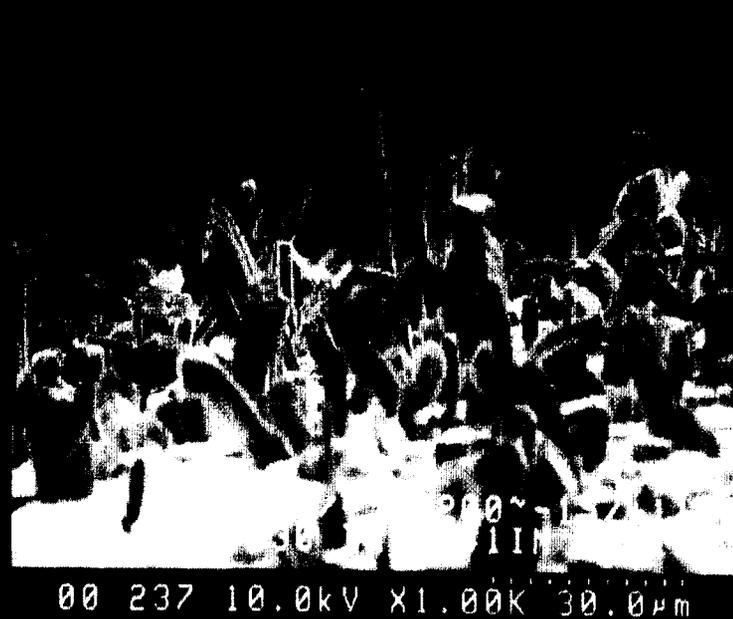
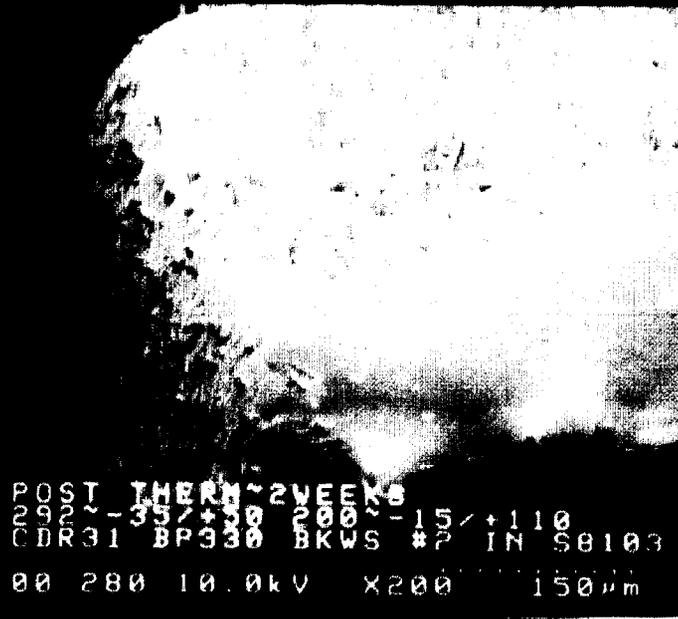
Thin film heater attached to the brush motors tested for MER under extreme temperatures

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Mercury Technology Development Program



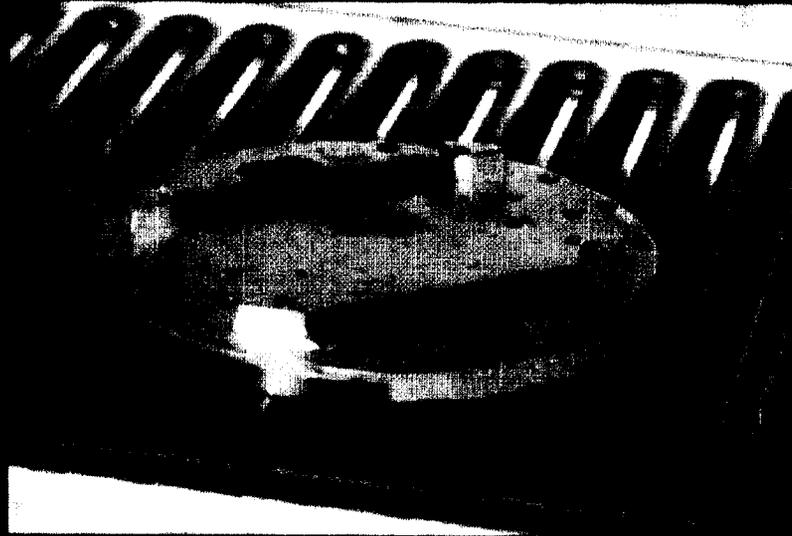
Tin whiskers study for MER to assess their influence on MER hardware

