"Thermal Cycling Testing to Failure of a Ceramic Column Grid Array Package for Space Applications"

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OUTLINE

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- ❖Introduction
  - Environmental challenges driving the need for thermal cycling
  - CCGA Packaging Overview (includes1752, 717)
- ❖Experimental Details
- ❖Results and Discussion
- ❖Acknowledgements

Purpose

"Assess and mitigate the risk associated with the Virtex-5 CCGA 1752 Advanced Package and other hardware to enhance the probability of sustaining the hardware functionality for long life"

We assembled daisy-chains of CCGA-interconnect packages using polyimide printed wiring boards, inspected the boards nondestructively, and then subjected them to thermal cycling to assess by testing to failure in thermal environments from +125°C to -40°C±25°C

JPL Design Principles

- **Electronic Packaging (Avionics)**
  - **Qualification of electronic packaging designs -** Electronic hardware shall be capable of surviving **three times the planned mission expected number of thermal cycles, each over the allowable flight temperature (AFT) extremes,** plus an estimate of the thermal cycles expected in the planned ground operations. In the absence of a specific mission thermal cycling profile, electronic hardware shall be capable of surviving 10,000 cycles, each of a 15 degrees C delta-T (ΔT) excursion.

Thermal Cycling

- Thermal cycling is generally represented as "**ON-OFF**" or **day and night** thermal environment conditions. This warrants the assembly survivability/reliability.
- Self-heating due to operation of the associated electronics.

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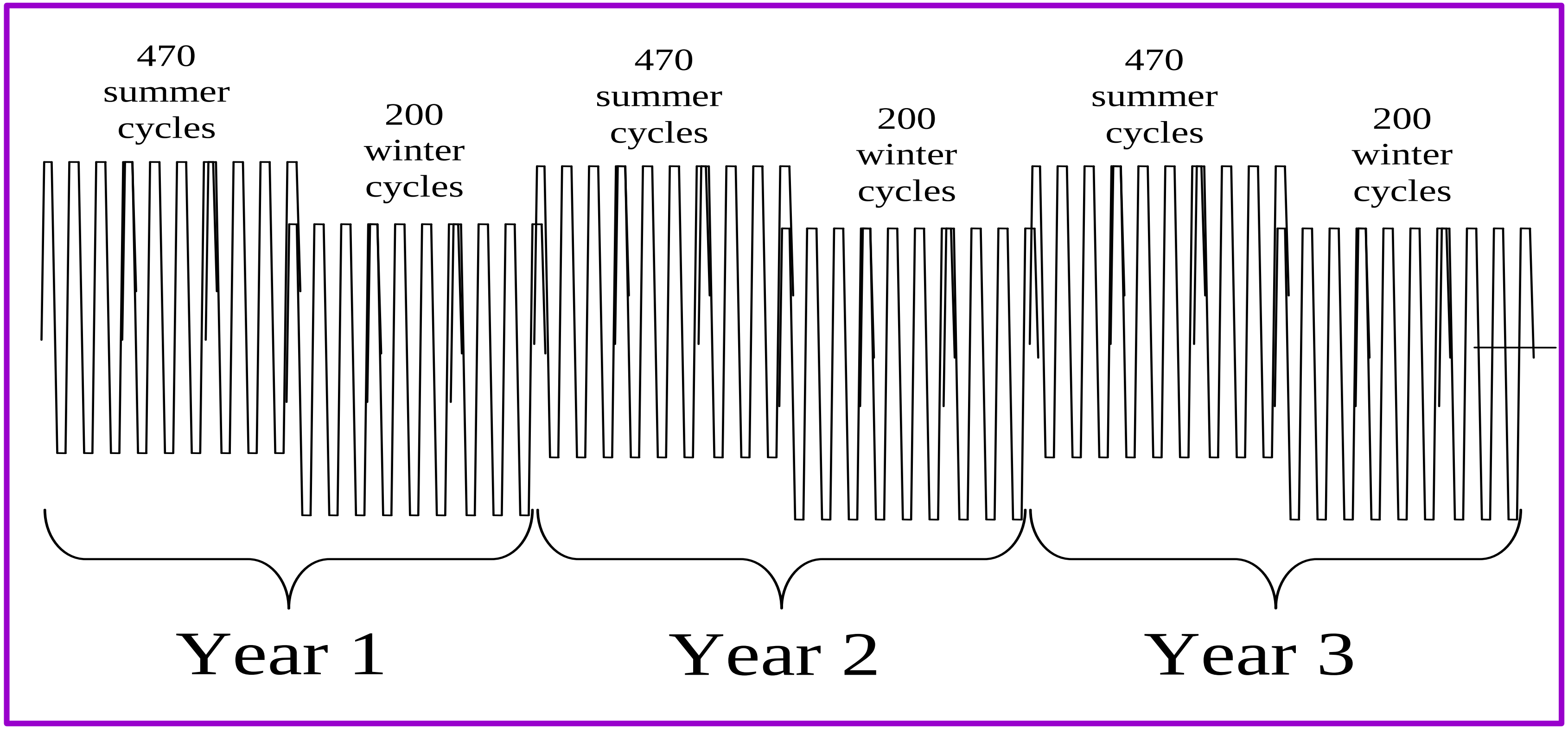
SMTA Pan Pacific

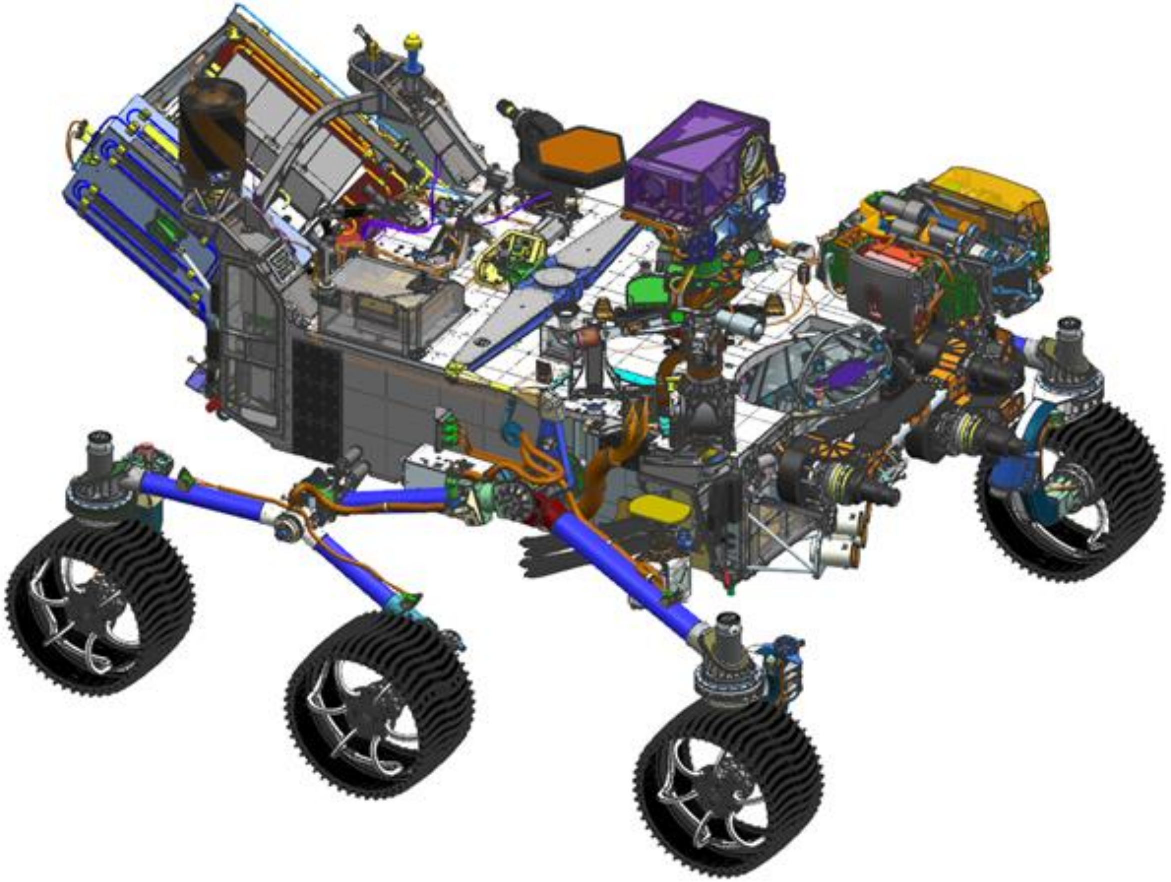
Mars Rover Family: Pathfinder, Spirit/Opportunity, Curiosity, InSight Lander & Mars 2020 Rover Project Duration

Sequence of Thermal Testing Profile for Mars Projects



Ref.: Rajeshuni Ramesham, Justin N. Maki, and Gordon C. Cucullu, Journal of Microelectronics and Electronics Packaging (JMEP), Vol. 6, No. 2, Quarter 2, 2007, pp: 125-134.

