



M2020/NEPP TCL Evaluation for Electronics Packaging

TCL= Thermal Cycle Life

by

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<http://nepp.nasa.gov>



Outline

- **Electronics Packaging Technologies Evaluation**
 - NEPP : Standard COTS and Advanced New BGAs/CGAs
 - Generic/standard thermal cycle life (TCL) Evaluation
 - M2020 : Standard and Advanced
 - Standard TCL, but short
 - Standard TCL environmental control, but long
 - Specific Martian environment short and mostly long
 - **M2020/NEPP link** via Standard TCL especially instrument/Technology demonstration, knowledge for specific

- **M2020/NEPP TCL Standard Environment**
 - Technology demonstration Control Environment
 - 3D Stack design/part developed under NEPP task
 - Built 5 partially populated assemblies for M2020 funded by project
 - Subject to TC standard environmental requirement
 - TC results for single- and double-sided assemblies
 - Fully populated assemblies under NEPP task

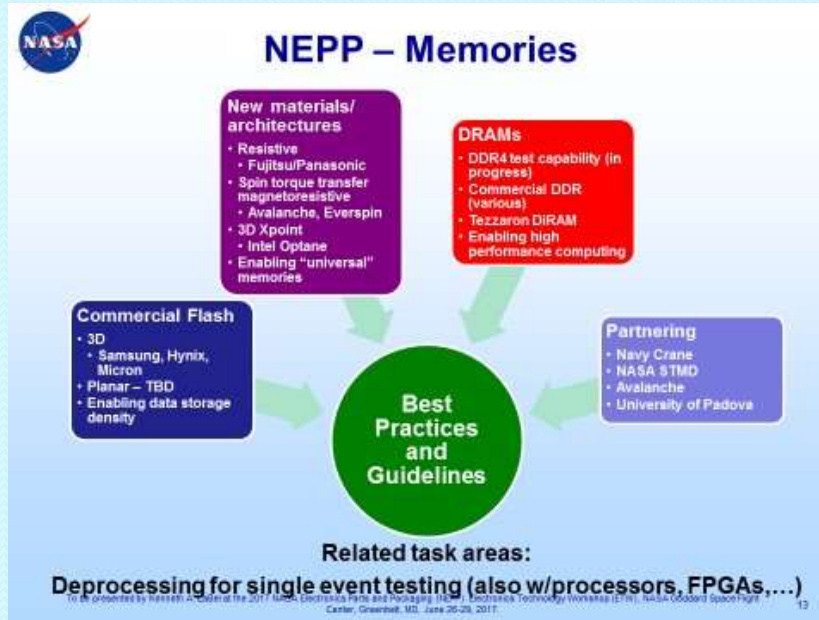
- **Unique Martian Environment**
 - PGA, first attempt & physics of failure (PoF) under extreme cold TC
 - Pin height increase and PoF under extreme cold TC
 - Author's proposed robust approaches via bonding & test verification

- **Summary**

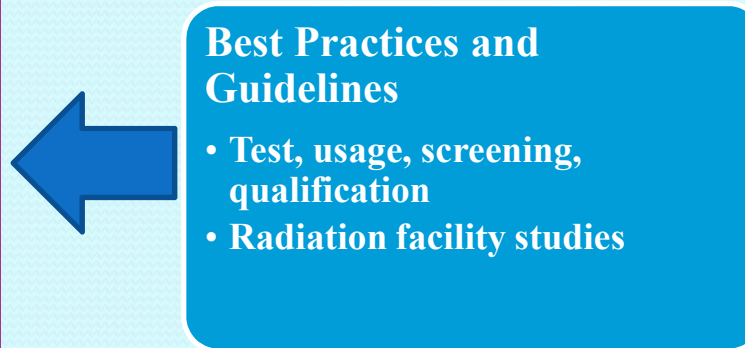


NEPP TCL & Guidelines

Electronics Packaging Evaluation



Test Results
on
NEPP
Website





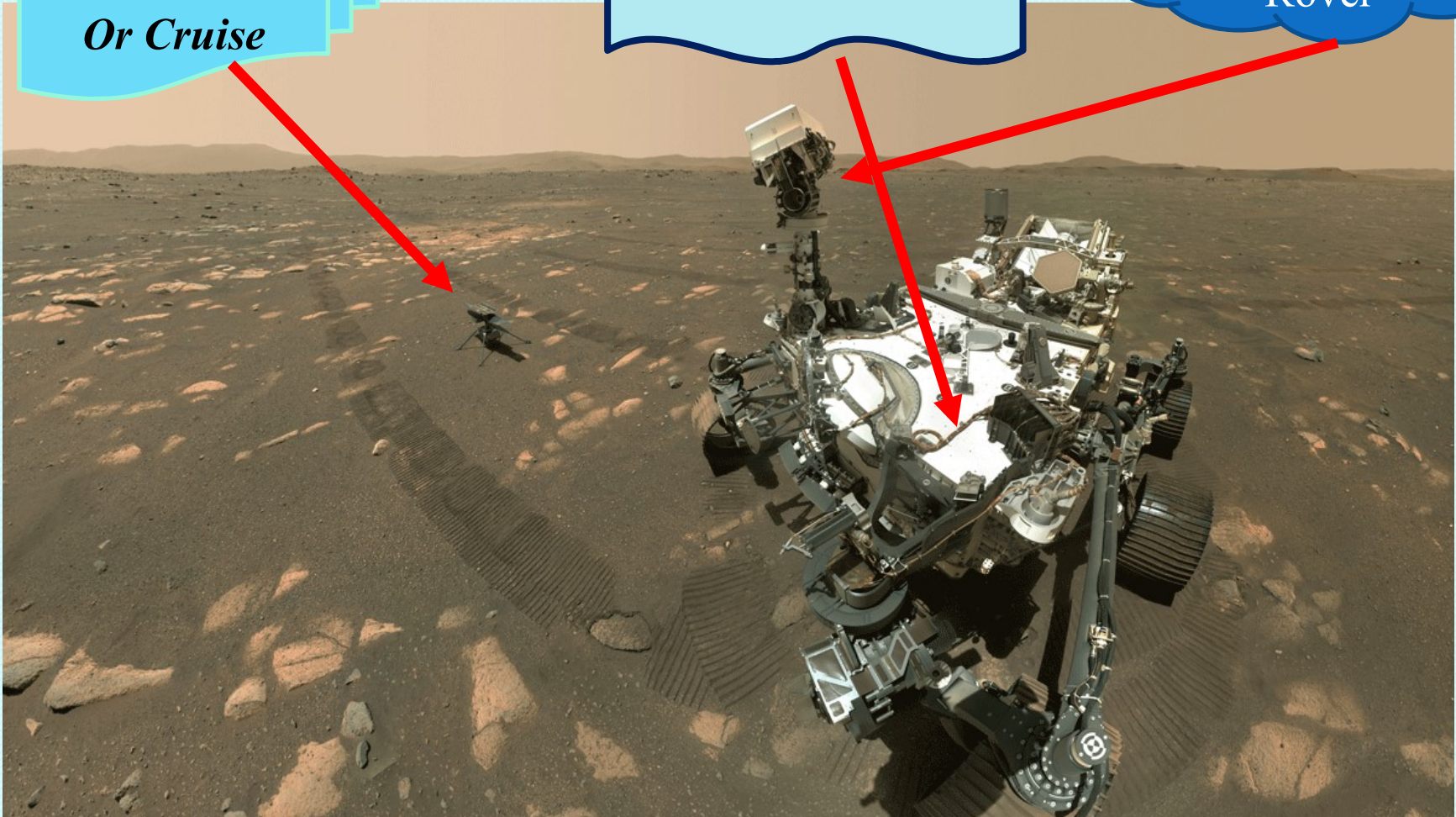
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M2020 TC Environment