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Microelectronics Development Division

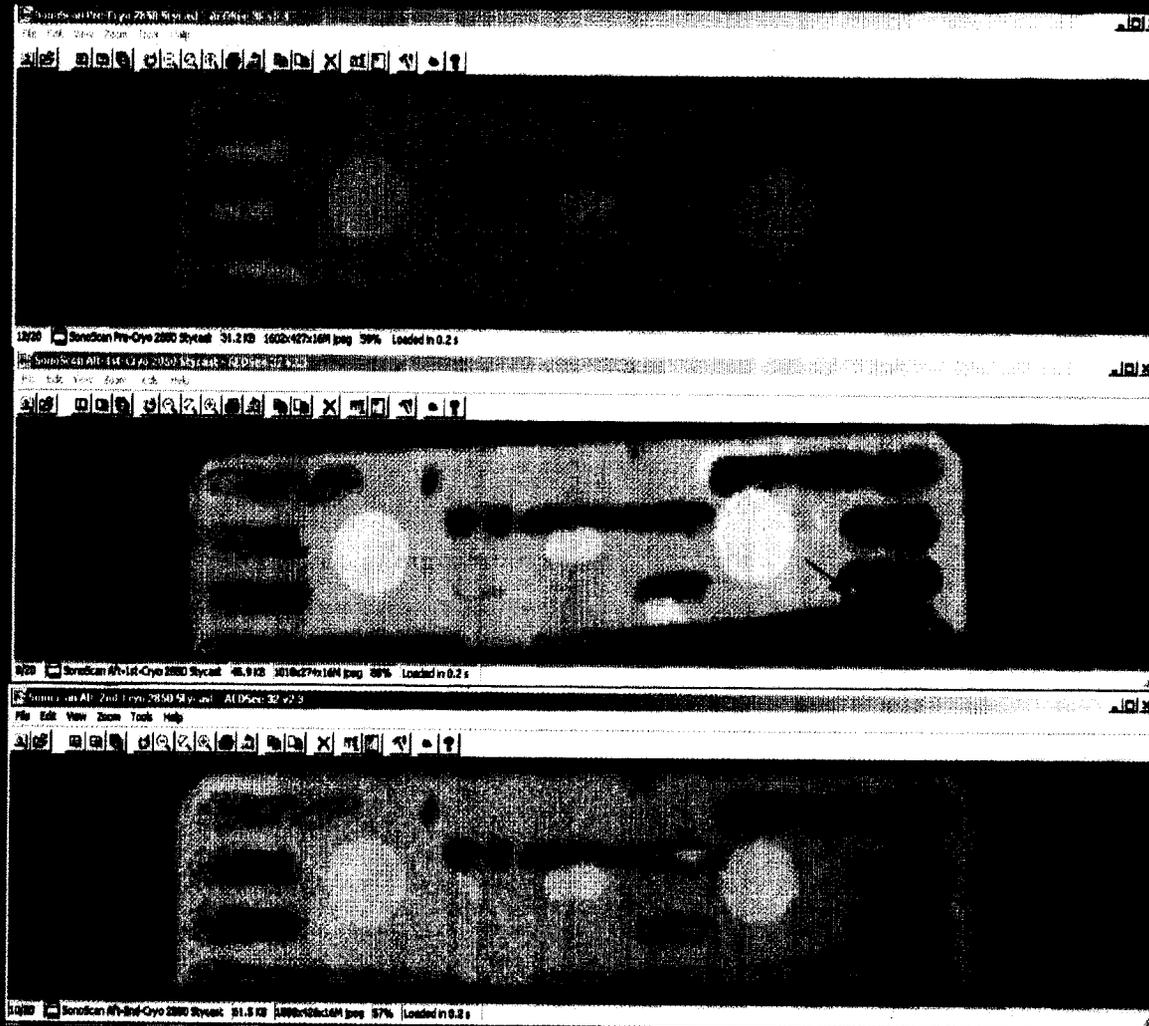


SPIRE/HP Project: Evaluation of epoxies
under extreme temperature cycling

Package Qualification and Verification (PQV)

