Ball Grid Arrays (BGAs) NASA-Guidelines: Update

by

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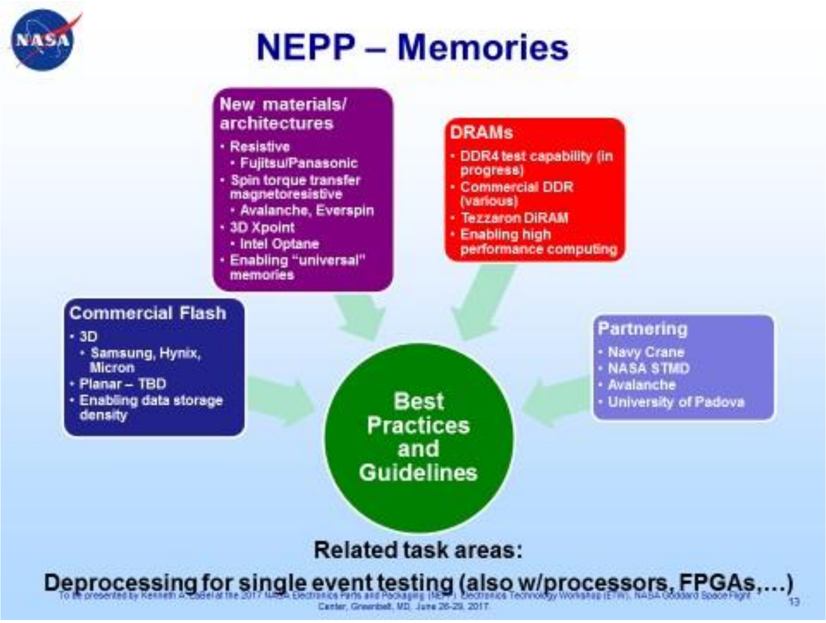
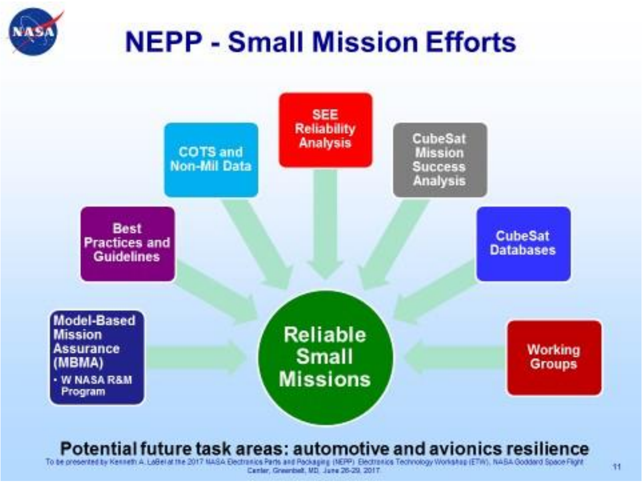
https://nepp.nasa.gov/workshops/etw2023/

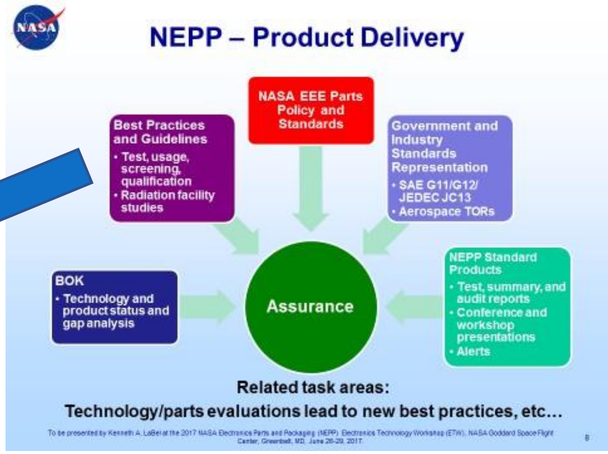
Outline

- **BGA/DSBGA Guidelines**
  - Thermal Cycle Results BGA Packaging Technologies
  - Part, PCB, Assembly, Qualification, MEAL, and Recommendations
- **FCBGA & Lessons Learned**
  - FBGA1924 X-section and Failure Analysis after 200 TS (-65℃ and 150℃)
  - BGAs with Cu-Wirebonds are Here
  - FCBGA Solder Bump Transition to Lead-Free Solder
  - RTG4 CGA Last Buy with SnPb Solder Bump 208/228/360 with 0.8,0.5, 0.4 pitches
- **BGA Reviews**
  - Standards to Review before BGA/DSBGA Selection
  - BGA and Lead-Free Transition
  - Polymer and Moisture Sensitivity
  - Electrical Testing Considerations
  - PCB
  - MEAL
- **Summary: Key Findings**