*Technology
Demonstration
Or Cruise*

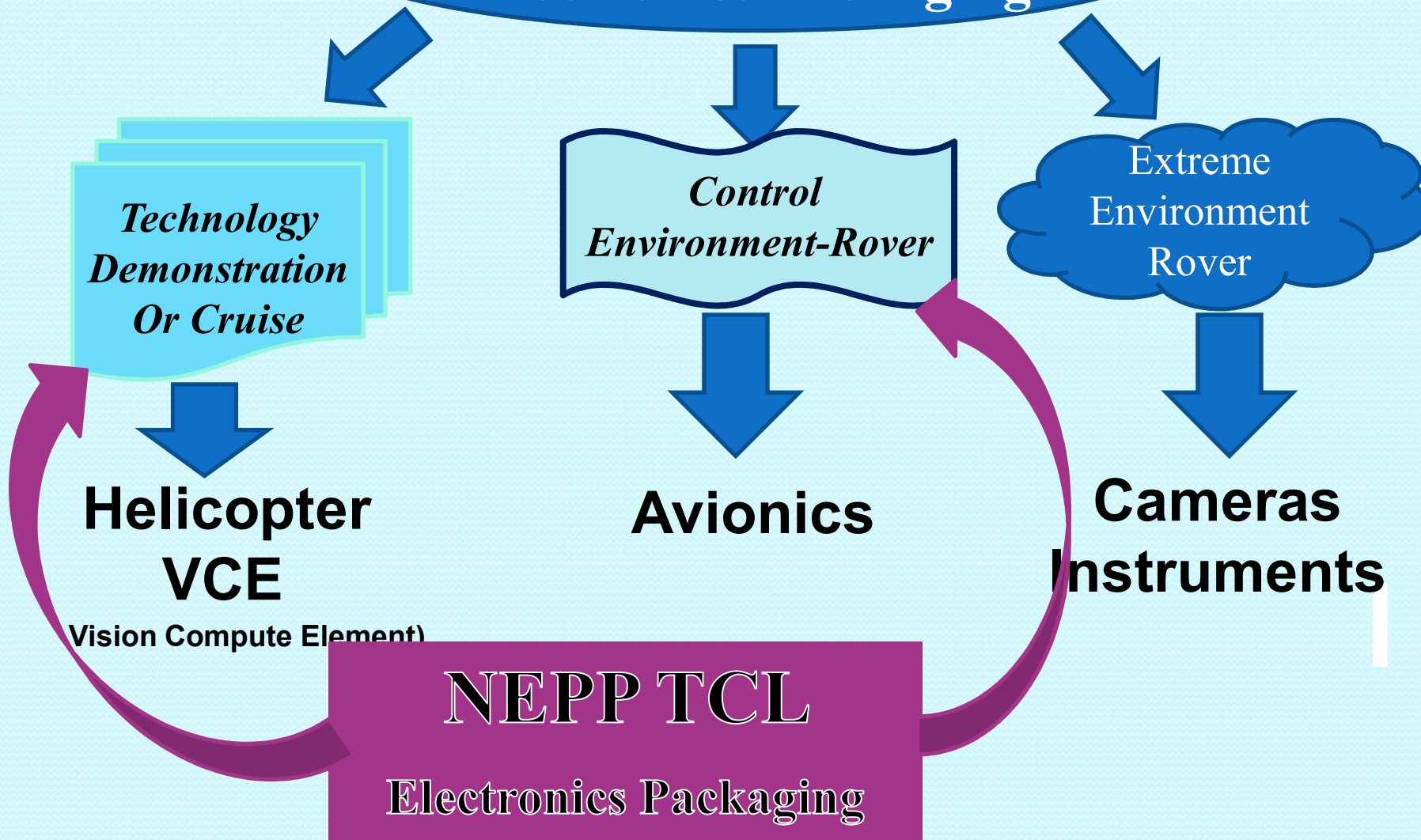
*Control
Environment-Rover*

Extreme
Environment
Rover



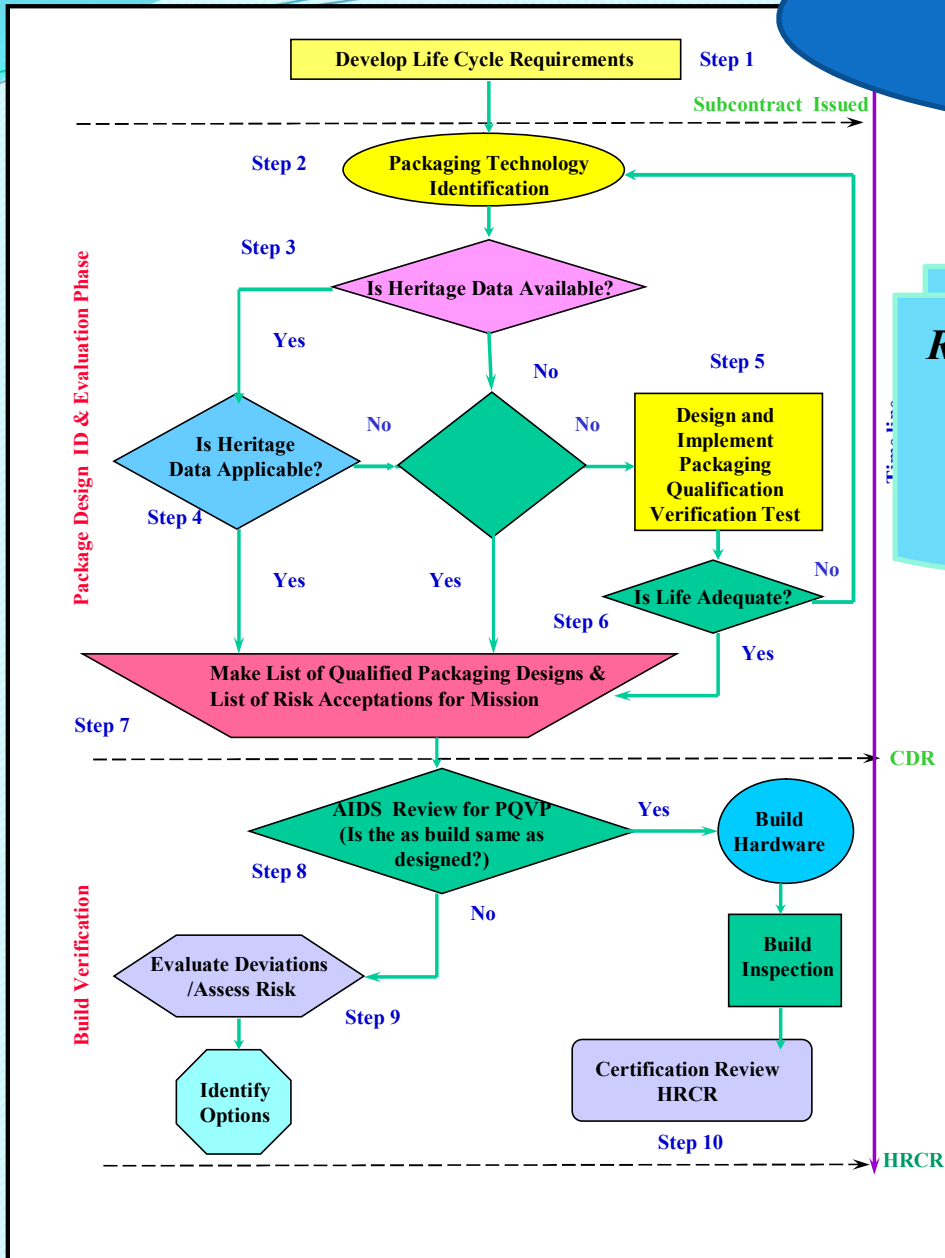


M2020 TCL for Electronics Packaging





M2020 TCL/PQV Process Flow Review/Test



*Review If Testing
Required
Technology
Demonstration Or
Cruise*

*Review for Heritage
Control Environment-Rover*

*Review for
Heritage & Modify
Extreme Environment
Rover*

PQV Team
Parts, Packaging
Reliability, QA
CogE



M2020 TCL/PQV Review Results

*Review If Testing
Required
Technology
Demonstration Or
Cruise*

*Review for Heritage
Control Environment-Rover*

Review for
Heritage &
Modification
Extreme Environment
Rover

Helicopter VCE

Avionics

Cameras Instruments

- ❖ MSL + New Pkg
- ❖ Standards
- ❖ Connector Interface
- ❖ BGA Memory

- ❖ NEPP Design/Pkg

- 1.5 TCL of MSL
- Review- All MSL Hardware
- 2 Modified-No test
- 5 TCL tested
- 4 Passed
- 1 Modified/3 approaches
- Re-tested
- Implement modification

- NEPP CGA data for mod

- ✓ MSL + New Pkg
- ✓ Modified > 20 Pkg
- ✓ Cameras: New
- ✓ TCL>1000 Cycles
- ✓ Re-modification