Thermal Cycling

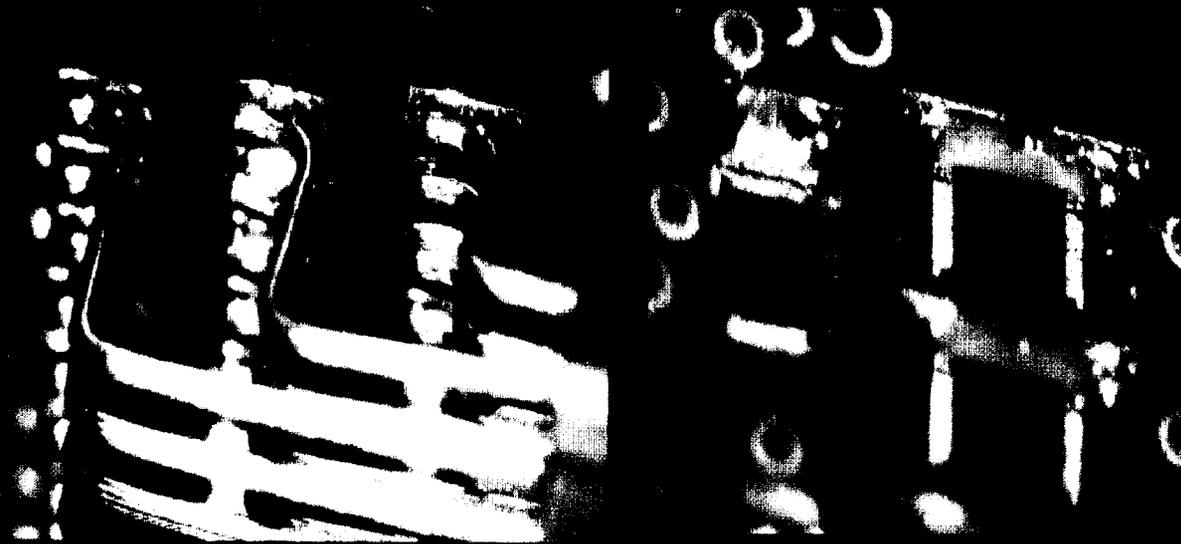
Scanning Acoustic Microscopy



C-SAM of Silicon bonded to metallic substrate before and after 5 and 10 cryogenic (-190C to room temp cycles). Dark areas are adhesive bonded to the silicon. Onset of bond failure is shown by lightened areas.

Package Qualification and Verification for NASA Projects

Minus 100 Test/Inflator Development Program



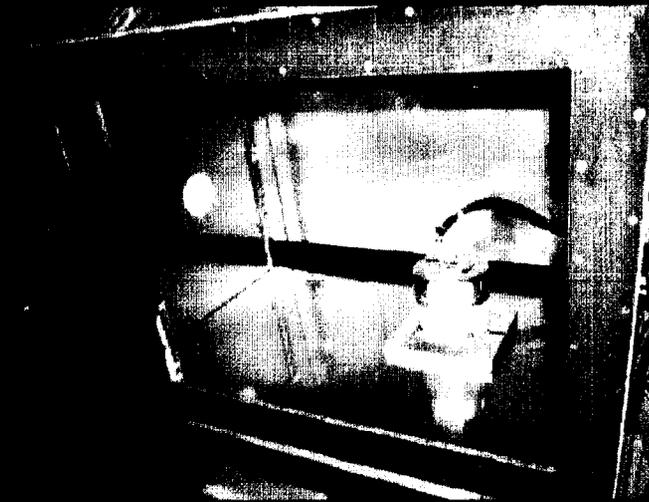
JFET board package components for SPIRE/HP
Project tested under extreme temperatures