BGA/DSBGA Guidelines





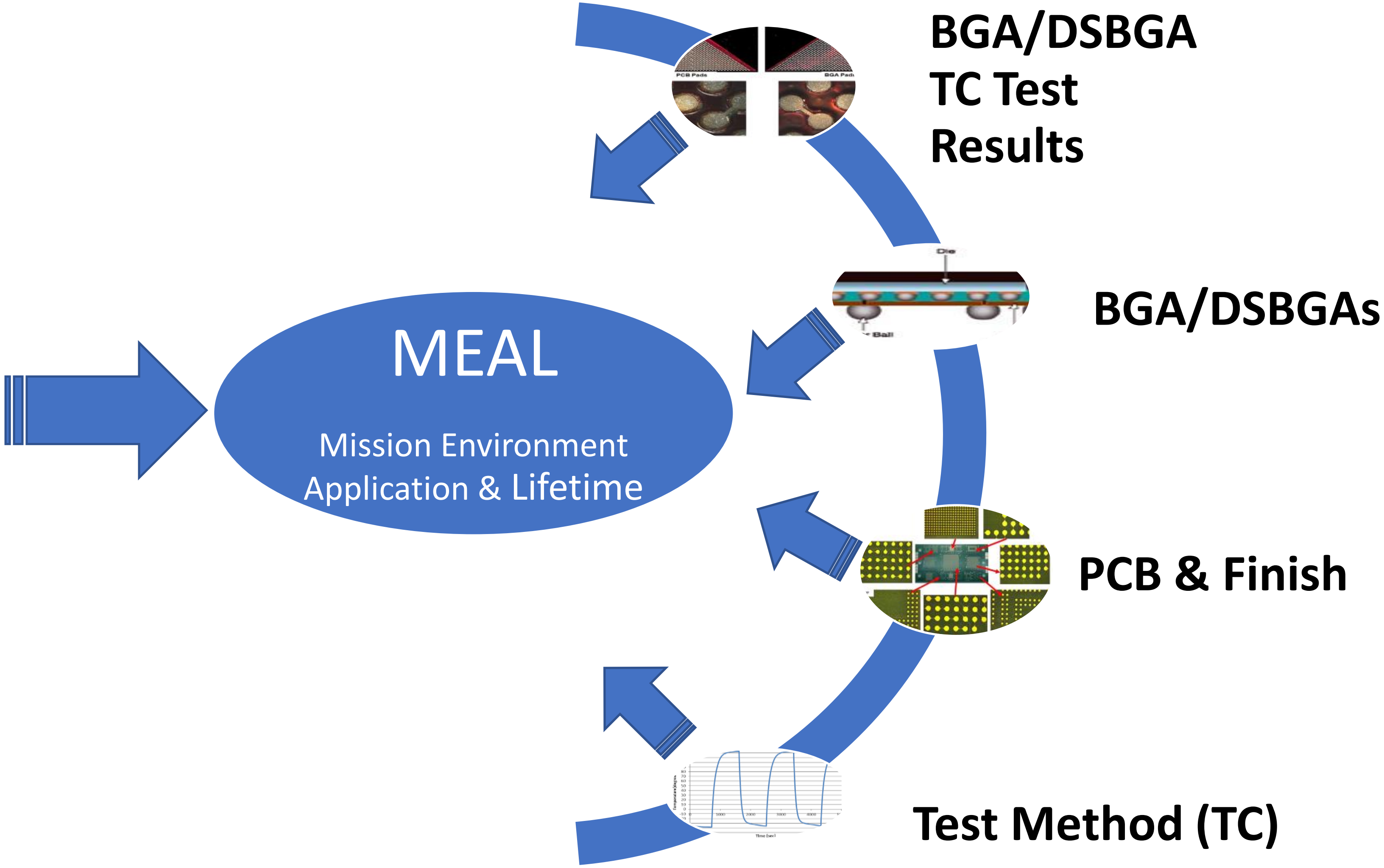


Best Practices and Guidelines

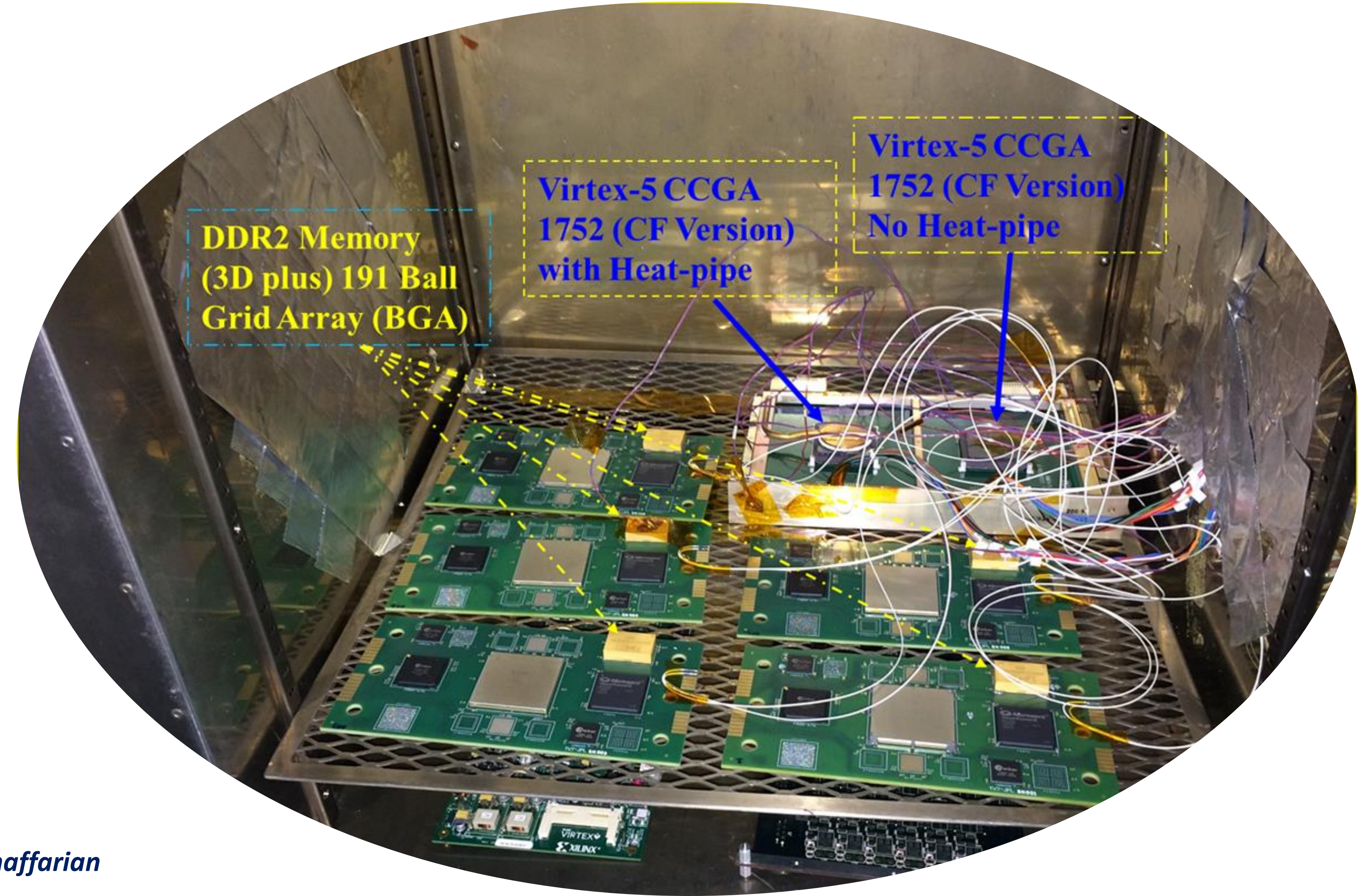
- Test, usage, screening, qualification
- Radiation facility studies