- ✓ NEPP Knowledge

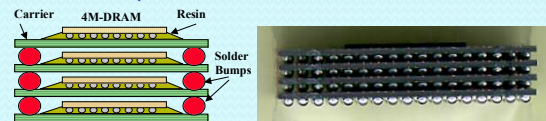


Conventional 3D Packaging Technologies

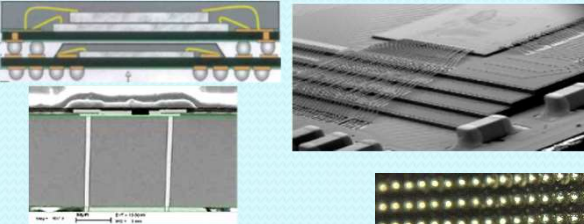
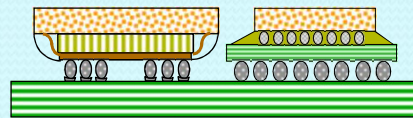
Area Arrays

Leads

PoP (Stack BGA/CSP/TMV)

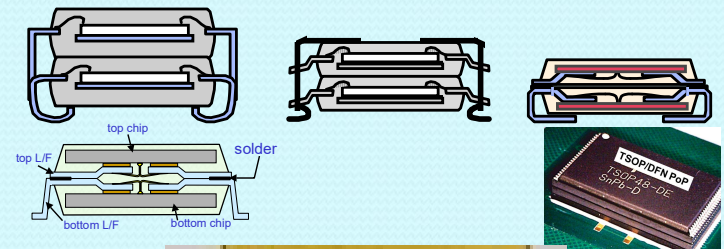


PiP -Stack Die/MCP

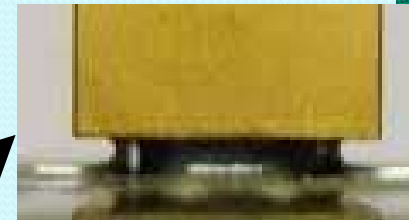


Leaded

Mix



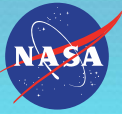
3D Stack BGA and Lead



- High I/Os
- Heat dissipation
- Large die, Warpage, Reliability?
- Assembly Robustness

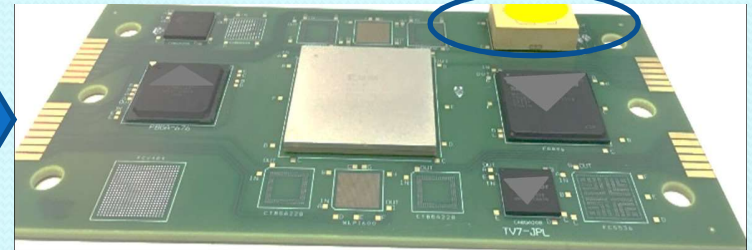
Array: Good Self Alignment

- Low I/Os
- Conventional Assembly
- Heat Dissipation ?
- Reliability?



3D Stack BGA M2020 & NEPP

- PCB designed under NEPP
- Test matrix covered 3D Stack & BGA daisy-chain
- M2020 VCE required TCL evaluation
 - Funded to build 5 assemblies, one double-sided
 - HASL surface finish, SnPb Solder Paste
 - Thermal cycle, TC= (-55°C/100°C)

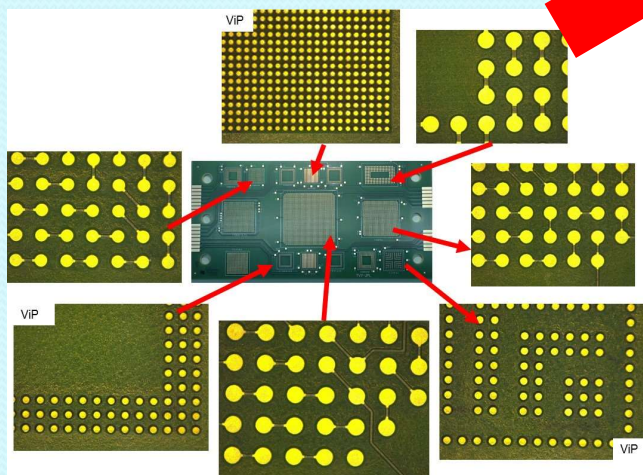
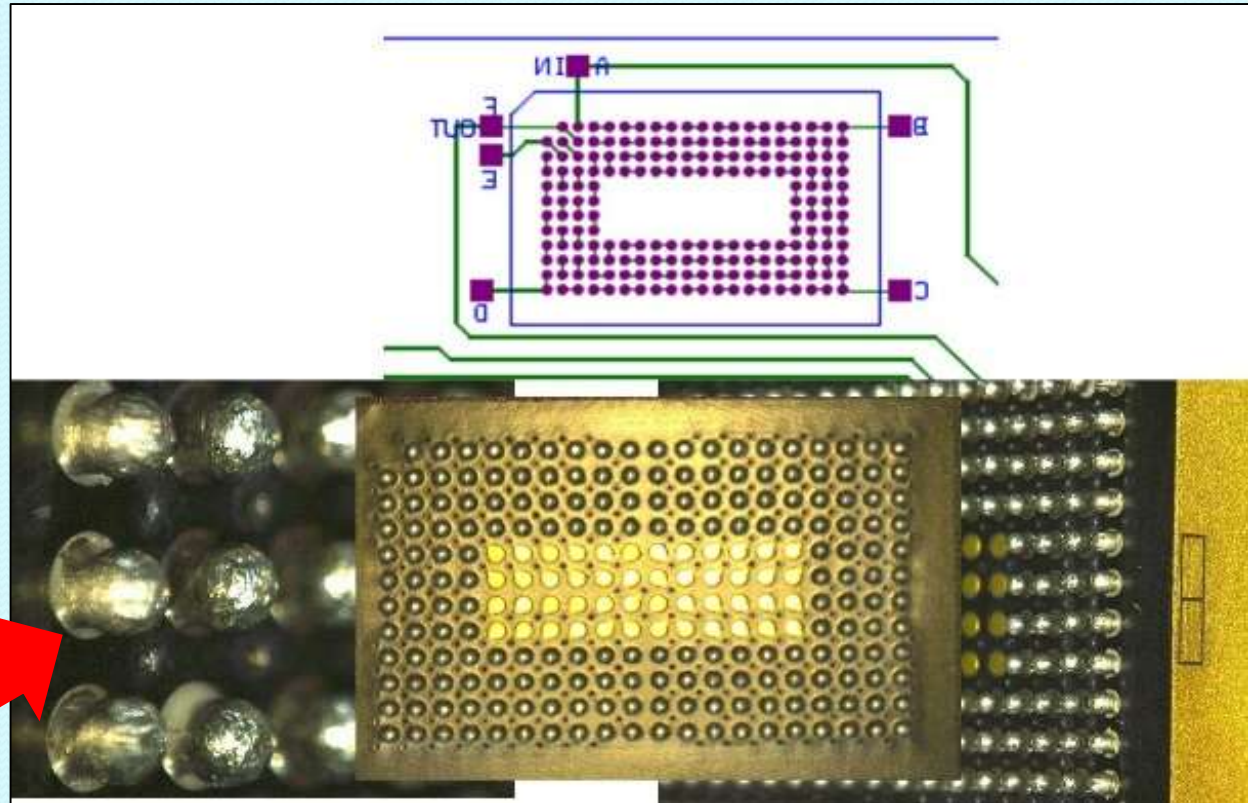