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Mercury Environmental Development Program



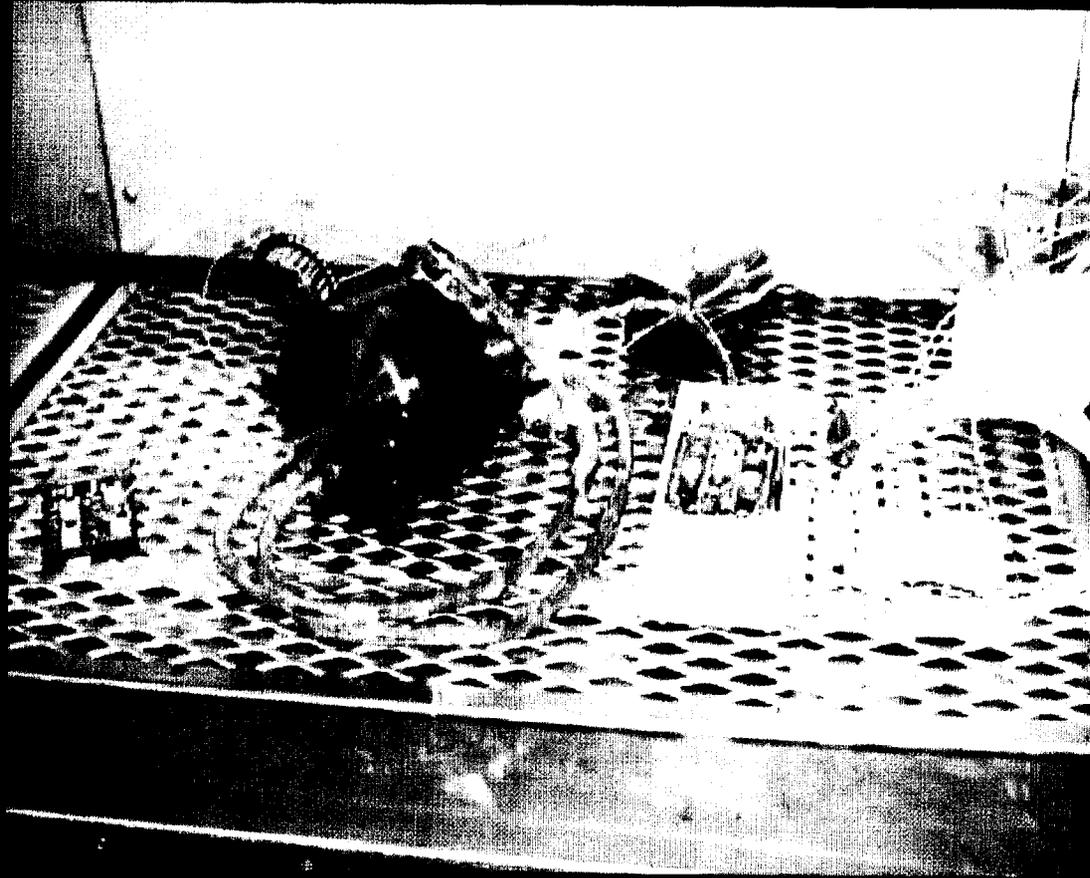
Qualification Testing of Inertial Measurement Unit for MER

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Motor (M) Test and More Development Program