Guidelines on NEPP Website

BGA/DSBGA Guidelines



Assembly TC Results & Lessons Learned in BGA/DSBGA Report



FCBGA 1924 – TC Test Resuts

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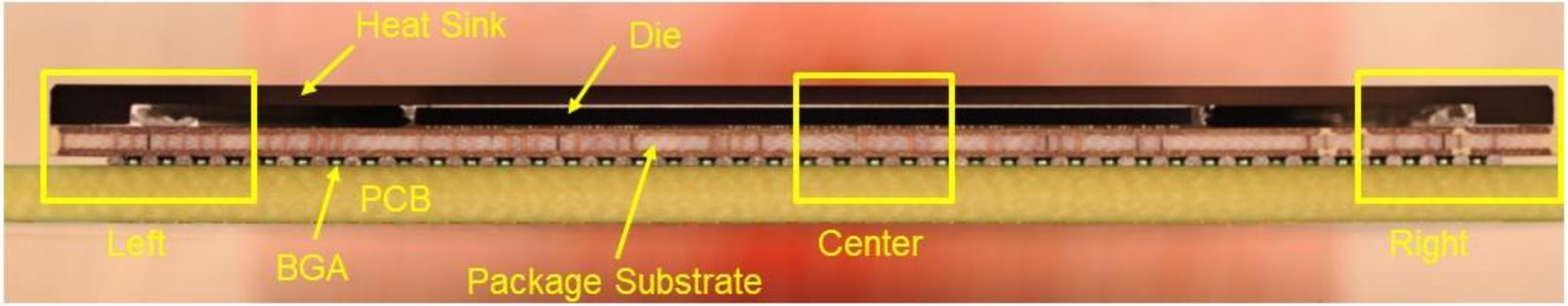

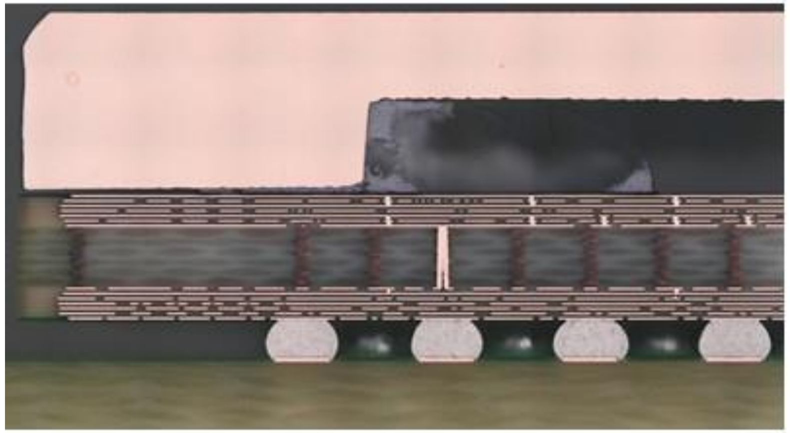

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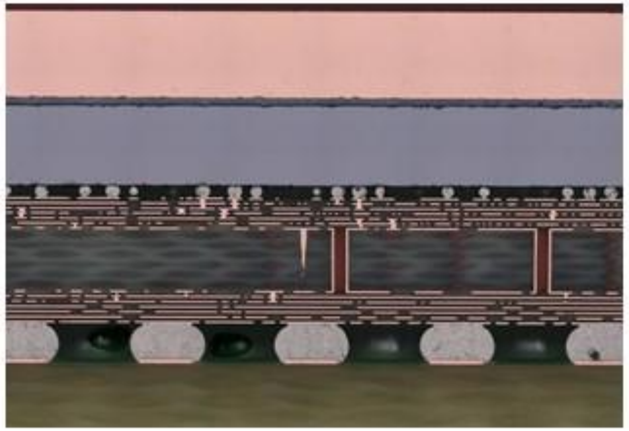