- **NEPP for additional build/TC/Failure Evaluation**



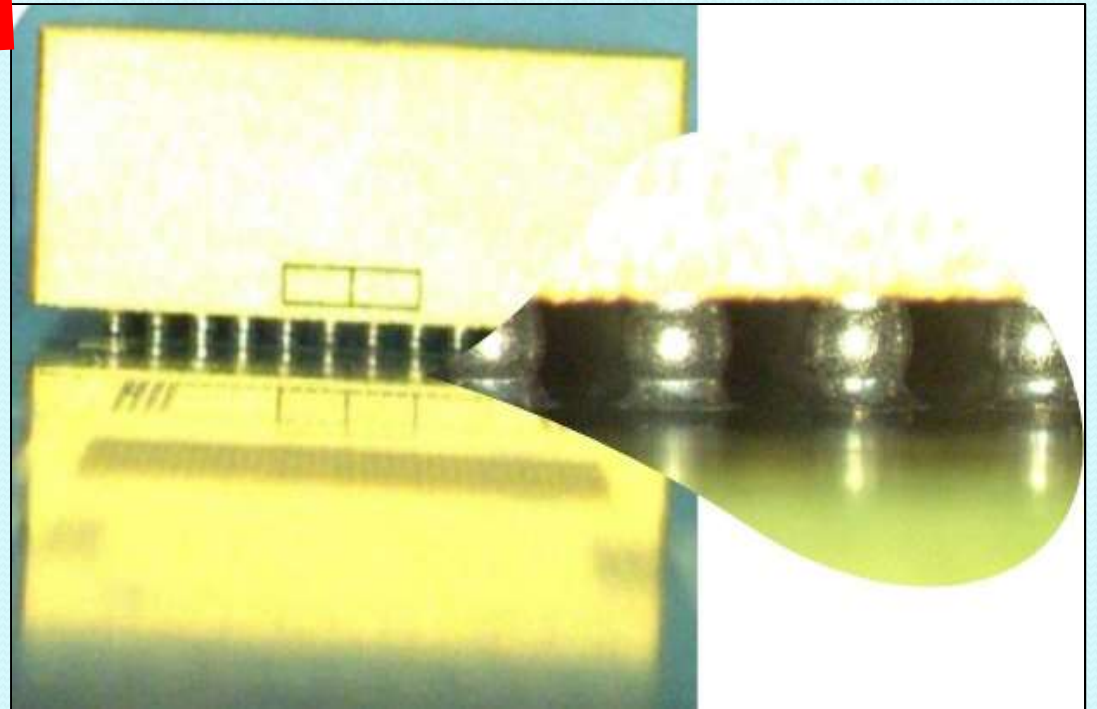
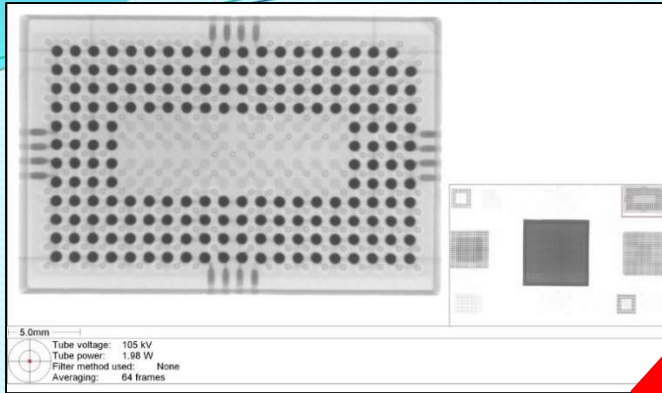


3D BGA Daisy-Chain



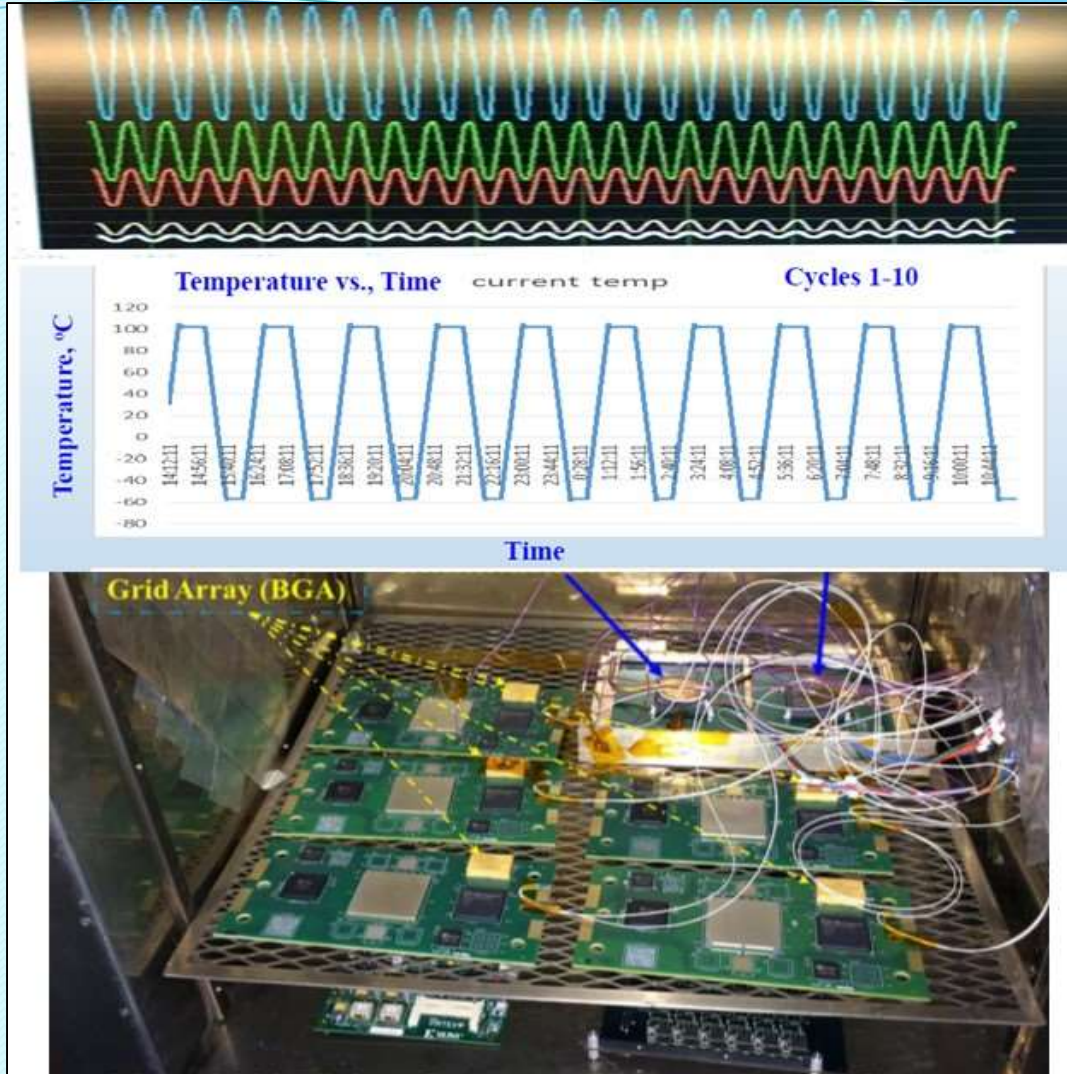


3D Stack BGA X-ray/Optical





3D BGA TC (-55/100°C)

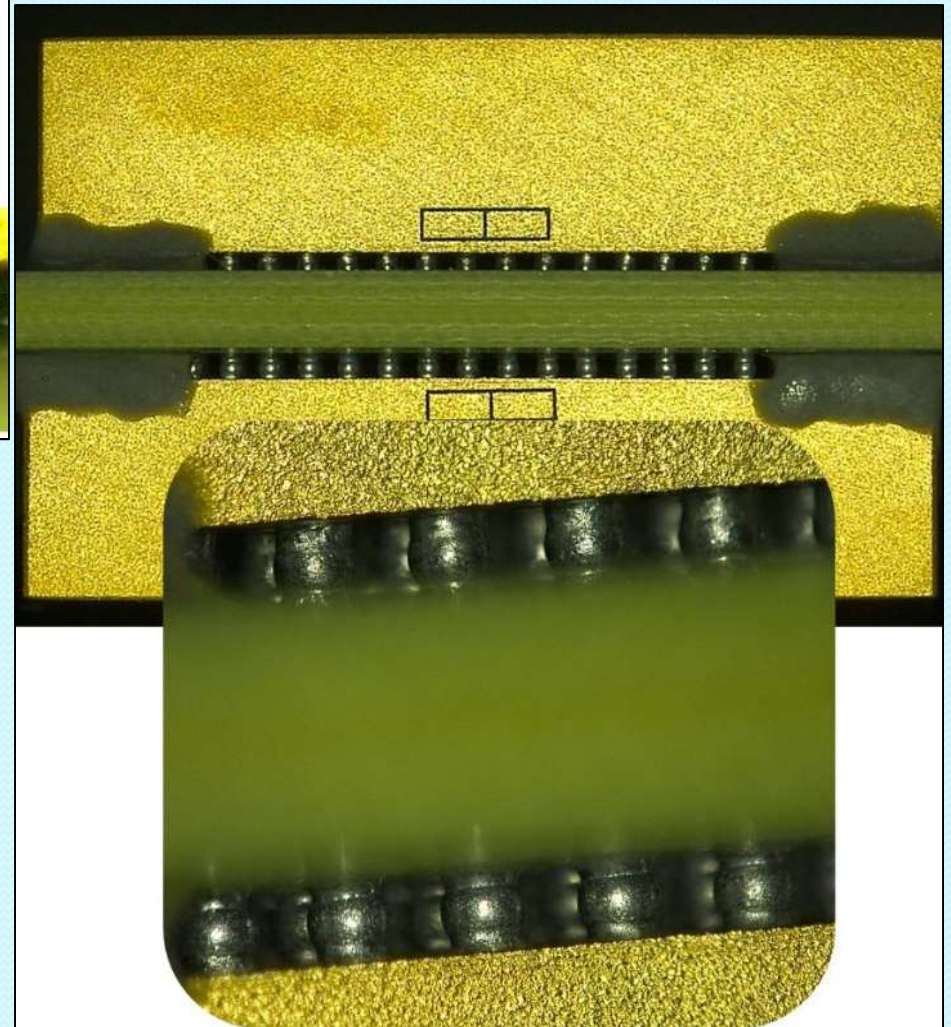
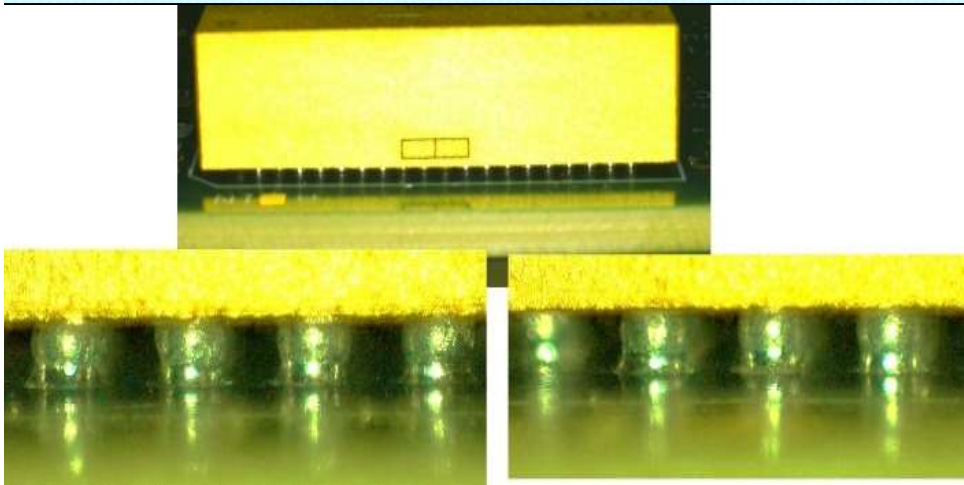