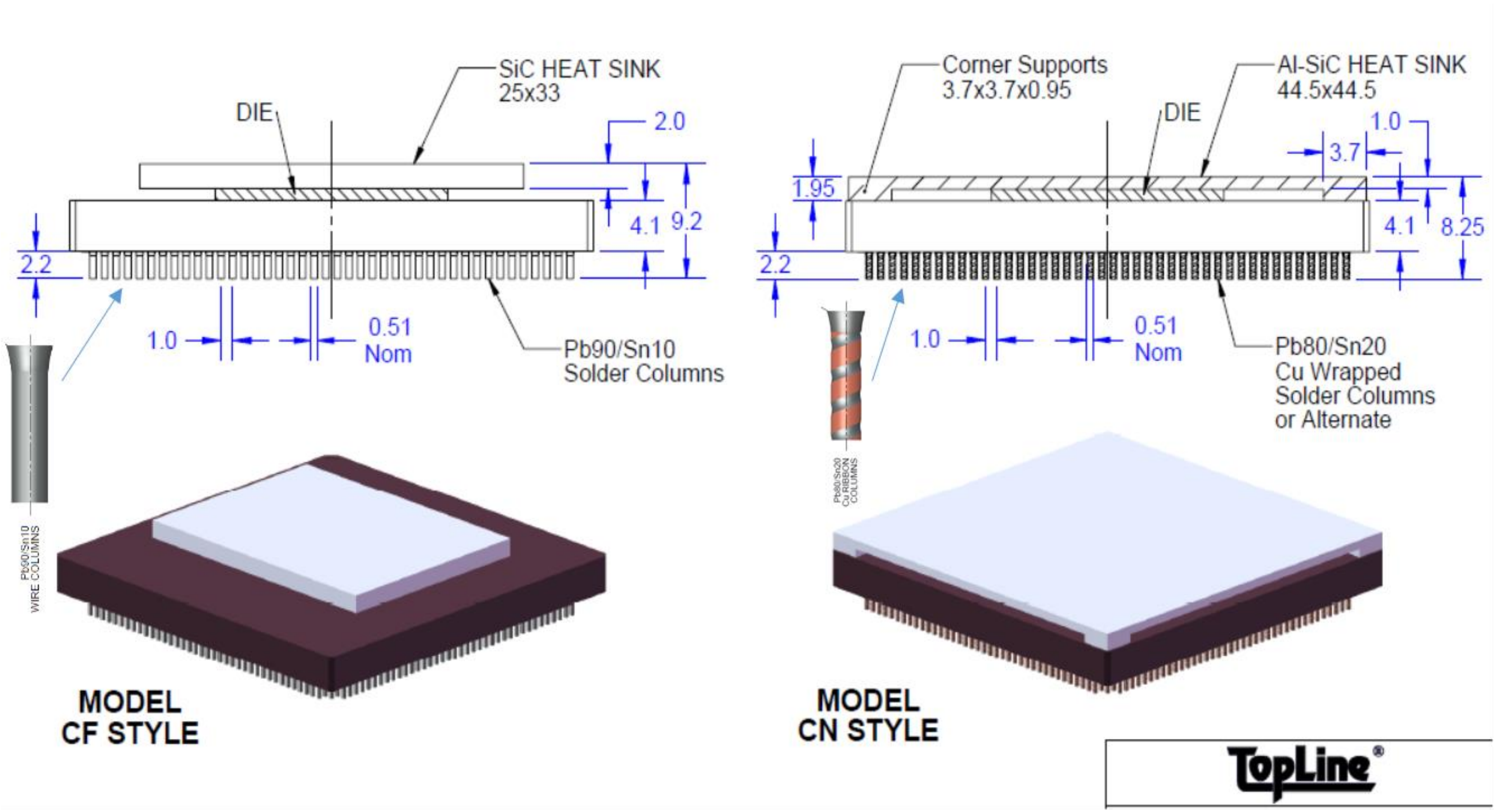
Rover Avionics and Payload Instruments: Thermally Uncontrolled and Controlled Hardware in Harsh and Benign Thermal Environments



Challenges in Thermal Cycling Environment of NASA Missions

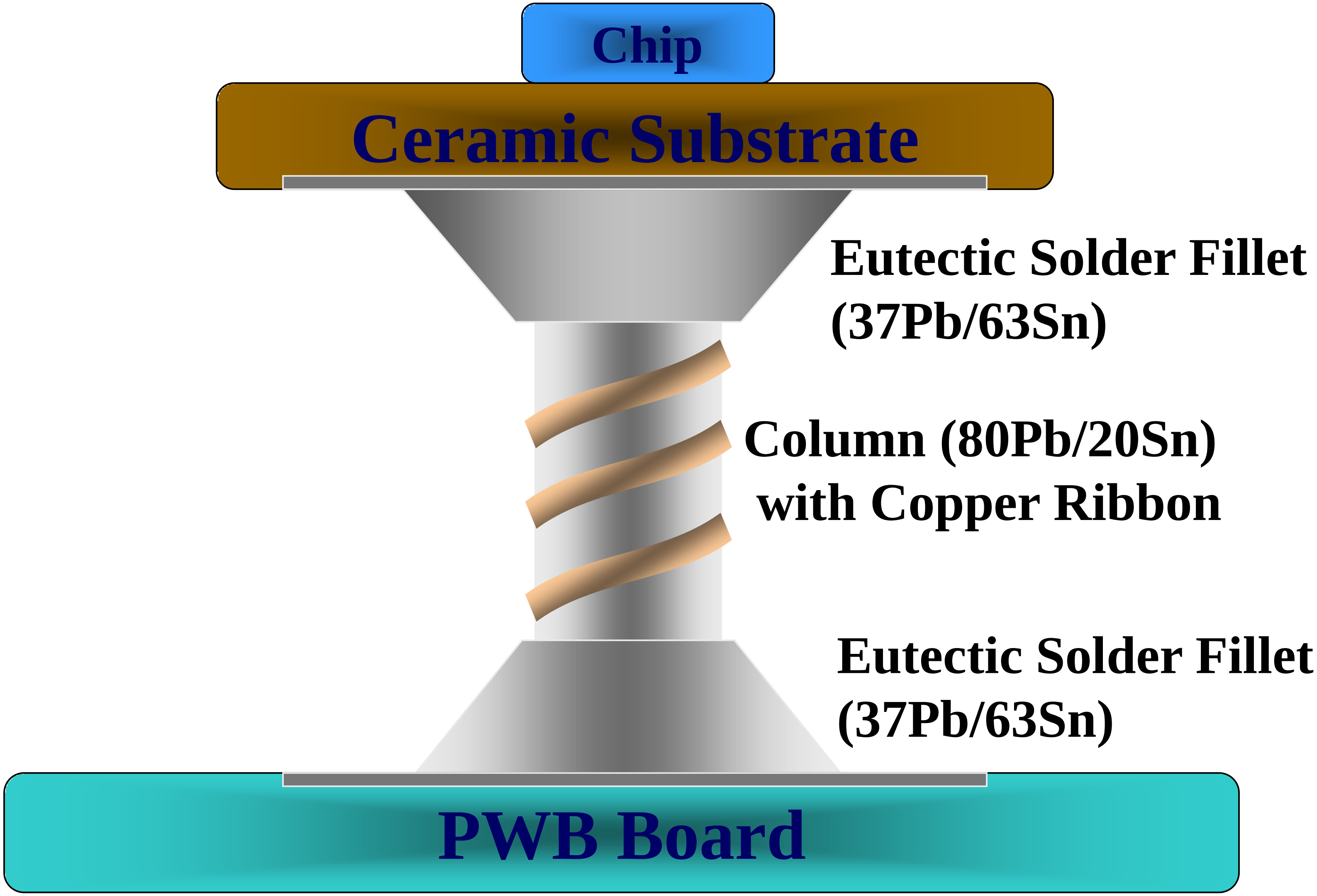
- The following will be experiencing severe thermal cycling environments.
    - Mars 2020 Rover.
    - Mars Helicopter Concept.
    - InSight lander.
    - Planned Europa Orbiter and Europa Lander Concept
- The following are experiencing severe thermal cycling environments.
    - MSL Curiosity Rover
    - MER Rovers (Spirit and Opportunity)
    - Phoenix lander
    - MRO/Mars Odyssey orbiters

Comparison of CCGA 1752 in CF and CN Versions

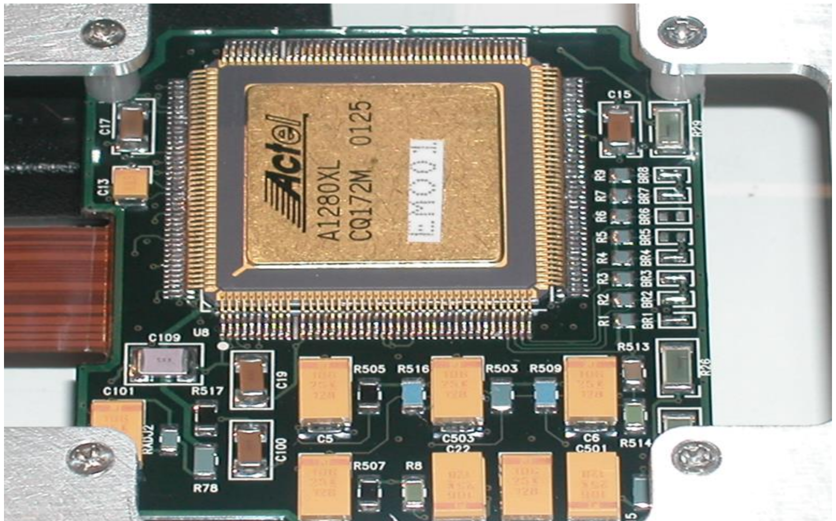


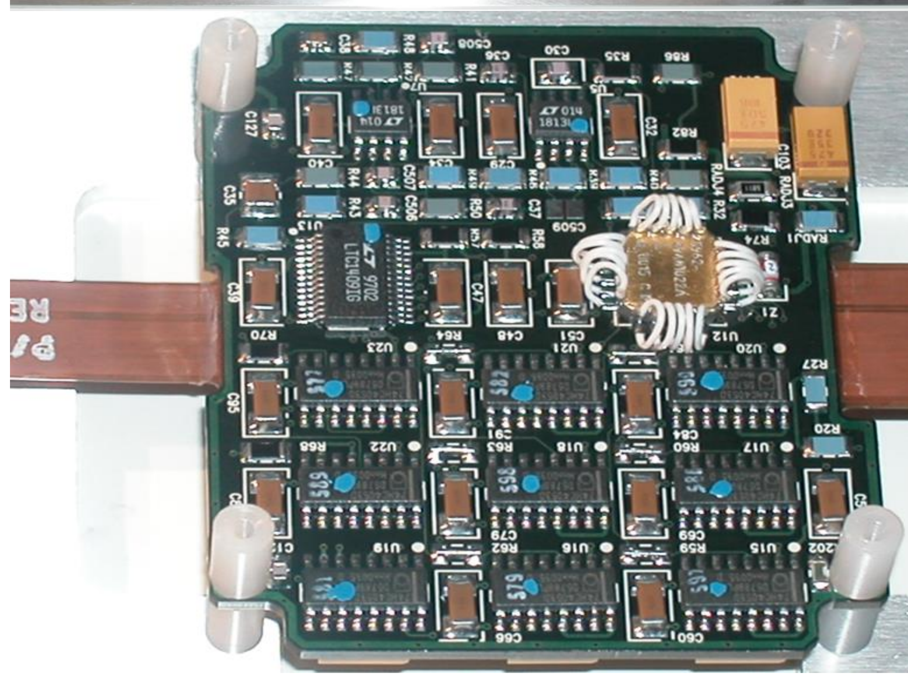
Ref: Topline schematic

CCGA Schematic



Electronics Assembly for MER (-120ºC to +85ºC)