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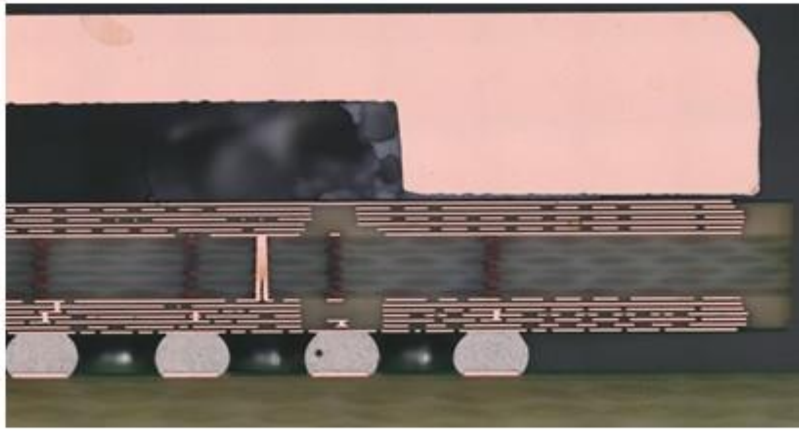
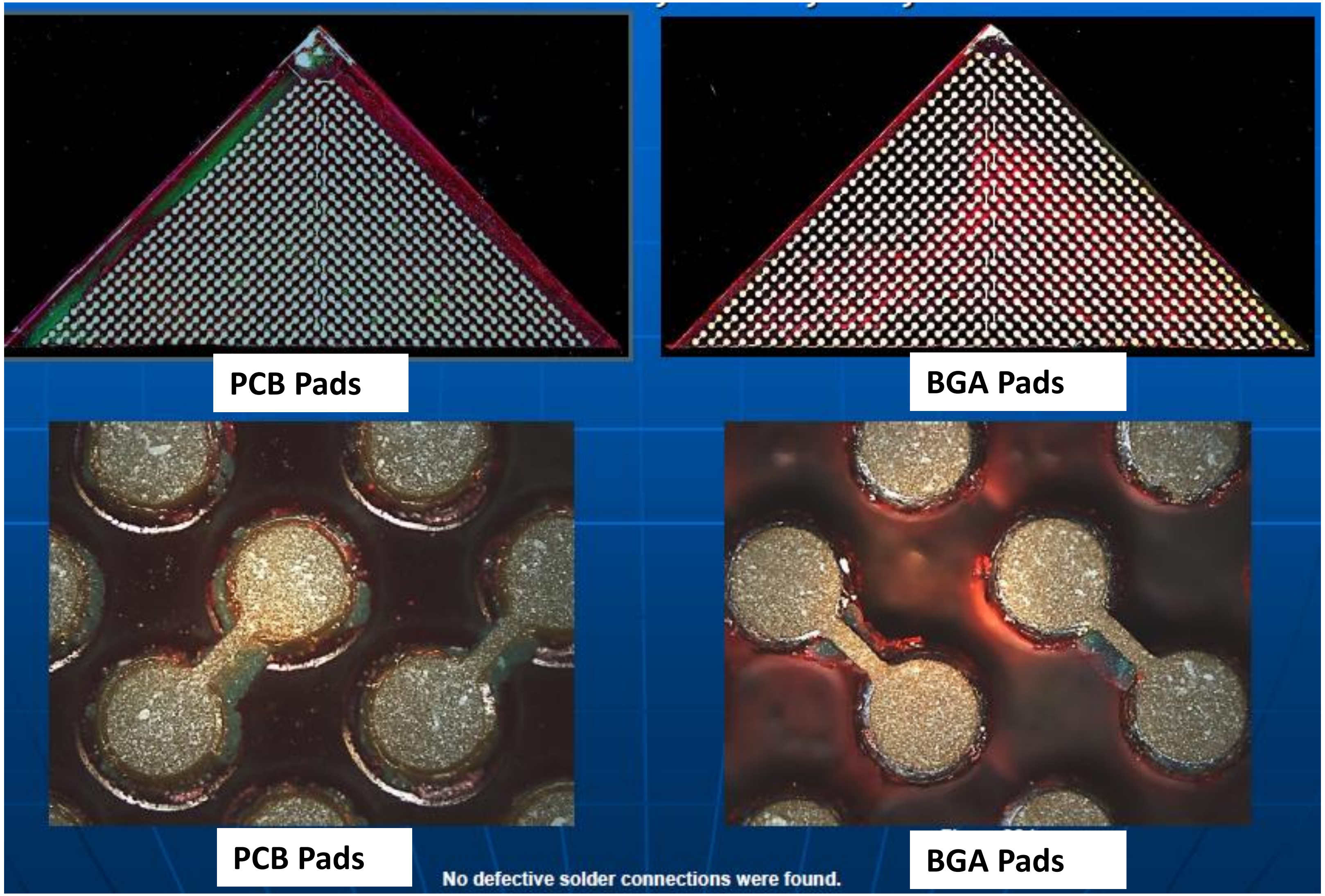
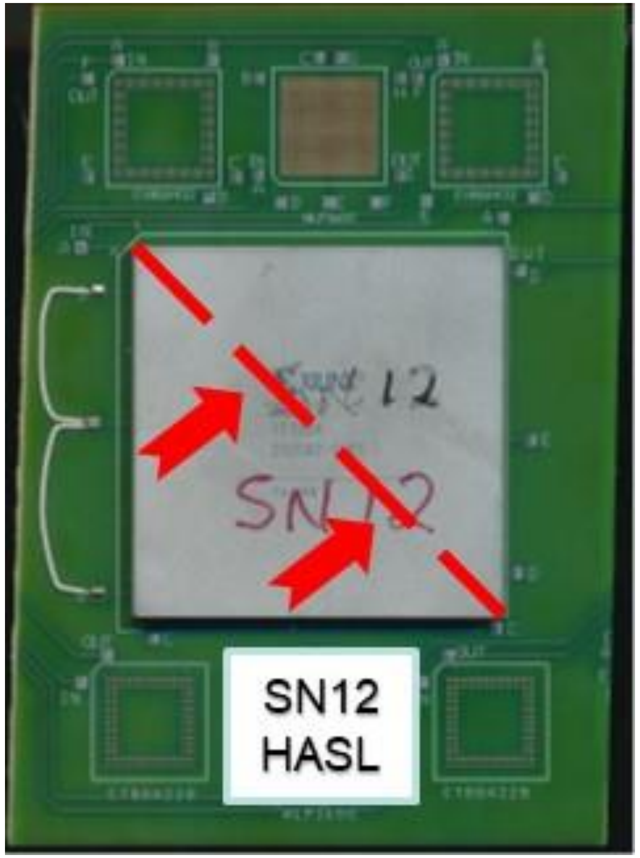