Representative of thermal cycle test profile (-55°C to +100°C) (top bottom), daisy-chain resistance changes with cycling (top rows), and single zone thermal cycle chamber (bottom). Chamber is fully loaded with five 3D stack BGA Assemblies, one double sided, which is shown by yellow arrows.



3D BGA Stack

200TCs (-55/100°C), Single- & Double-Sides



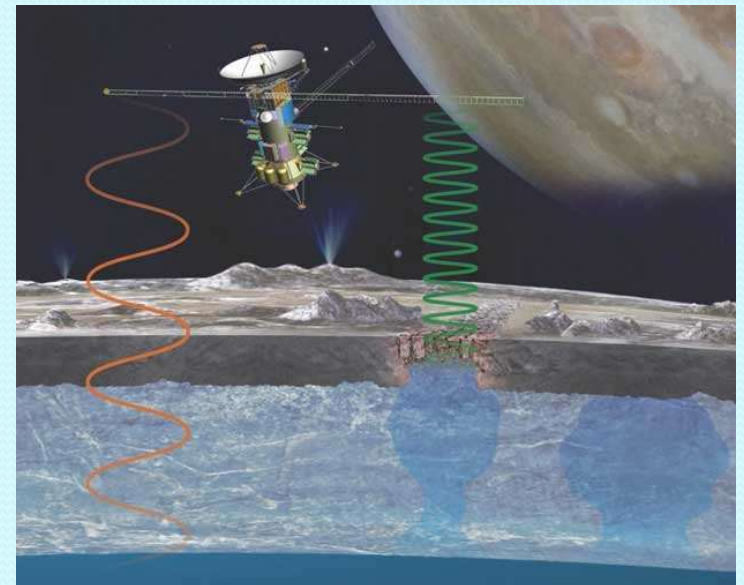
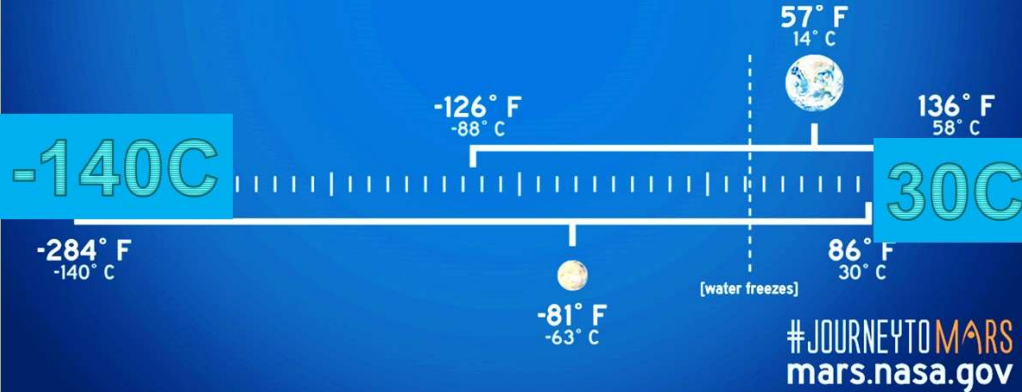