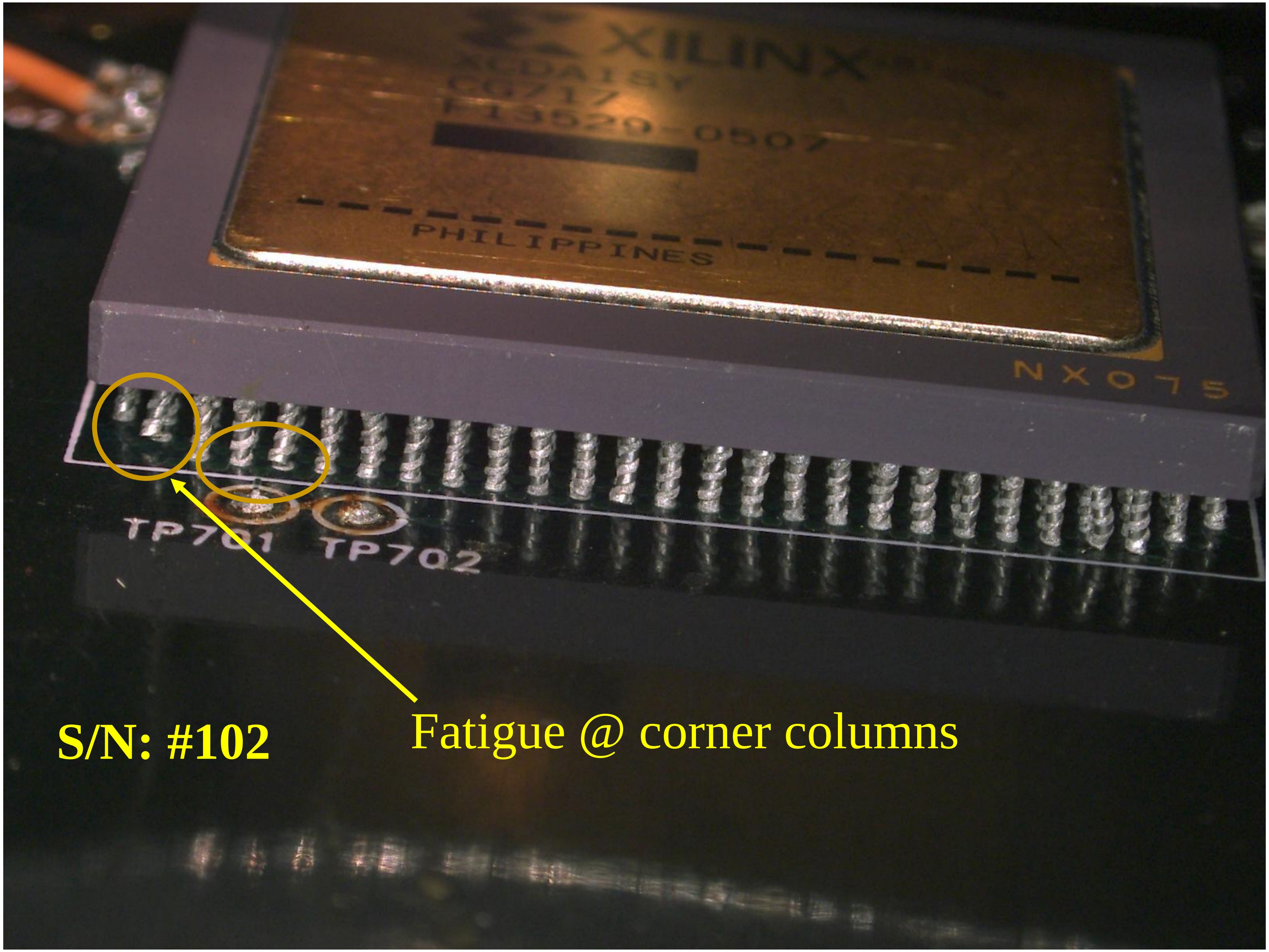




Ref.: Rajeshuni Ramesham, Justin N. Maki, and Gordon C. Cucullu, Journal of Microelectronics and Electronics Packaging (JMEP), Vol. 6, No. 2, Quarter 2, 2007, pp: 125-134.

717 CCGA Package

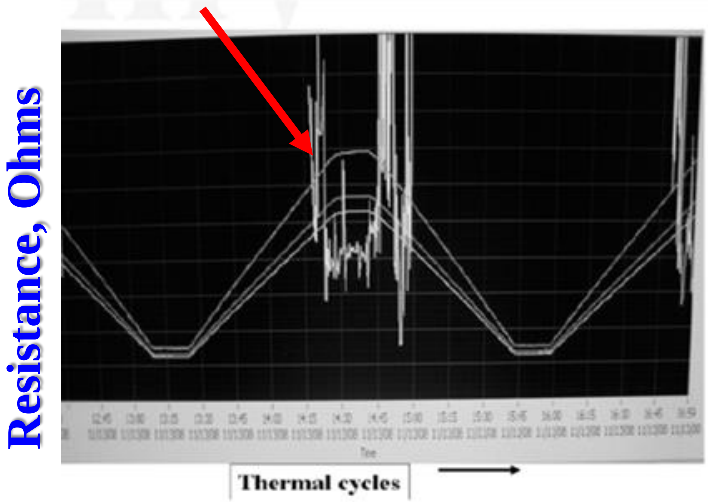
- Pad pitch: 1.27 mm (~51 mil)
- Diameter of the column: ~22 mil
- Solder fillet material: Pb37/Sn63
- Melting point: ~183^{o}C
- Column material: 80%Pb and 20%Sn
- Melting point: ~280^{o}C
- Copper spiral around column to enhance the integrity of column during reflow of solder

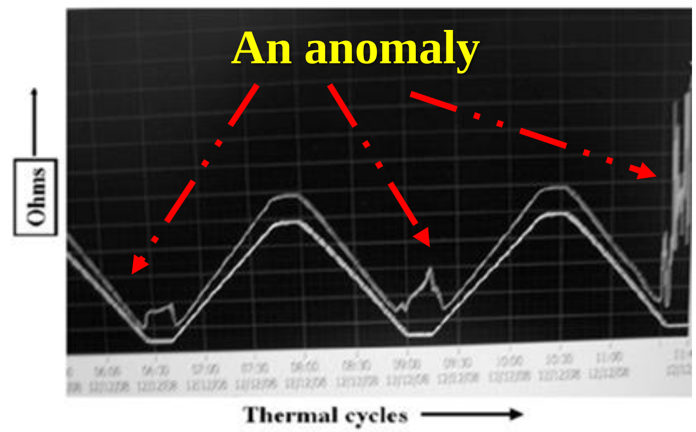


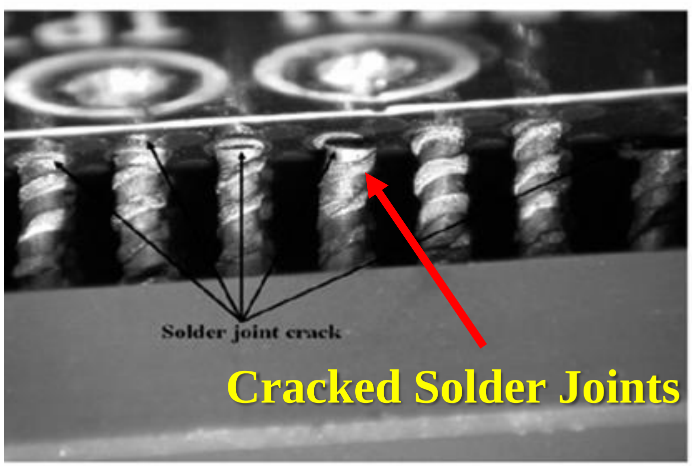
Ref.: Rajeshuni Ramesham, Journal of Microelectronics and Electronics Packaging, 2010, 7, pp: 1-9