Right

FCBGA 1924 on HASL PCB Finish

200 TSC (-65°C/150°C)





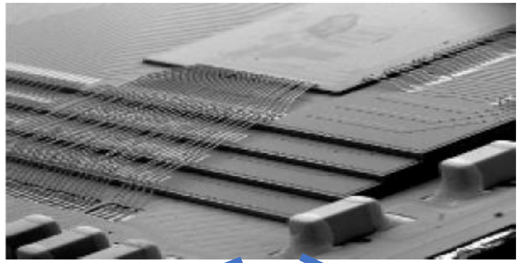
BGA SELECTION & Review-I

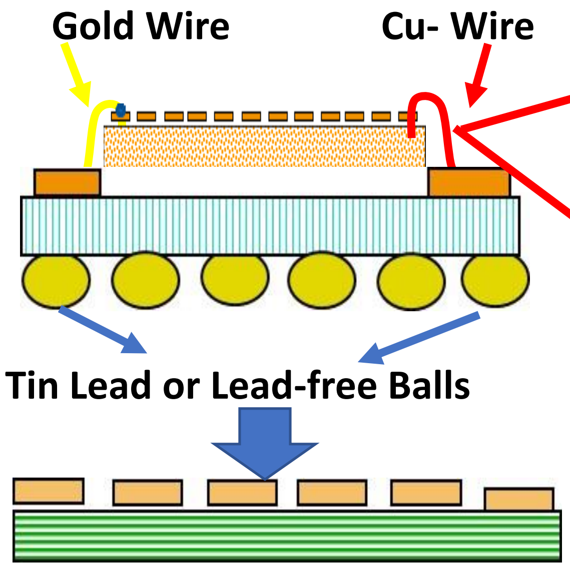
- **Review NASA, Military, and Industry Standards**
  - GSFC-STD-6001A
    - Area Array Package Assembly and Manufacturing Practices for Flight Hardware
  - NASA-STD-8739.1
    - Polymeric Applications
  - IPC 7095
    - Design for BGAs
  - IPC 7094
    - Design for Flip Chip
  - IPC 9701
    - Qualification and Performance for SMT
- **Define MEAL and Risk Posture**
  - Radiation, mechanical, thermal, life cycle, vibration, etc.

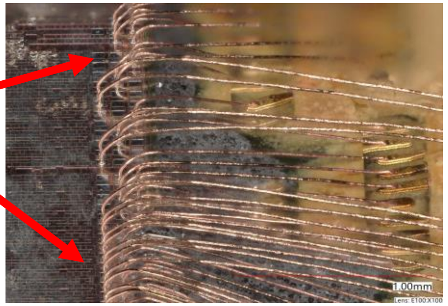
BGAs with Cu-Wirebonds Are Here
FCBGA: LF Creeps in

BGA/Cu-Wire
FCBGA/Lead-Free Bump

BGA with Internal Wire Bond

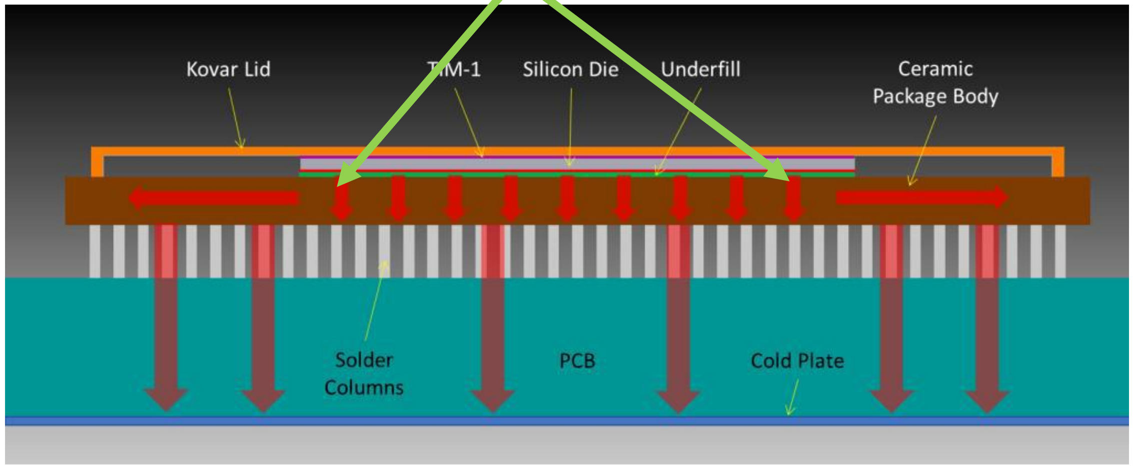






Cu-Wirebonds

RTG4: LF for Flip-chip bump inside package



BGA SELECTION & Review-II

- **Determine Solder Alloy of Solder Balls for BGA/DSBA**
  - Lead-free solder alloys, now 3rd generation
  - Compatibility with tin-lead solder is critical
    - Affects solder joint reliability under thermo-mechanical loading, shock and vibration