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M2020 Camera

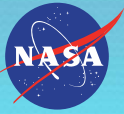
Cryogenic TC/Long Exposures

MARS FACTS / TEMPERATURE

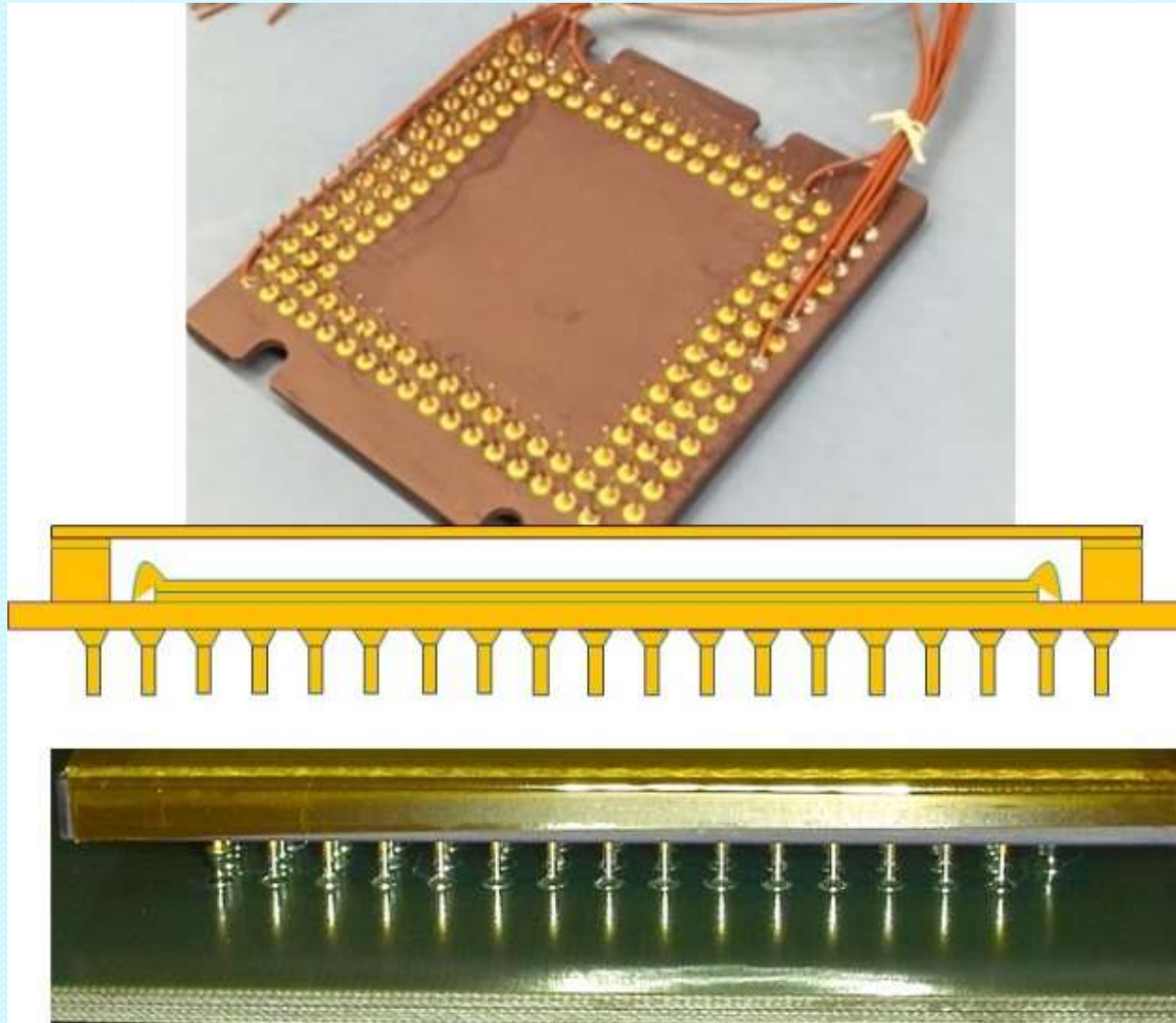


Jupiter-Europa

~ -240°C



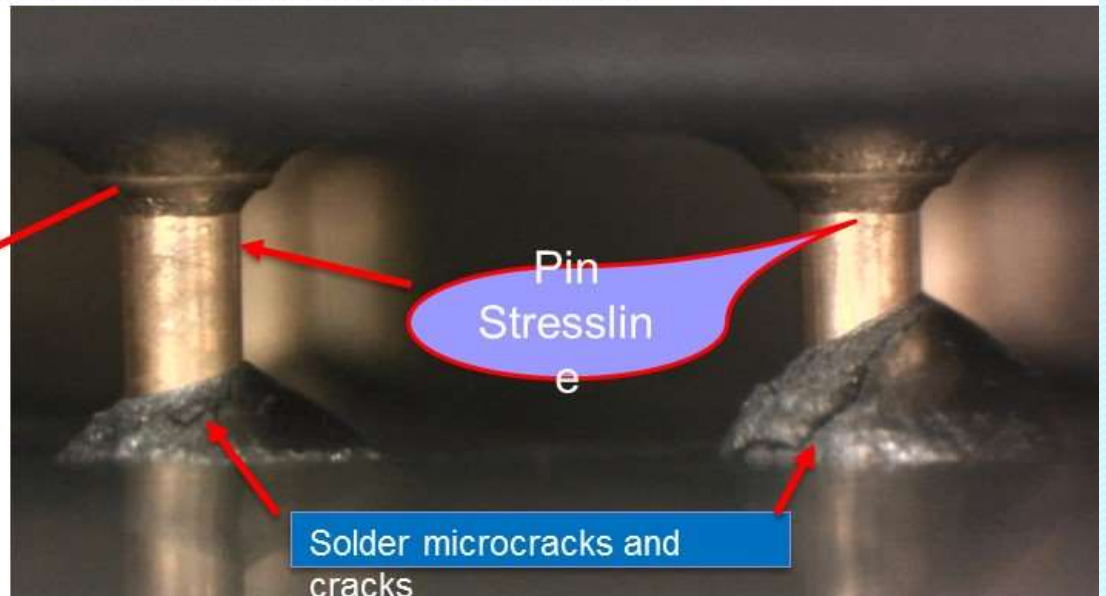
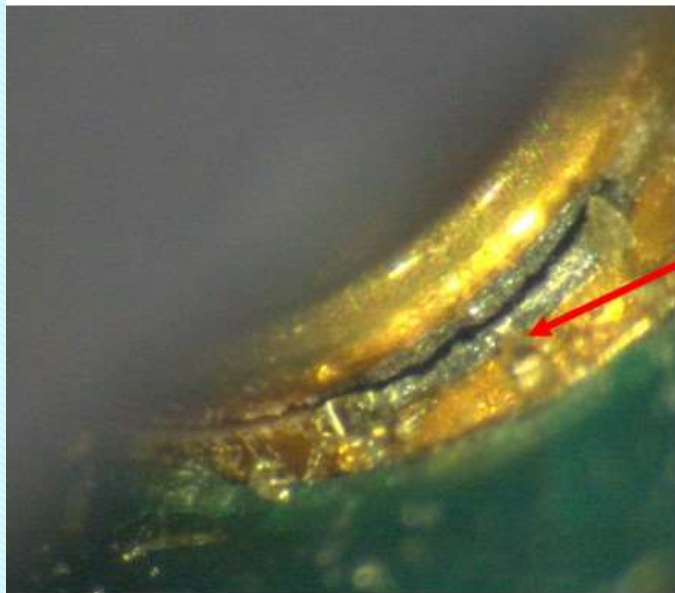
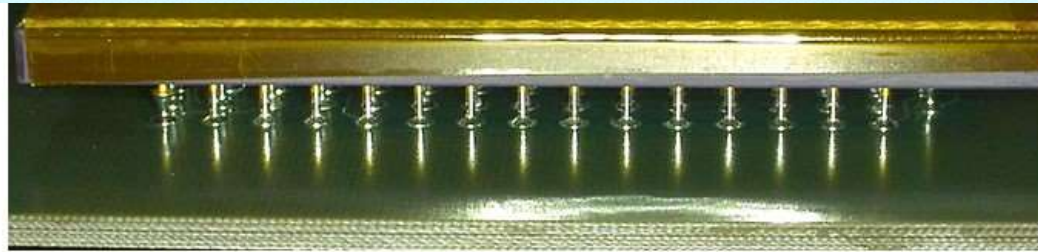
PGA Assembly Reliability





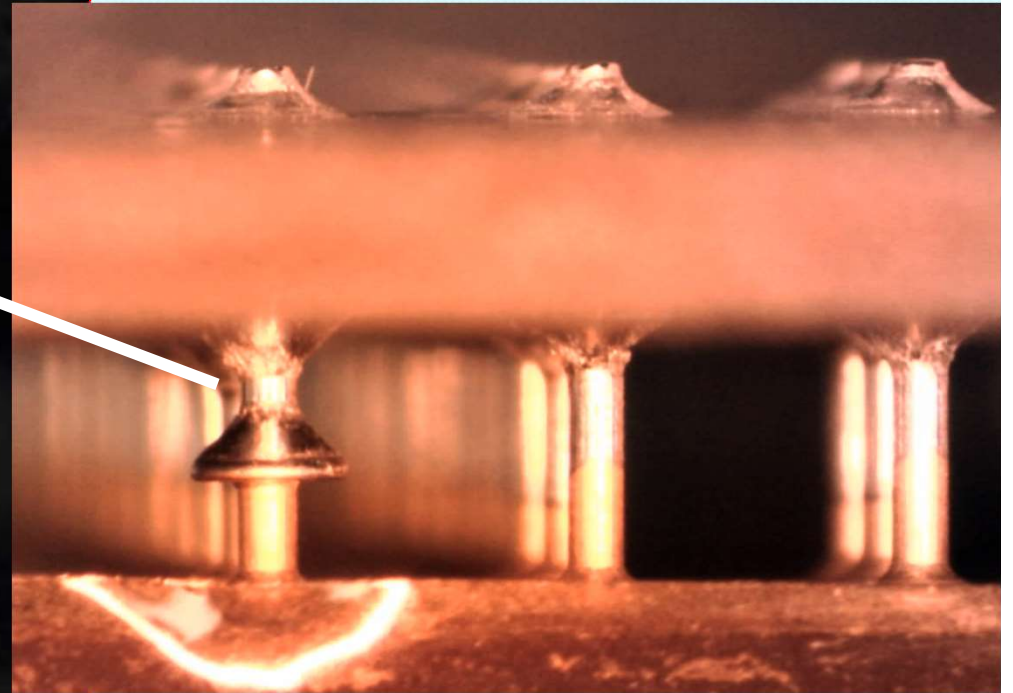
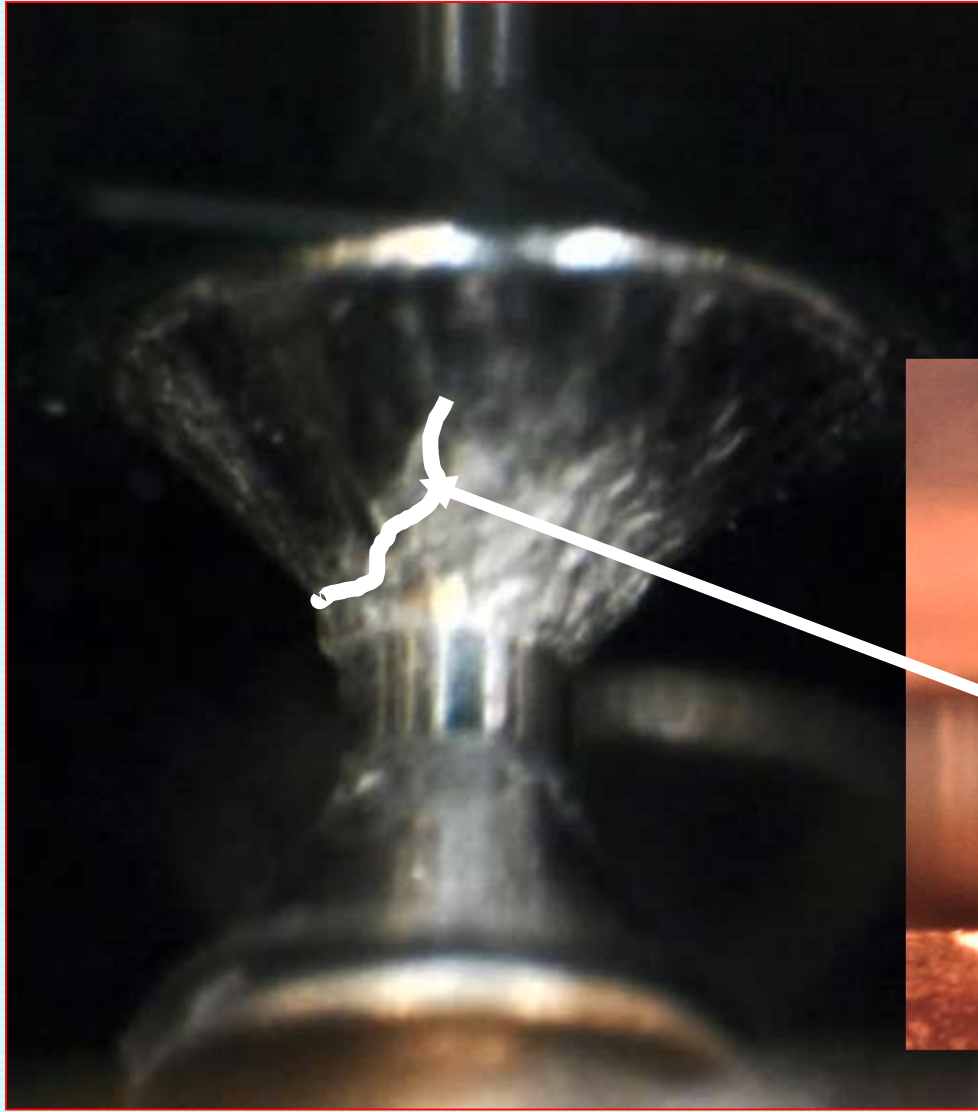
Extreme Environment Change in PoF