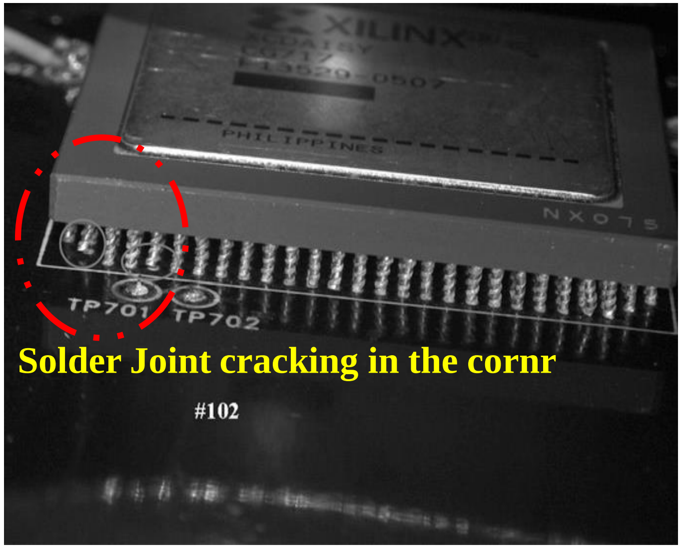
Failed CCGA Package vs. Thermal Cycling

Intermittent Failure



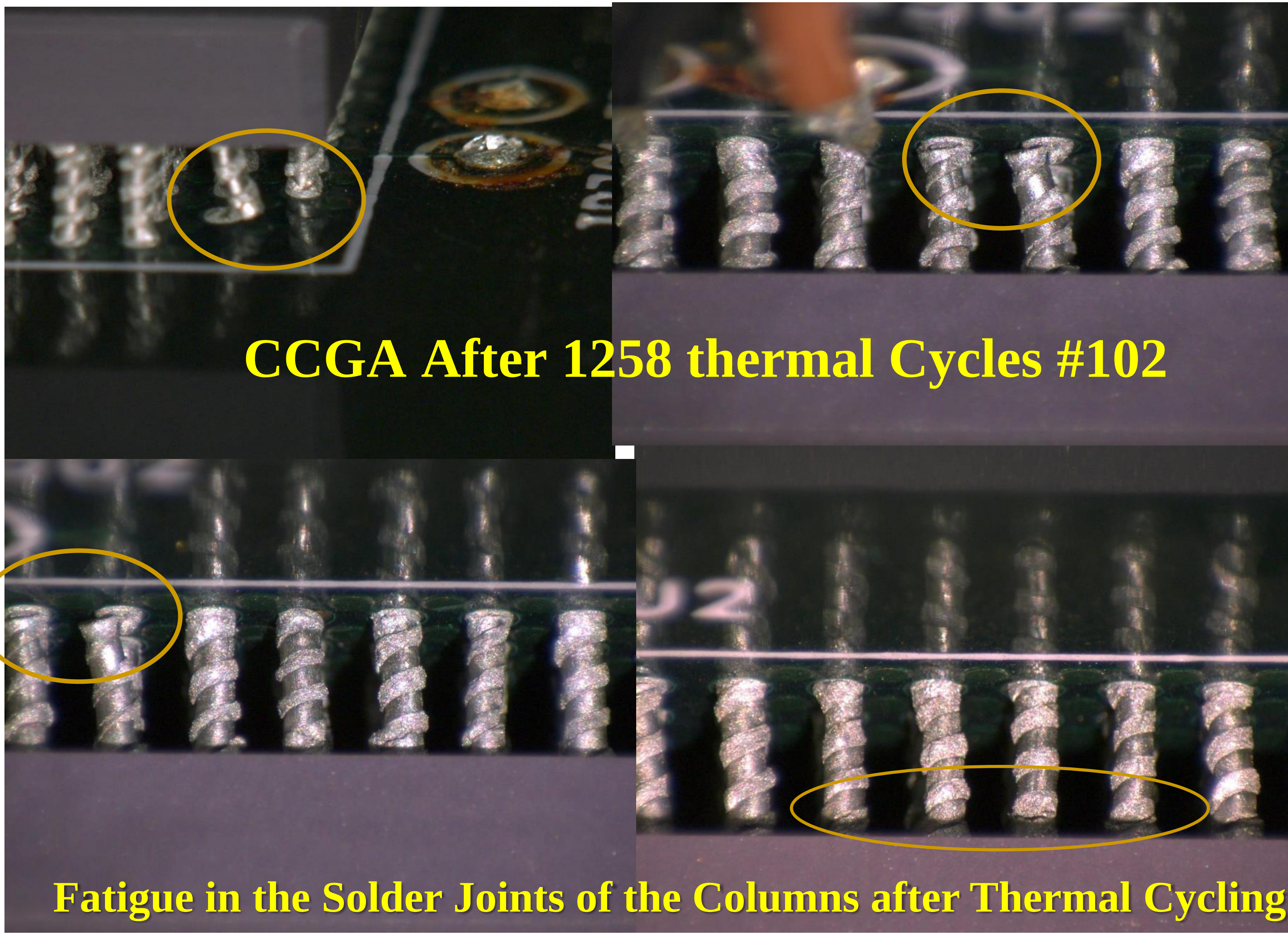






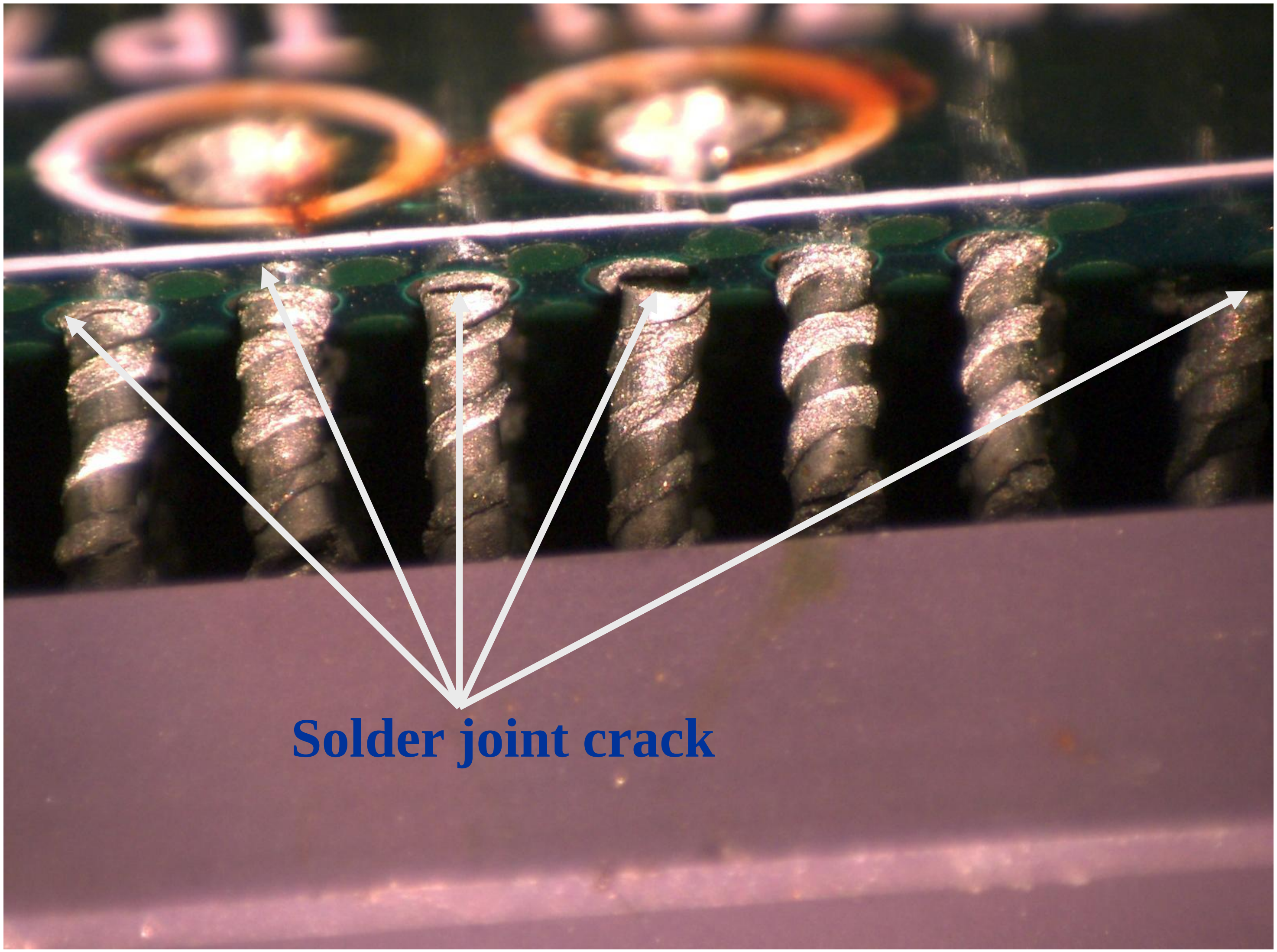
Ref.: Rajeshuni Ramesham, "Reliability of CCGA Interconenct…" J. Microelectronics and Electronics Packaging, Vol 7, No.1, 2010