High Silver (Ag)
SAC405(Sn, 4%Ag, 0.5% Cu)
SAC 305

1st Generation Lead-free Solder Alloys

SAC 405 for BGA Solder Ball

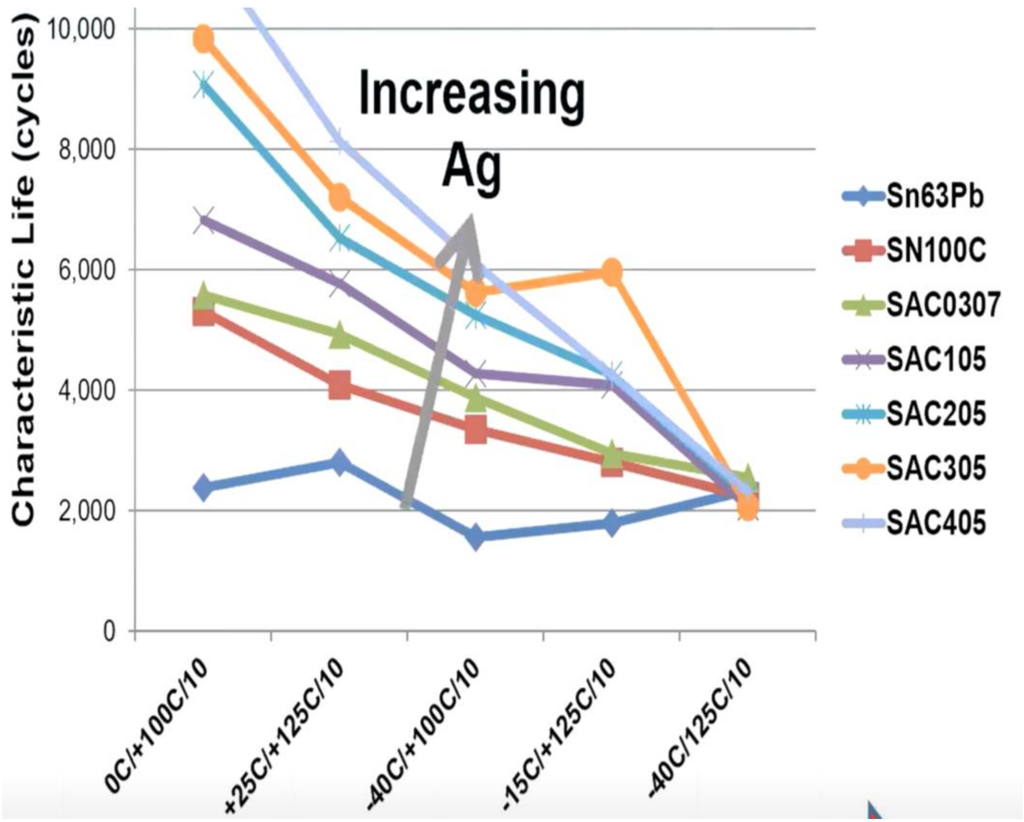
SAC305 for solder paste

Others: SAC387

Better or comparable to SnPb on resistance to thermal cycling (TC)

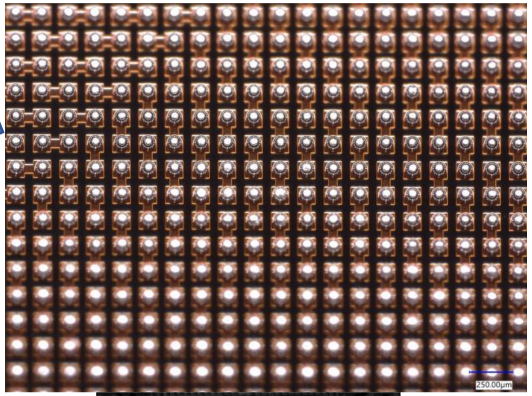
Low resistance to drop impact

High cost due to high Ag

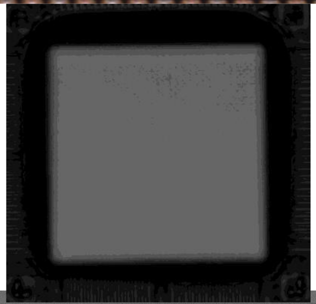


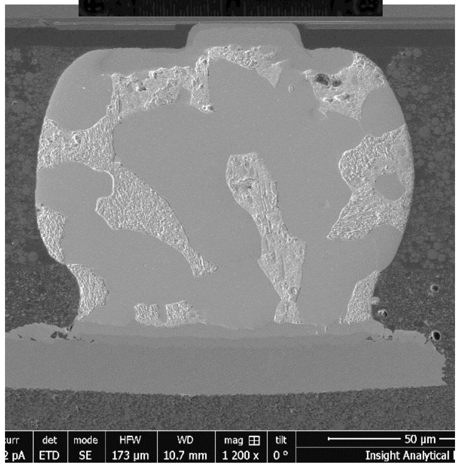
Lead-Free Creeps into High Reliability

- **SnPb Replaced High Lead Flip-chip Bump**
  - F150 SnPb shown to be robust (Ref: *Scott Popelar, ETW 2022*)
- **LF to Replaces SnPb Even for CGA**