- $-135^{\circ}\text{C}/70^{\circ}\text{C}$, $\Delta T=205$
- PGA Pin Height = 50 mils



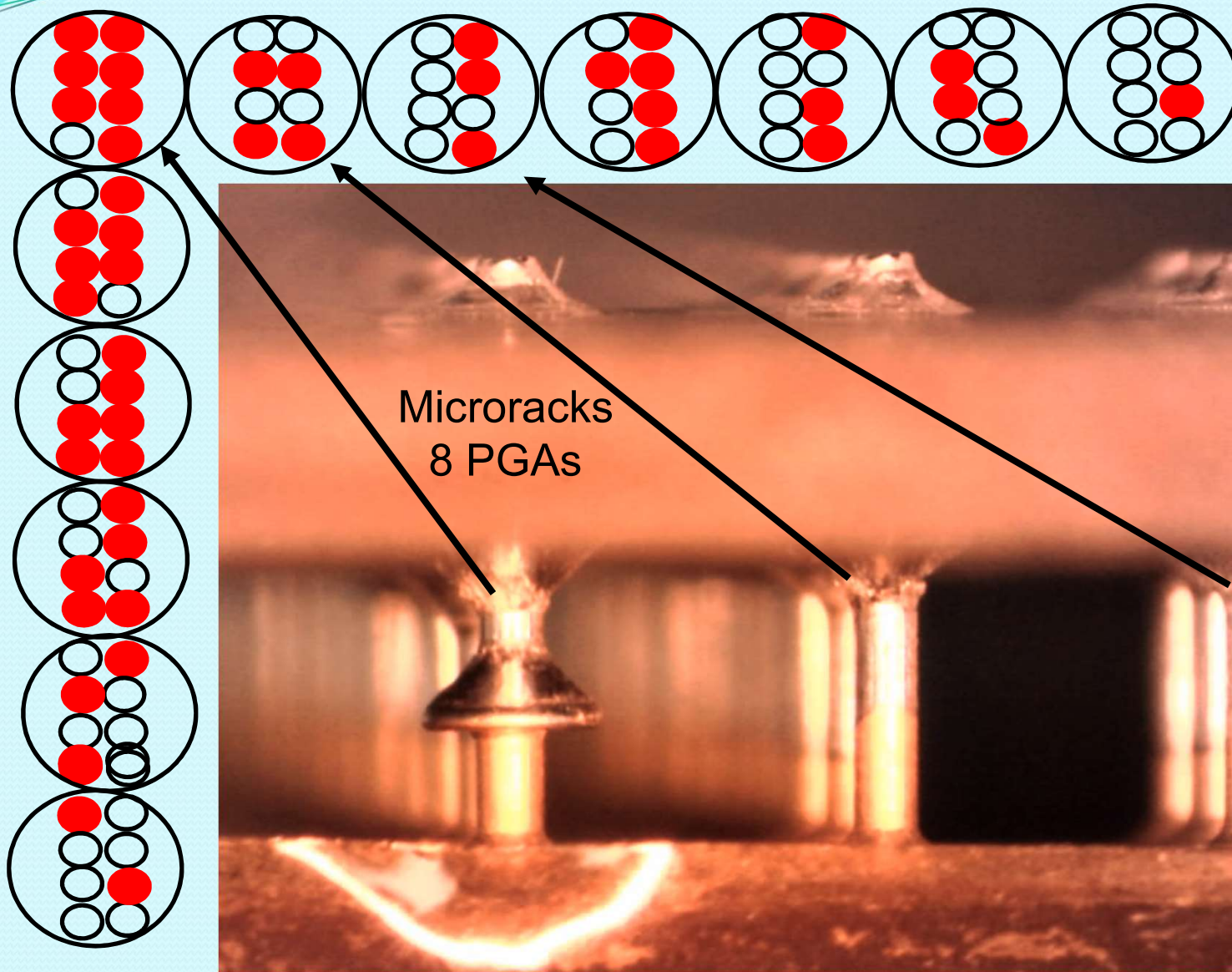


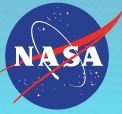
Height Changed PoF Initial Crack at Corners