CCGA After 1258 thermal Cycles #102

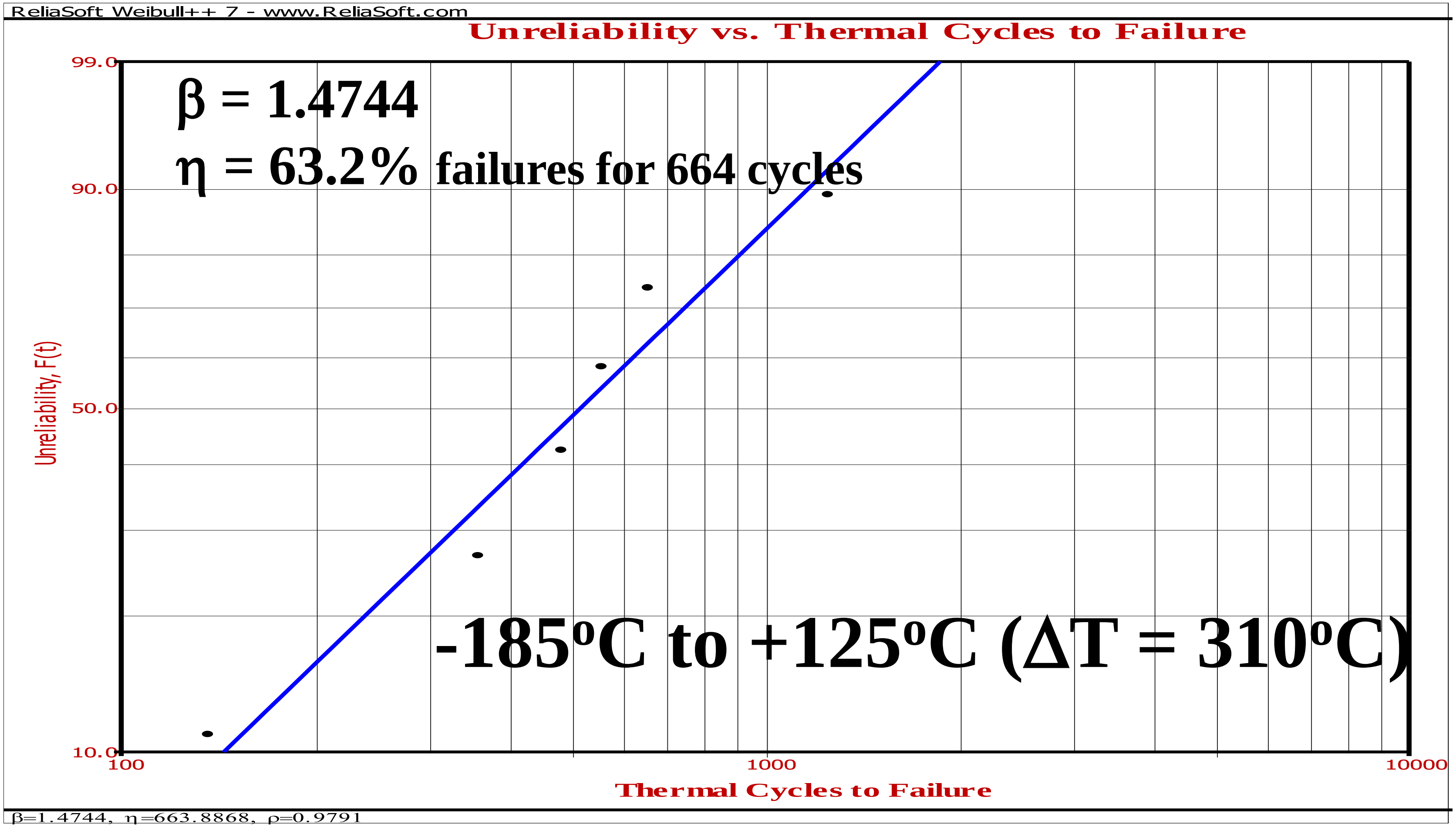


Fatigue in the Solder Joints of the Columns after Thermal Cycling

Solder Joints Associated with CCGA Columns



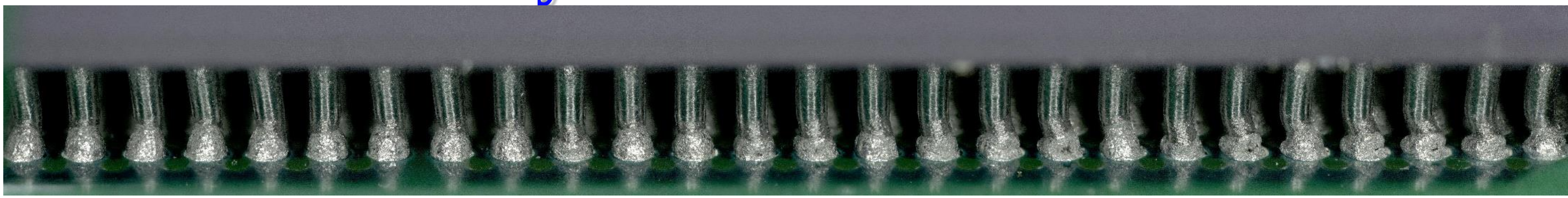
Ultra reliability vs., Thermal Cycles

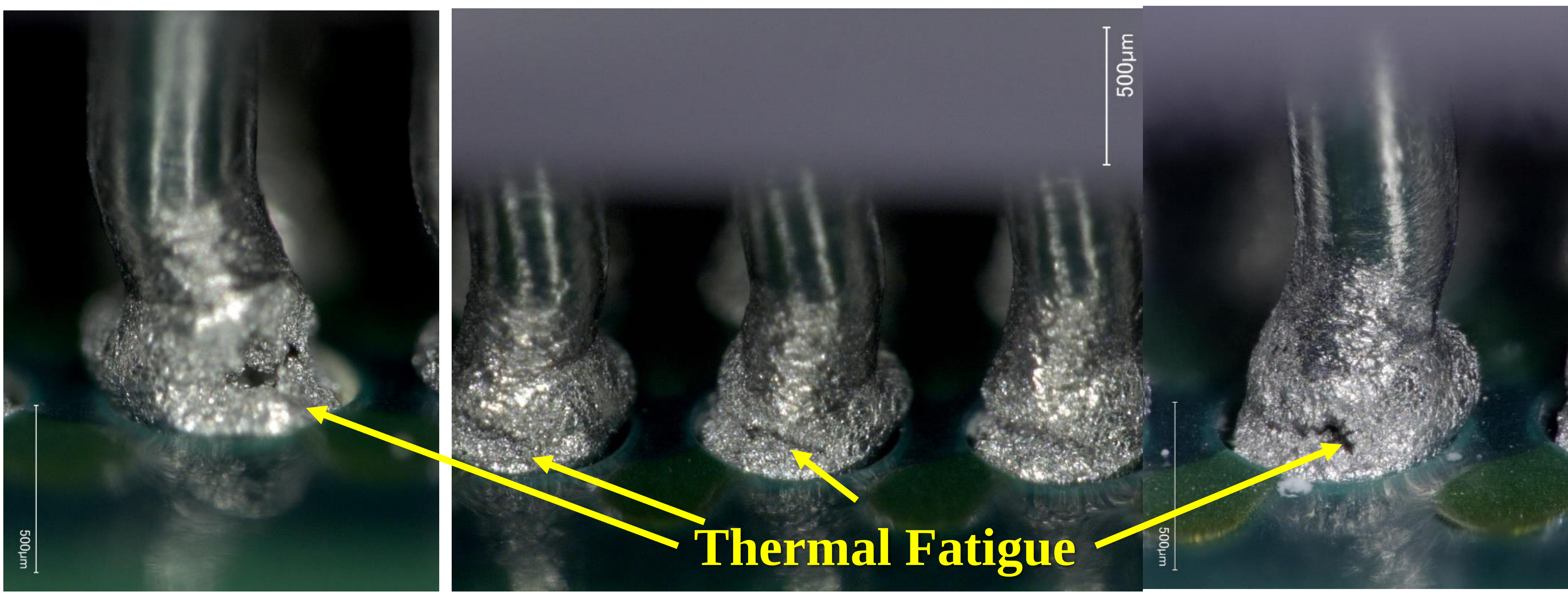


Thermal Cycles to Failure

Ref.: Rajeshuni Ramesham, Journal of Microelectronics and Electronics Packaging, 2010, 7, pp: 1-9

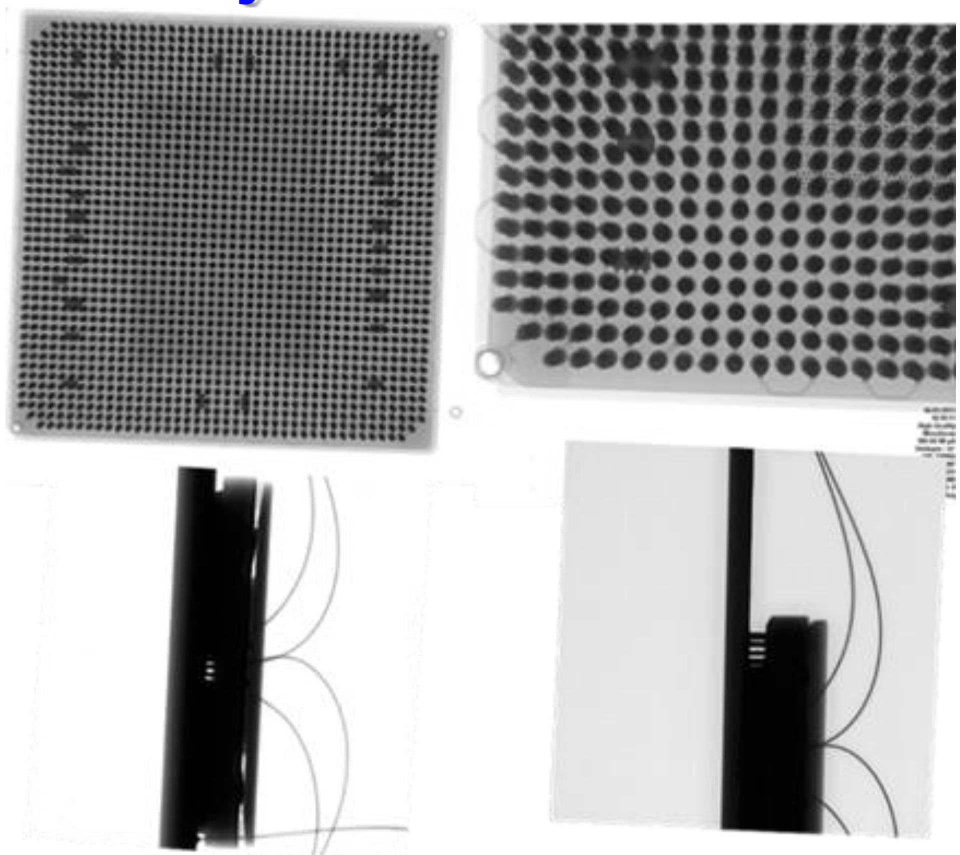
Virtex-5 CCGA
Package CF Version
492 Cycles -55ºC to +100ºC





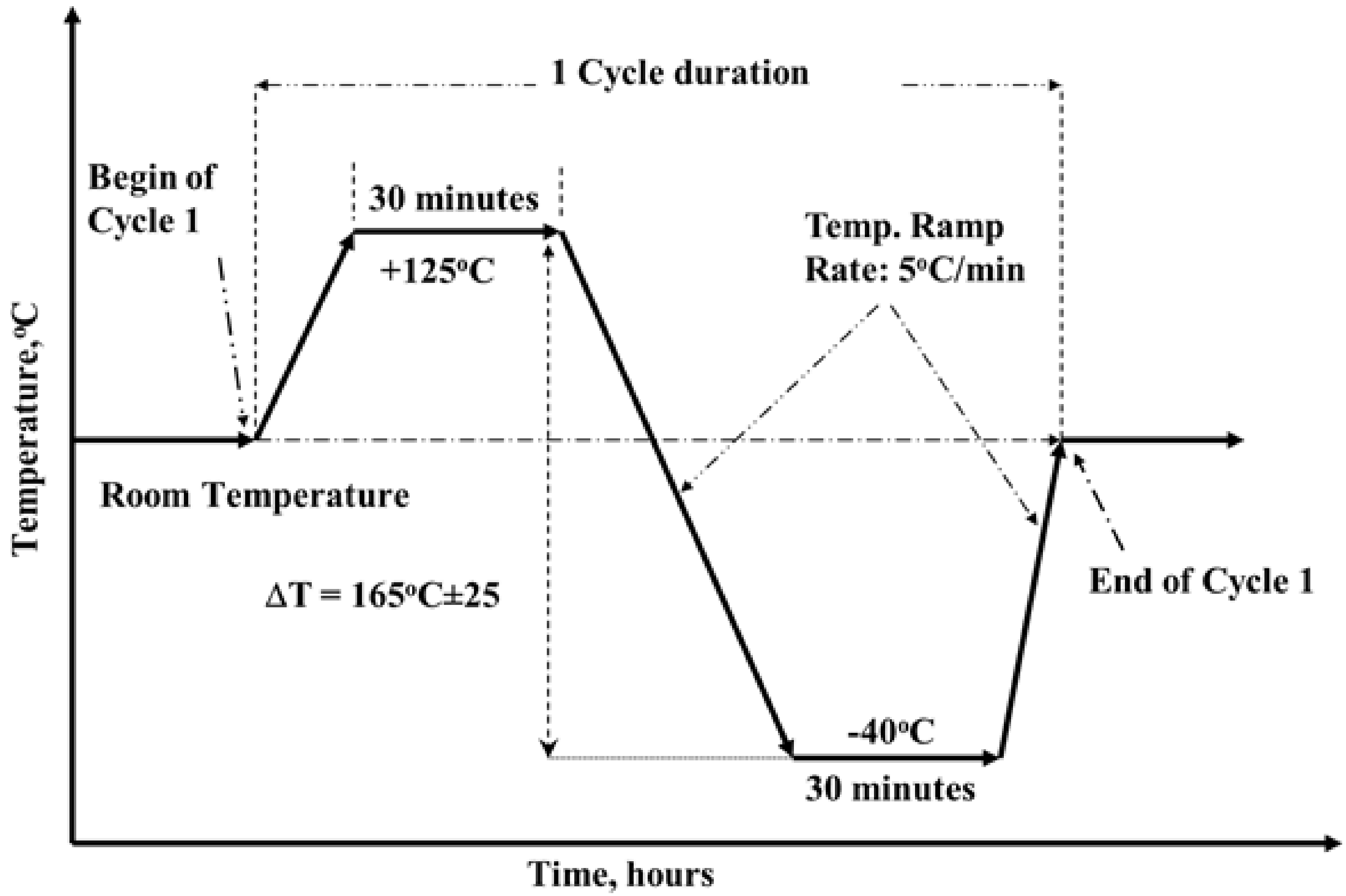
2 Test Coupons, Daisy-chain components, tested for NASA Cycles (-55C to +100C)