- **FC150 Test Die Solder Bump**
  - 70µm eutectic 63Sn/37Pb solder bump
- Condition B Temperature Cycle Testing (-55/125℃)
  - Parts assembled with underfill
- 5000 cycles, no failures detected
  - Extended testing to 8000 cycles (3 failures detected)
- 125℃ High Temperature Storage
- 4000 hours, no failures detected
- 150℃ High Temperature Storage
- 4000 hours, no failures detected





LF for RTG4 Flip-chip Bump

Problem

- Leaded flip-chip bump solder discontinued by Microchip vendor, Amkor, in June 2022
- Impacting all RTG4 in ceramic packages (CG1657 and CQ352)
  - Solder Bump Alloy 98.2% Sn, 1.8% Ag (SAC1.8)
- RTG4 in **plastic package** and RT PolarFire are NOT impacted
  - **They always use lead-free bump**

Tests Performed

- RT4G150 CGG1657, Passed, 1000 TCs (-65 to 150℃)
- RT4G150 CGG 1657 passed, 2000 TCs (-65 to 150℃)
- RTPF500 CG1509, Passed 1000 TCs (-65 to 150℃)
  - **No whisker**, flip chip bump integrity TM2010, 2013 and DPA.
- RTPF500 CGG1509, Passed thermal shock (MIL STD 883, TM1011), Cond B, 15 cycles)
  - No issue for flip chip bump integrity connection
- RTPF500 CG1509, HTS (high temperature storage of 1000 hours at 150℃), and long term room storage up to 1.5 years
  - Passed tri temp production test flow limits with delta measurement. No issue for flip chip bump integrity connection. **No whisker**

Ref: Microchip, Minh Nguyen, March 14, 2023

Polymer & Moisture Sensitivity-III

- **Review Moisture Sensitivity and Bake out Recommendation**
  - BGAs/DSBAs absorb moisture, which has degradation effect
  - Assigned different moisture sensitivity and bake out
  - For bake out, use either manufacturer recommendation or J-STD-033 or equivalent
- **Provide Controls Steps Based on Moisture Sensitivity**
  - Use Moisture Barrier Bag (MBB)
  - Drying cabinet, or nitrogen-blanket.
- **Polymeric Underfill for Flip-chip and Adhesively Bonded Heat sink**
  - Avoid polymeric underfill to cleaning solvent
- **Consider Tg and Filler Content for Molded BGA/DSBGA**
  - Molding compound effects thermal cycle reliability.
- **Look for Vent Holes in BGA**
  - Small vents to allow for outgassing/moisture
  - These become a reliability issue
  - Cleaning solvents seep through
  - Attacks materials inside the BGAs
  - Recently, suppliers add note on vent

Electrical Test Consideration-IV

- **Electrical Verification is Challenging**
  - FCBGA/BGA field programmer array packages
  - User has limited access to burn-in/electrical tests
- **Review Electrical Burn-in Socket Approach**
  - It may induce stress, especially at high temperatures
  - Could cause damage and/or dislodge/dislocate solder balls
  - Reliability of burn-in on assembly is not well established
- **Consider the Effect of Burn-in Beyond the Part Degradation**
  - It affects the die behavior
  - It affects the integrity of BGA/DSBA solder ball joints
  - It subjects solder balls to shear or tensile loading
  - It affects assembly reliability
- **3D Stack Die with Head-on-Pillow (HoP)**
  - Perform 3D X-ray for HoP
  - Closeness of wirebonds for BGAs

Key PCB Guides-V

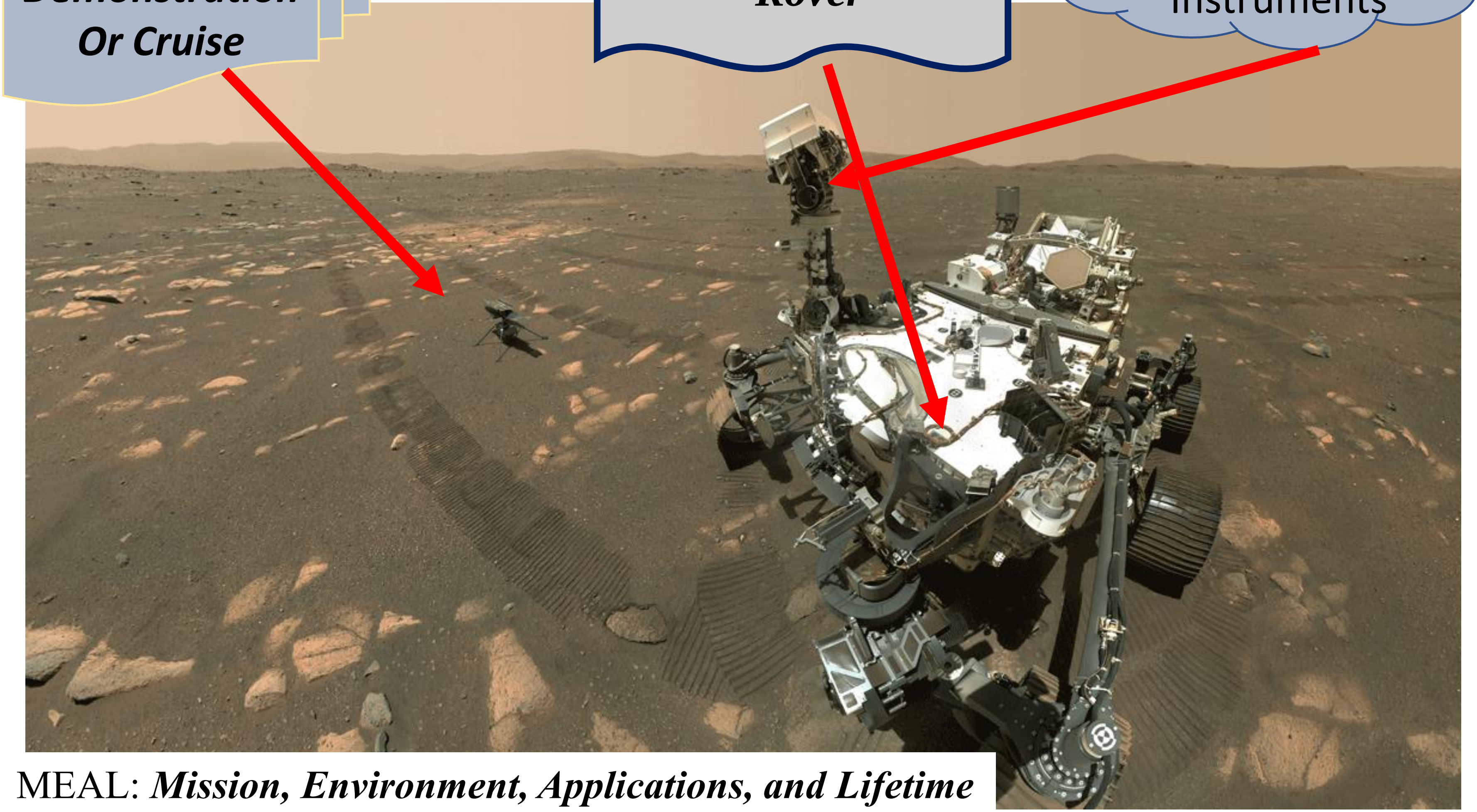
- **Review Non-standard PCB Technologies for MEAL**
  - Modifications required for BGAs//DSBGAs
  - Microvias, stacking vias, surface finish, pad opening/mask
  - Stack vias prone to latent failures
- **BGAs: Design Non-Solder Mask Design (NSMD)**
  - NSMD PCB pads, mask openings larger than the pads
    - NSMD prevents crack initiation in solder joints
    - NSMD reduces solderable pad size
    - SMD (Solder Mask Defined) initiates crack via mask being in proximity contact with solder joint
- **DSBGAs: SMD is Better**
  - SMD reduces the likelihood of the pad lifting during the soldering or de-soldering process