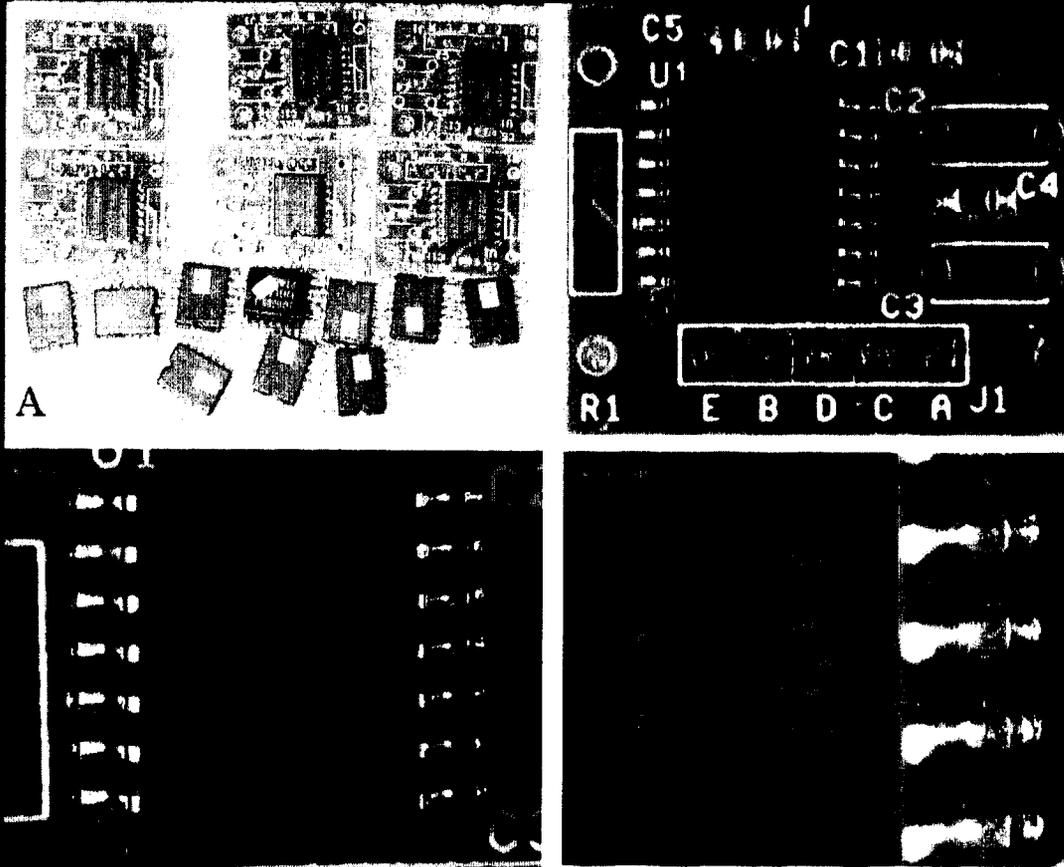
Brush-less motors qualified for MER under extreme temperatures

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Package Qualification and Verification Program



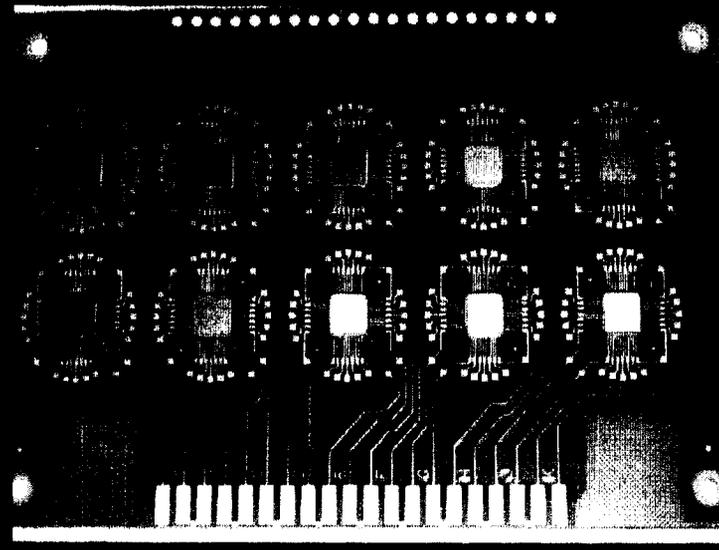
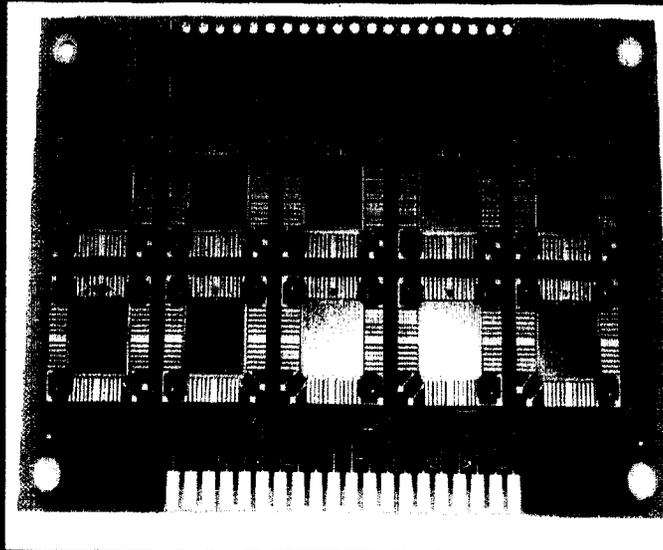
Accelerometer packages tested under extreme temperature thermal cycling