X-Ray Image of the CCGA 1752 Daisy-Chain Test Board



No internal shorts are seen qualitatively in the x-ray image

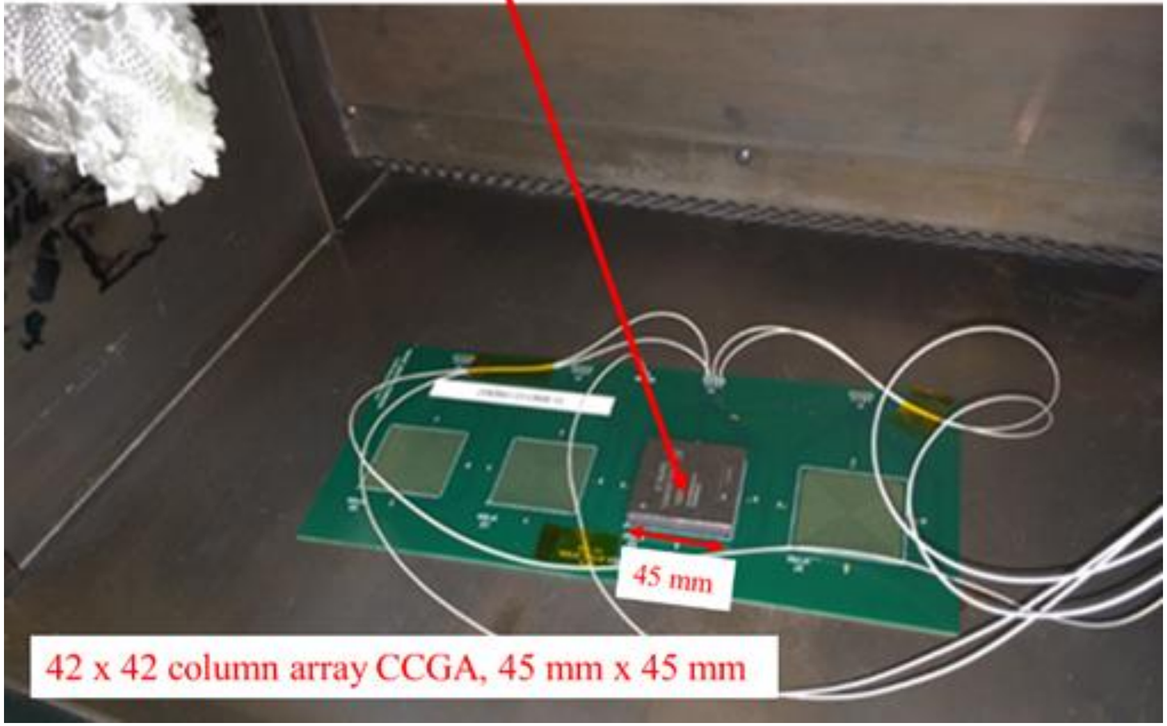
Temperature Thermal Cycling Profile Used in This Study