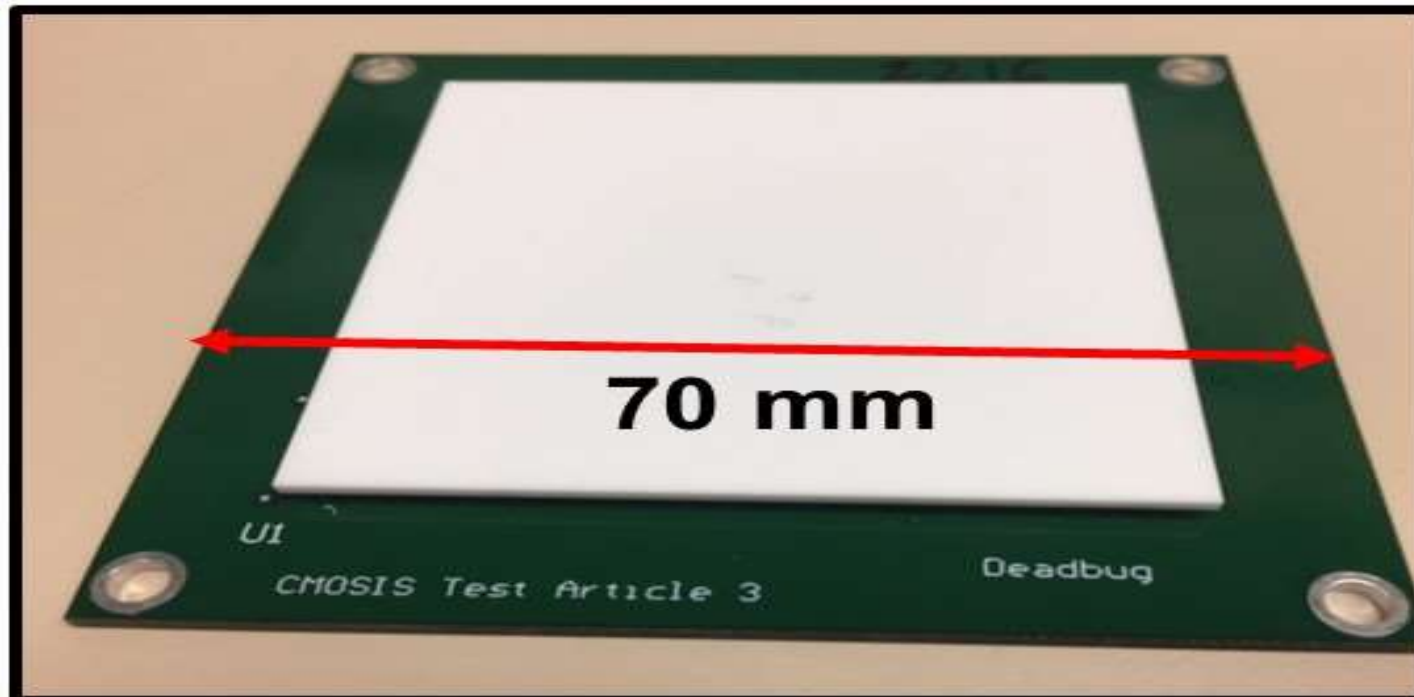
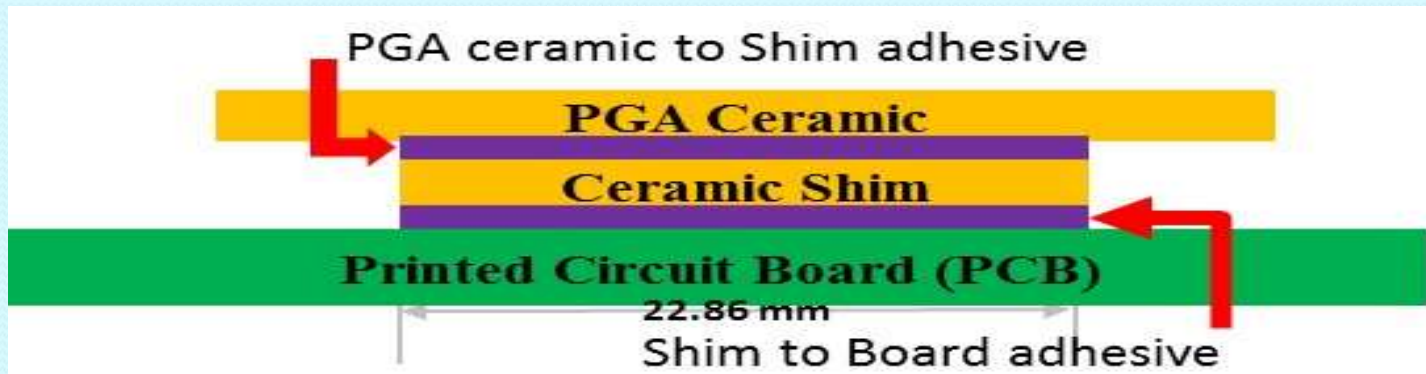
Validate DNP Effect





Modification Evaluation

➤ Two Adhesives



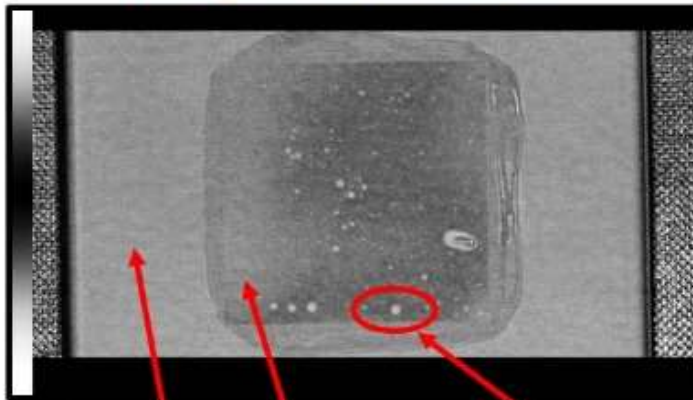


C-SAM Evaluation for Bond Integrity

PGA ceramic to shim interface

Adhesive #1

Voiding observed in bond line



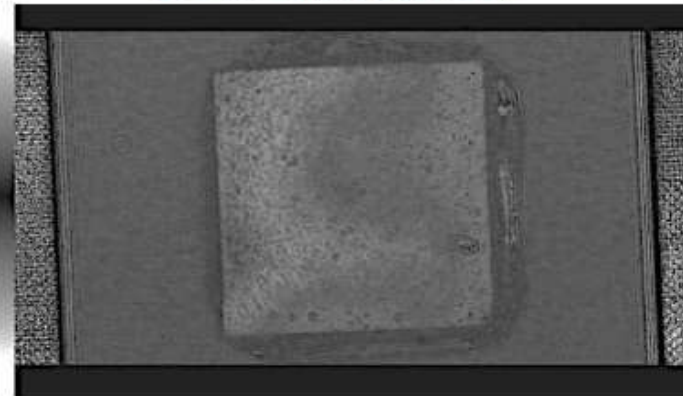
PGA ceramic
Bonded shim area

Voiding (bright round appearance)

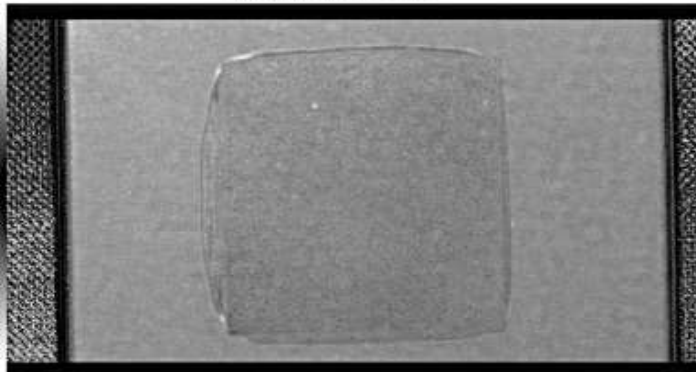
Shim to PCB adhesive interface

Adhesive #1

No anomalies observed

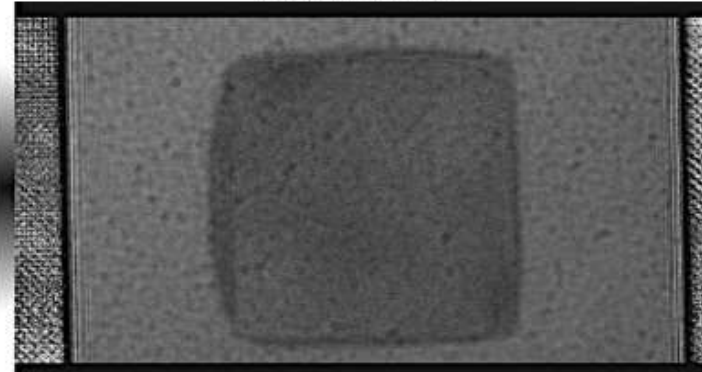


Adhesive #2



No significant voiding observed

Adhesive #2



No voiding observed



Summary- I

- **Solder Joints are Weakest Link for Advanced Electronics Packaging**
 - Solder joint failure under standard TC conditions
 - **NEPP reliability evaluation packaging task enveloped**
 - **M2020 Cruise TC environmental requirement**
 - **M2020 Controlled TC environment**
 - M2020 unique and extreme cold TC PQV test verified

- **M2020 Leveraged NEPP PCB/3D Stack BGA**
 - Package long lead-time schedule impact
 - M2020 funded building 5 test vehicles from NEPP
 - Standard TC (-55/100C) was used for qualification
 - Additional test vehicles were built under NEPP fund
 - Further TC and failure analysis performed under NEPP task
 - All test results published under NEPP task

- **M2020 Harsh Thermal Cycles (Cold Biased)**
 - PGA cracking at the pin braze joints
 - PGA solder joint microcracking when pin height increased
 - **Author's modified versions with adhesive bonding were test verified: Minor solder joint changes after Harsh TCs and robust to shock/vibration via bond**

- **Understanding PoF is critical to develop robust modified packaging to meet TC requirement under Harsh TCs**



Acknowledgment

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**Thank
You!**