Example of MEALs

Technology Demonstration Or Cruise

Control MEAL Rover

Extreme MEAL Rover & Instruments



MEAL: ***Mission, Environment, Applications, and Lifetime***

Summary: Key Discussion

TC Results for FCBGA/DSBGA

Example for FCBGA1924

200 TC (-65/150℃)

Detailed on BGA/DSBGA Part

LF in CGA Flip Chip Bump

LF for BGA Solder Balls

Cu-Wire bond for BGA

Moisture Control/Bake out

Assembly Reliability

Detailed on Qualification Methods

(Also ETW 2022)

PCB Pad Design

NSMD for BGA

SMD for DSBGA

Avoid Stack Microvia

MEAL
See NASA
BGA
Guidelines

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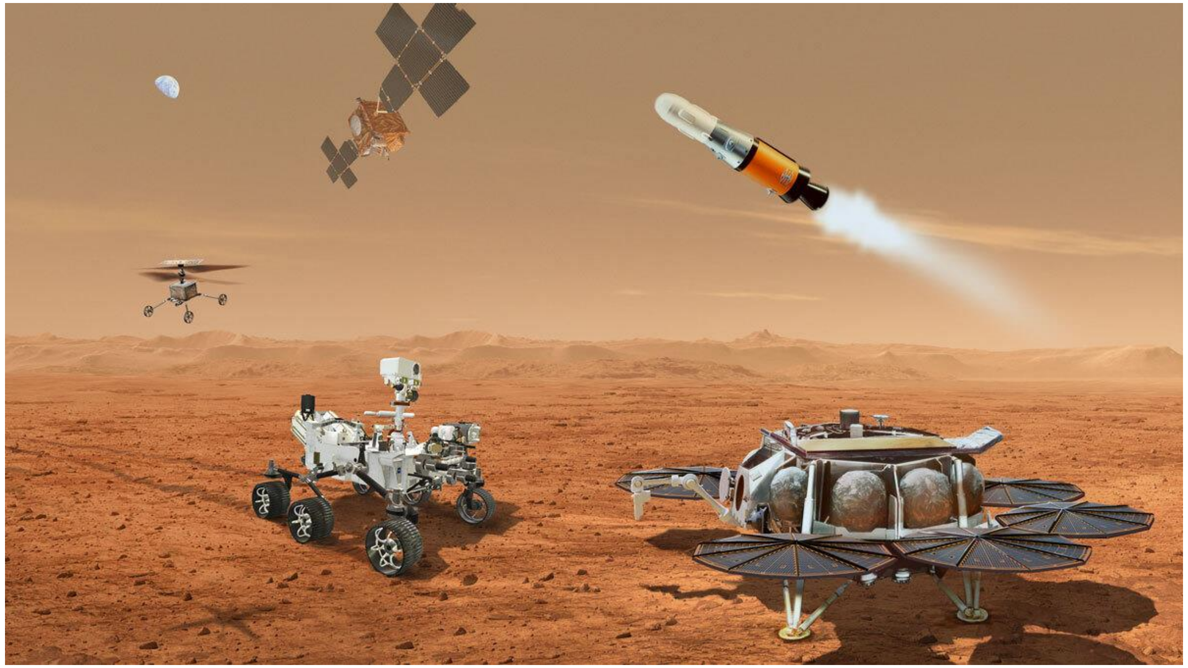
Mars Sample Return



Note: **Pre-Decisional Information – For Planning and Discussion Purposes Only**

Thank You!