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Mars (D) Technology Development Program



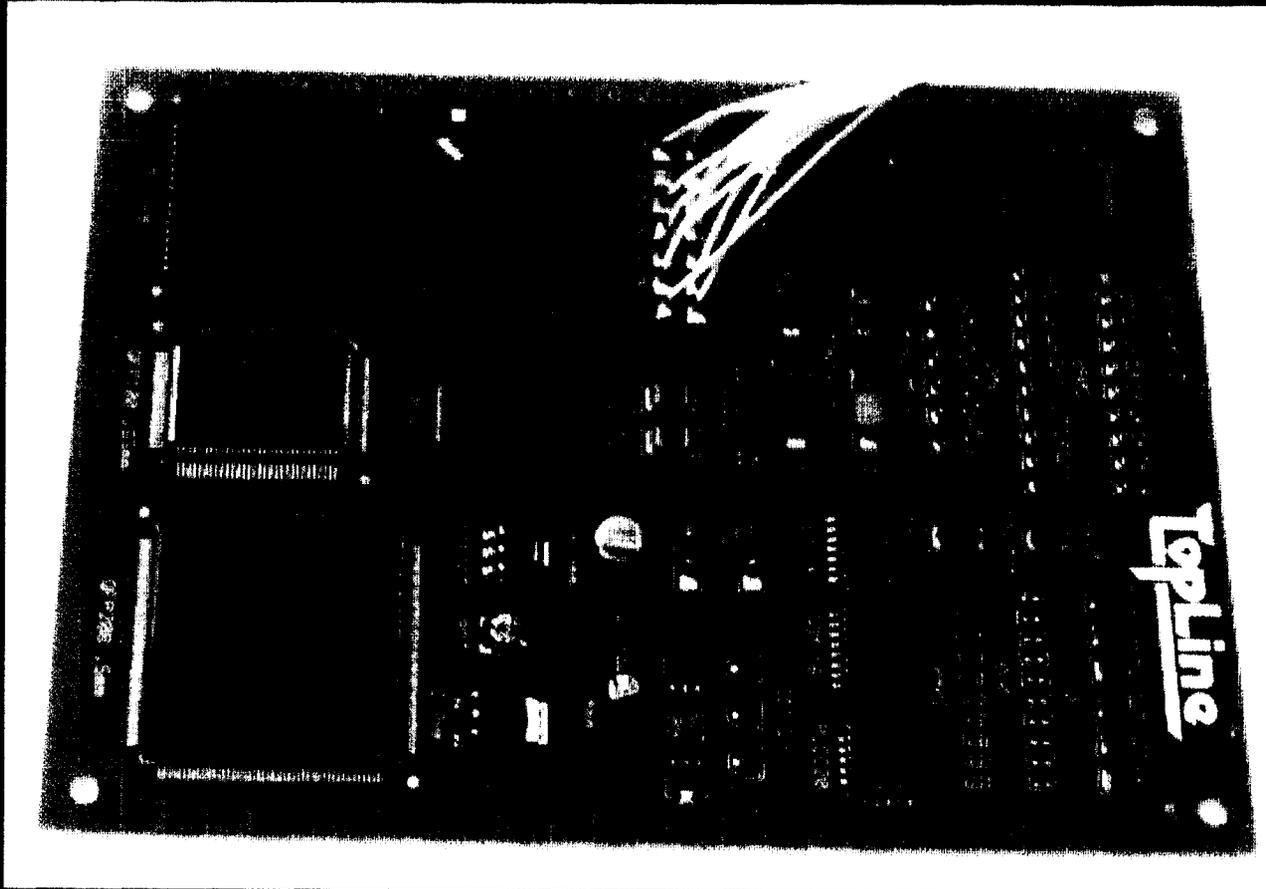
Evaluation of flip-chip technologies under various
Extreme temperature regimes