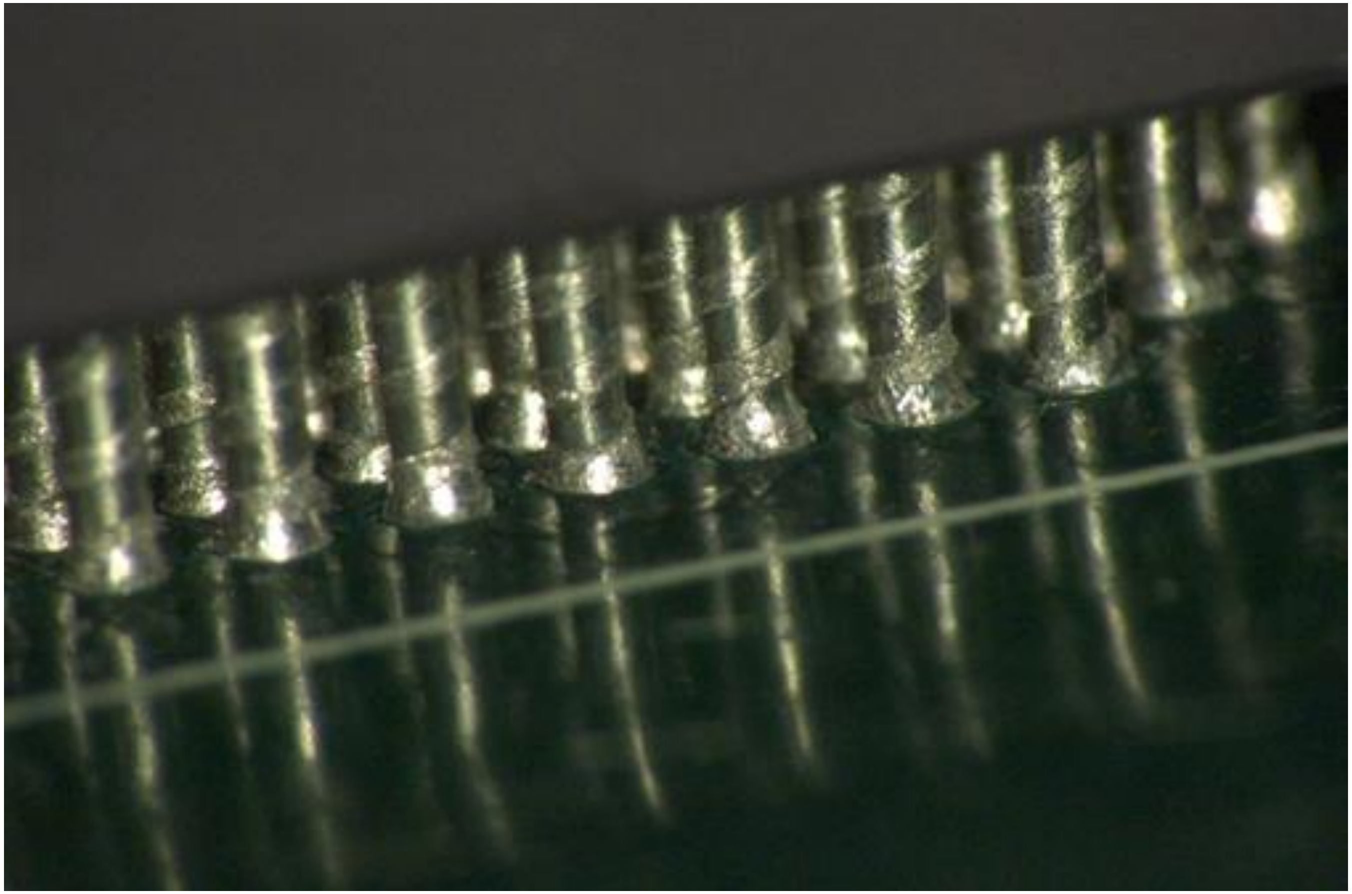
Ram

CCGA 1752 Advanced Package

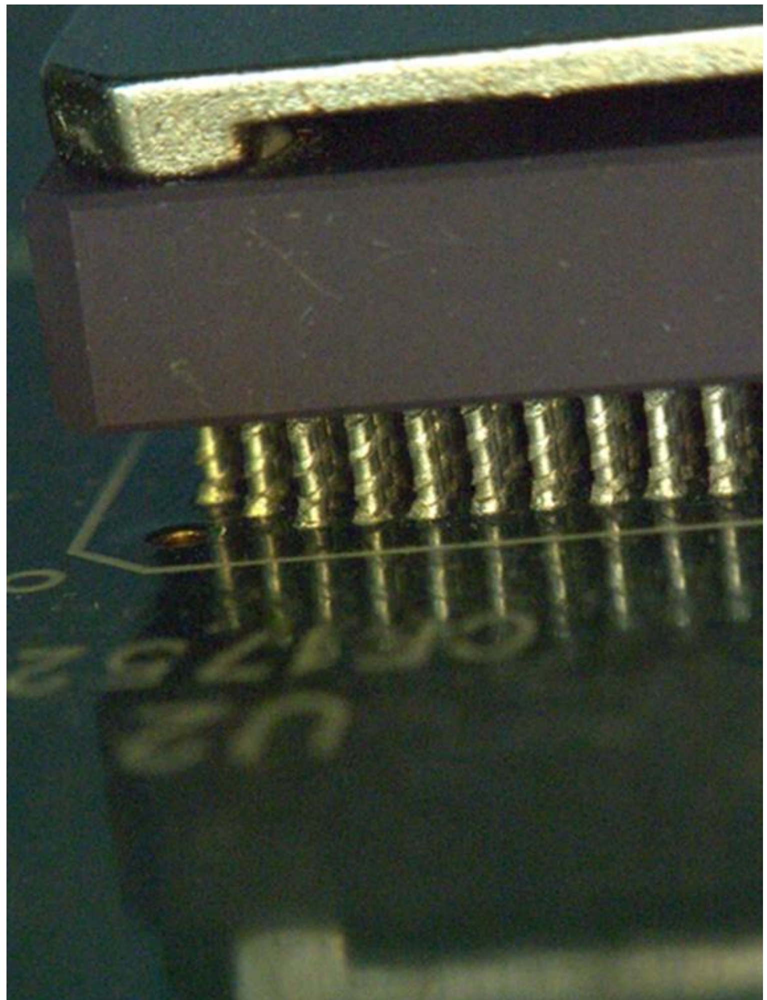
CCGA 1752 Package Test board



Optical Image of the CCGA 1752 Packages after 623 Thermal Cycles



CCGA 1752 Packages after 1460 Thermal Cycles at a Corner



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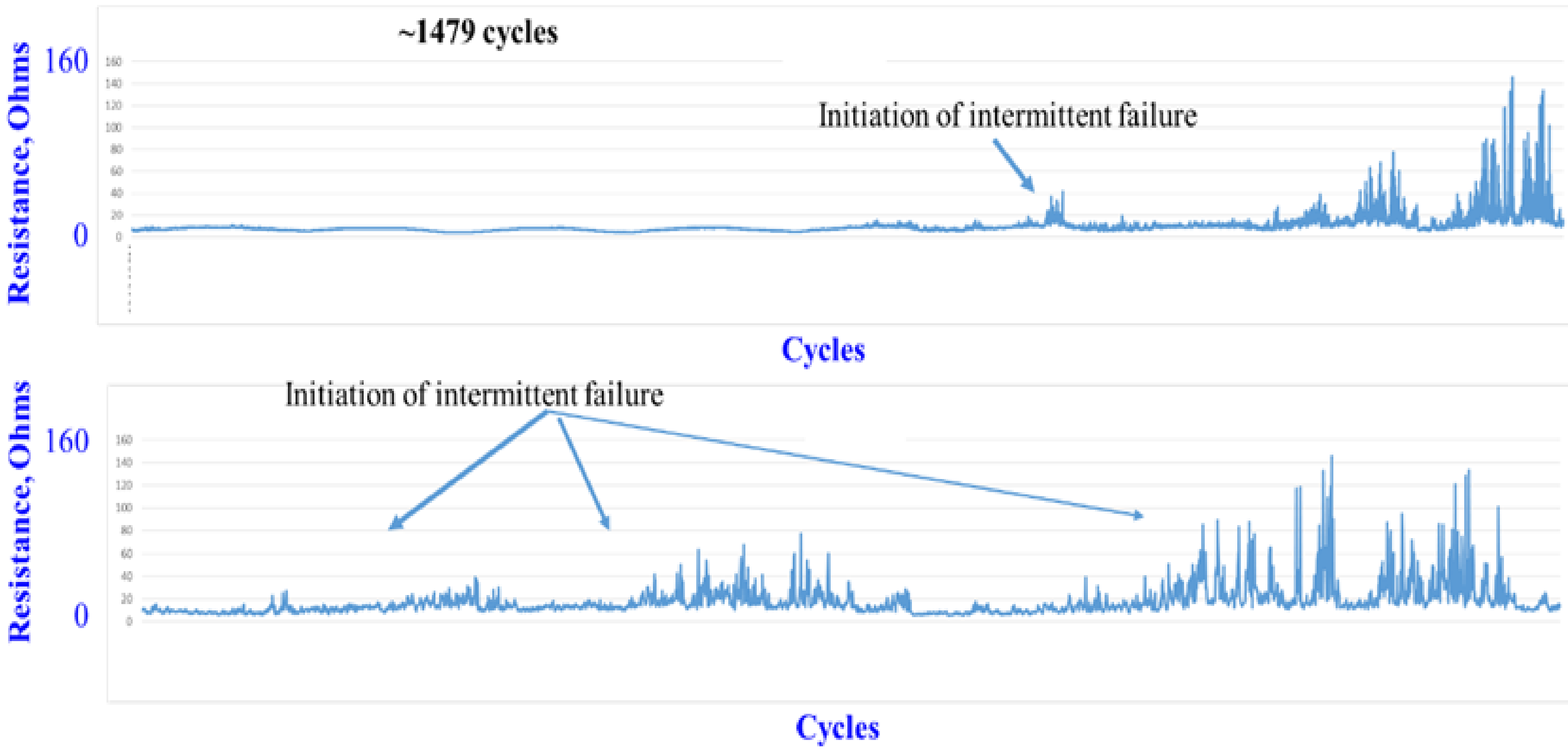
Daisy-Chain Resistance vs. Temperature during Thermal Cycling around 1479th Cycle



 Ram

Daisy-Chain Resistance vs. Temperature during Thermal Cycling Around 1479th Cycle