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Mar'09 Technology Development Program



A test article that has several types of advanced packages subjected to extreme temperature thermal cycling

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Atlas 02 Technology Development Program

Optical Photograph of
COTS Electronic
Nose sensor package
before and after
thermal cycling.



Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Mars (V) Technology Development Program



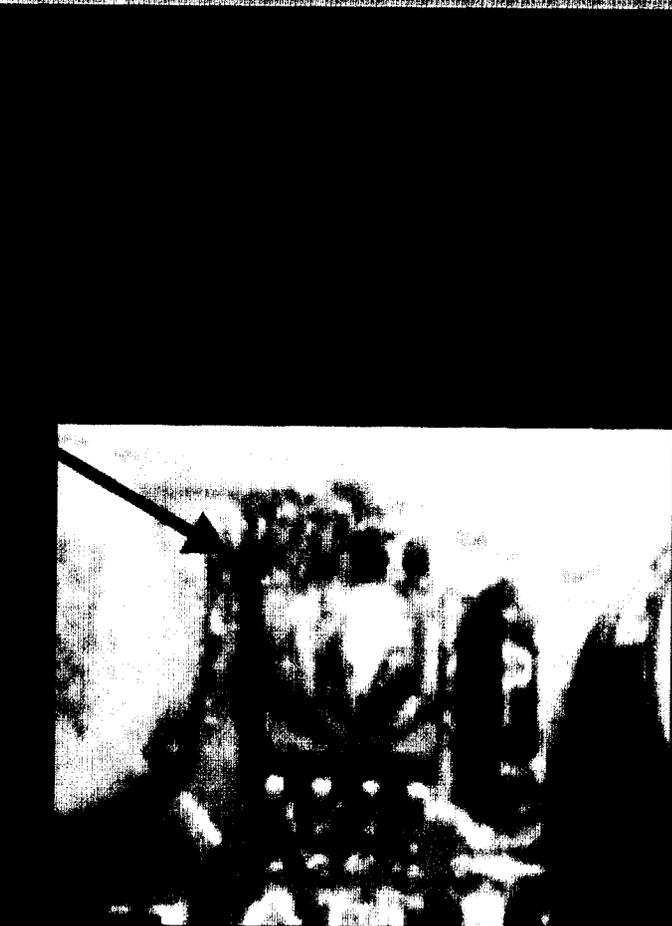
Optical Photograph of Electronic Packages
of COIS E-Nose after 30 thermal cycles -120°C to 115°C

Package Qualification and Verification (PQV)

Thermal Cycling

Package Qualification and Verification for NASA Projects

Package Qualification and Verification Program



Destroyed step down converter

Failed/Damaged Step down converter as a result of over voltage in a COTS E-Nose

Package Qualification and Verification (PQV) *Thermal Cycling*

Package Qualification and Verification for NASA Projects

Mars'09 Technology Development Program

Summary

- * Shown experimental long term thermal cycling data performed in our laboratory using the various test articles that consist of advanced technologies for various missions and projects.
- * Leadless packages have shown problems in extreme temperature thermal cycling
- * Adhesion/delamination has been observed under extreme temperature thermal cycling
- * Flip-chips have been in test under extreme temperatures
- * PQV team has closely worked with MER CofEs, Project Managers, etc. to address several issues associated with the electronic packaging for extreme temperatures.
- * Technical infrastructure is in place to perform extreme temperature thermal cycling of new and advanced technologies for the Mars Technology Focus Plan/Thermal Cycling Resistant Electronics (TCRE) Task

Package Qualification and Verification (PQV)

Thermal Cycling