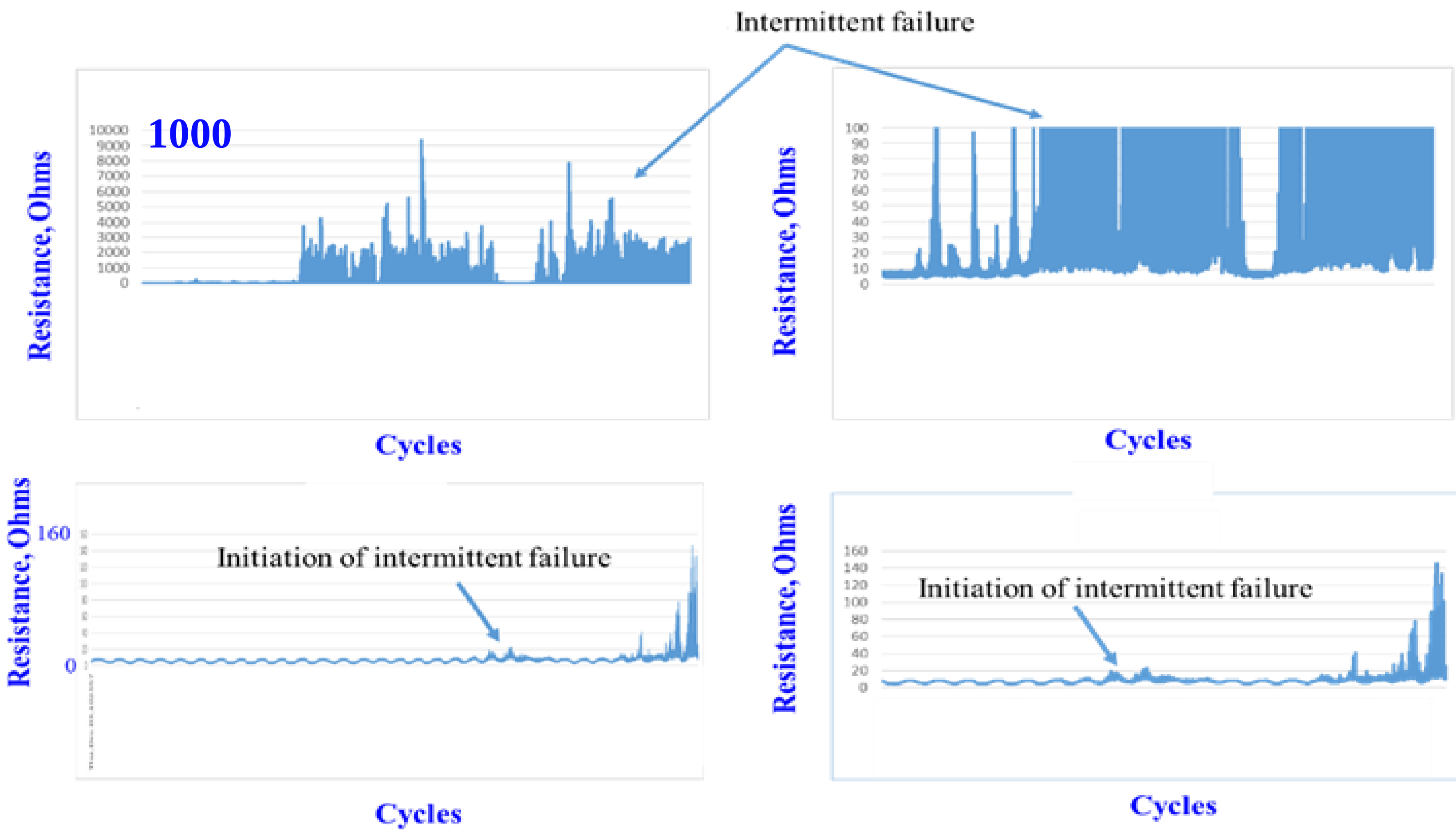
Resistance, Ohms

Cycles

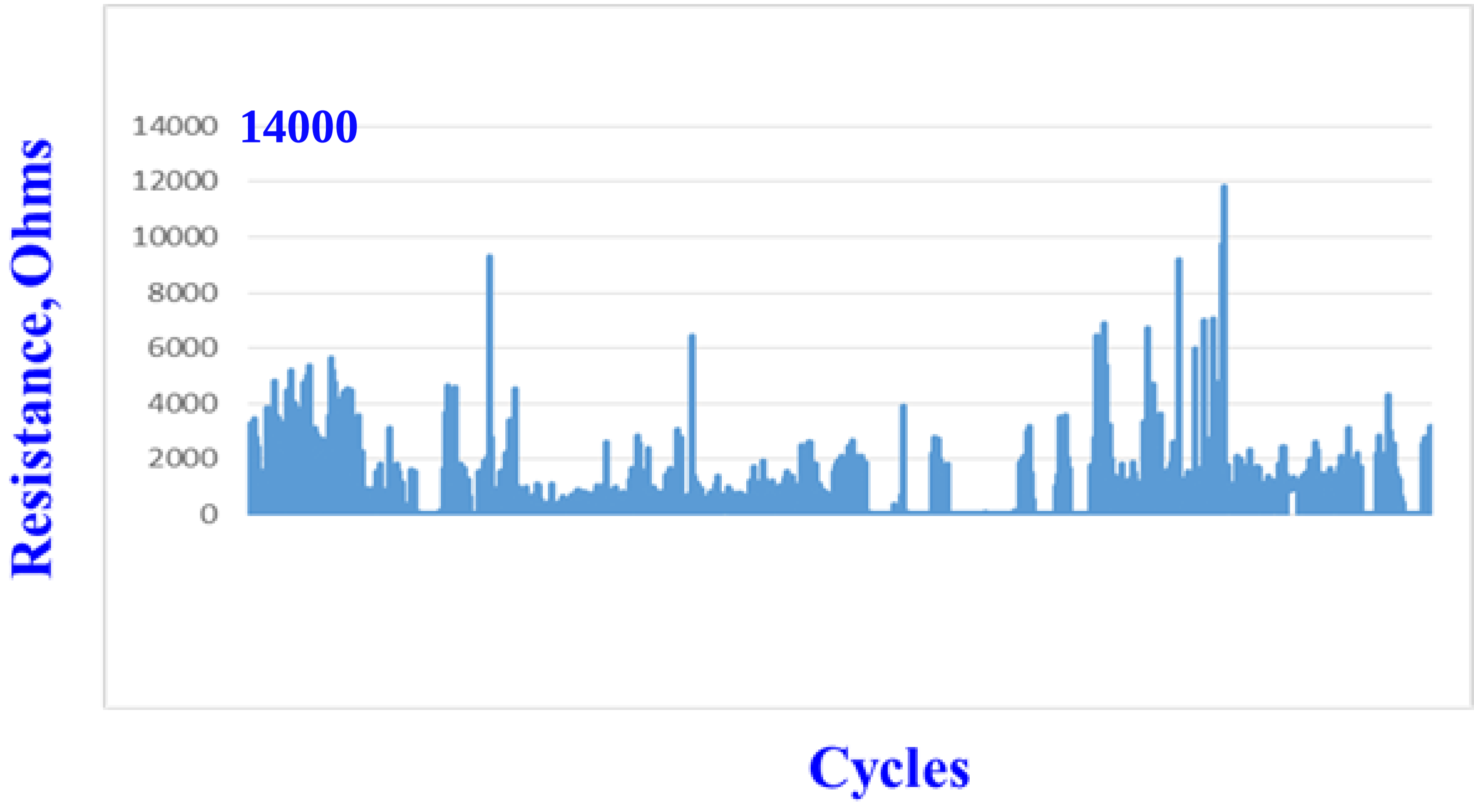
Resistance, Ohms

Cycles

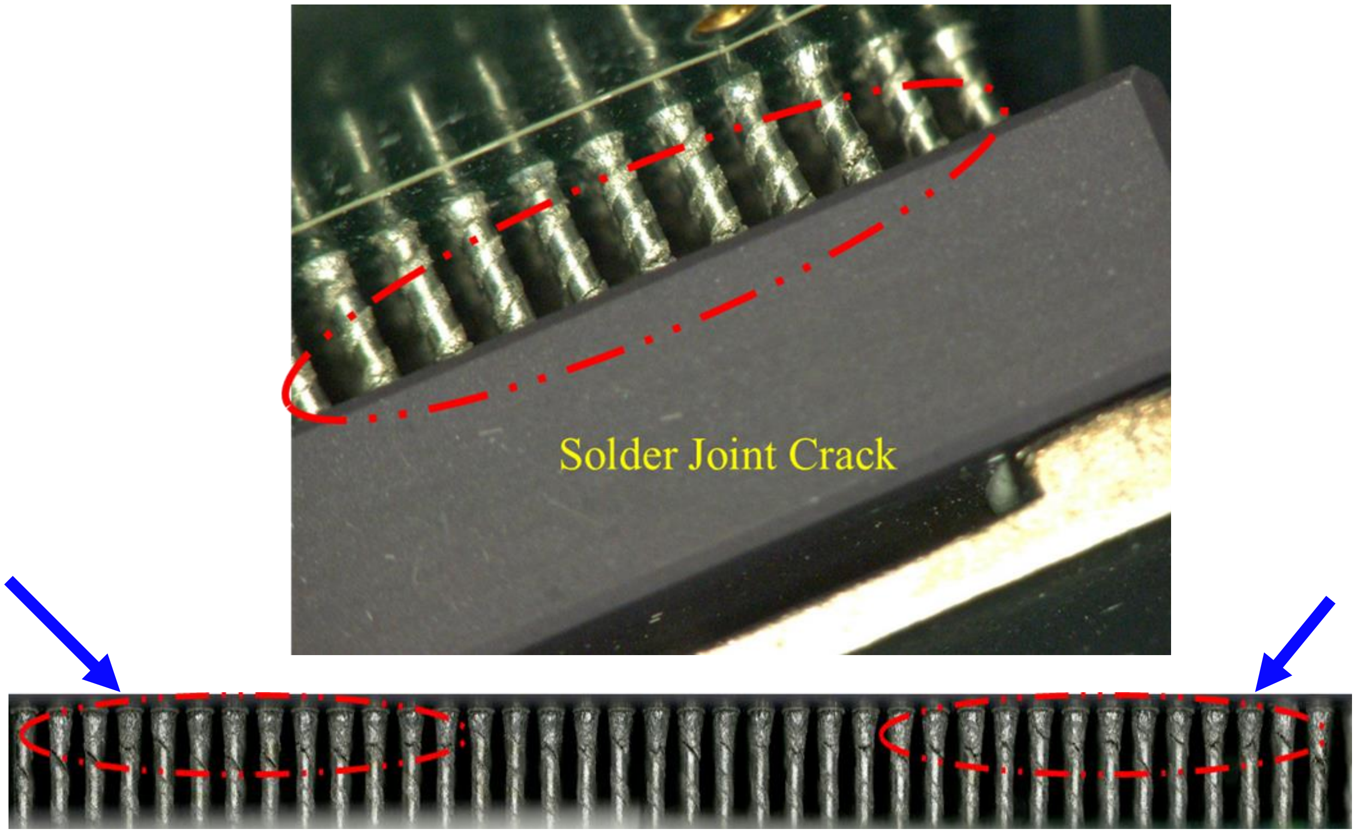
Daisy-Chain Resistance vs Material. The First Failure Was Observed During Thermal Cycling around 1479th Cycle



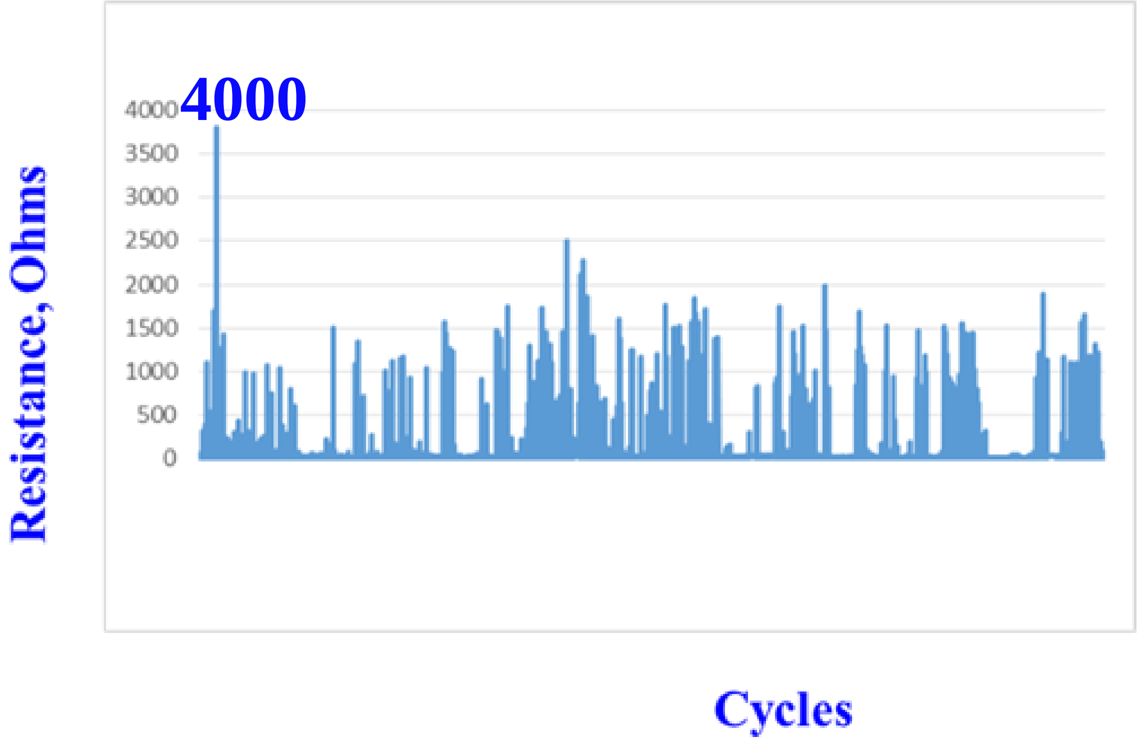
Resistance vs. Time around 1479th Thermal Cycle



CCGA 1752 Packages after 2500 Thermal Cycles (Fatigue at a Corner)



Resistance vs. Time Around 2500 Thermal Cycles



Conclusions

- Many challenges and issues were observed during various projects which have been addressed to minimize the risk.
- Preliminary Experimental long term thermal cycling was performed using a daisy-chain CCGA 1752 CN version hardware for projects to assess reliability by testing to failure.
- First solder joint failure was observed at 1479 thermal cycles for a ΔT of 165°C.
- All the daisy-chains have shown an anomaly associated with solder joints was around 2500 thermal cycles for a ΔT of 165°C.
- Further research is in progress to address various aspects of anomaly.

Acknowledgments

- The research work described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

- Thanks are due to Component Engineering and Assurance Office, Office of Safety and Mission Success, JPL-NASA, Caltech. Thanks are due to Ryan Ross, Dr. Mohammad Mojarradi, Jeremy Bonnell for their review comments.

- Finally, thanks are due to Atul Mehta, Noly A. Neverdia, and Javeck Verdugo for their help during this assessment process.