NEPP ETW Packaging Overview

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Package evolution – where does NASA fit in?

Ceramic

The space "standard"

Not designed for space. Upscreening partial solution sometimes

BGA - Ball-grid Array
QFN - Quad Flat. No-leads PKG
PoP - PKG on PKG
SIP - System in PKG
CSP - Chip Scale PLG

1990
2000
2010
2014 ~

Advanced Packaging

2.5D, 3D TSV, Fan-Out

3D TSV
2.5D Si Interposer
Fan-out

What about a custom 2.5/3D space package?

SWaP revolution possible but upscreening becomes much more challenging

K. Lee IRPS 2019

www.completehermetics.com
Reliability of Commercial BGAs – 1000 cyc TC limit

- All capable of 1,000 0-100C cycles, but significant variation in actual response
- Physics/materials science difference drive actual failures
- Interdependences w/ solder type, geometry, bump pitch, etc.
- How to extrapolate / interpolate stress conditions to mission requirements?
- Complexity of design and materials use of 2.5/3D packages compound applicability assessments
IEEE Heterogeneous Integration Roadmap

Market Drivers
• High Performance Computing and Data Centers
• Medical, Health and Wearables
• Autonomous Automotive
• Mobile
• Aerospace and Defense
• IoT

Building Blocks
• Single Chip and Multi Chip Integration (including substrates)
• Integrated Photonics
• Integrated Power Electronics
• MEMS and Sensor integration
• 5G and Analog and Mixed Signal

Technical Areas
• Materials and Emerging Research Materials
• Emerging Research Devices
• Test
• Supply Chain
• Security
• Thermal Management
• Co-Design
• Simulation

Technology Areas for HI
• SiP
• 3D & 2D Interconnects
• Wafer-Level Packaging – WLP (fan in and fan out)

• Emphasis on DARPA CHIP HI and IP reuse program
• Doesn’t specifically address reliability, #1 space concern

Many areas of interest for NASA, but still mostly commercial focused solutions
# NASA focused HI reliability roadmap

<table>
<thead>
<tr>
<th>NPR 8705.4 Classification</th>
<th>(Class A)</th>
<th>(Class B)</th>
<th>(Class C)</th>
<th>(Class D or unclassified)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mission Description</strong></td>
<td>Large mission primarily built in house, highly visible, complex in nature, single string spacecraft.</td>
<td>Spacecraft with redundancy, large system contract for spacecraft, or large, highly visible instruments critical to meeting project level 1 requirements.</td>
<td>Spacecraft with shorter life and lower cost, instruments important to meeting project level 1 requirements.</td>
<td>Short life and low cost missions, instruments whose performance is not required to meet project level 1 requirements, and technology demonstrations.</td>
</tr>
<tr>
<td><strong>Risk Posture</strong></td>
<td>Very Low</td>
<td>Low</td>
<td>Medium</td>
<td>Med/High</td>
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<tr>
<td><strong>Lifetime</strong></td>
<td>&gt; 7 Years</td>
<td>2 – 7 Years</td>
<td>&lt; 5 Years</td>
<td>&lt; 2 years</td>
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<tr>
<td><strong>Modeling</strong></td>
<td></td>
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<tr>
<td><strong>Test devices</strong></td>
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<tr>
<td><strong>Products</strong></td>
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</tbody>
</table>

- Specific combinations of modeling, test devices and products for each mission class
- Leverage and extend JC-13.7 Class Y where possible
Evolution and Integration of Space Rad Hard HI Design Kit

- Technology
  - Roadmaps
  - IEEE HIR
  - A&D
  - DARPA
  - CHIPS
  - Cellular
  - HPC/AI
  - Automotive
  - Photonics
  - Power/IoT

- Packaging
  - Requirements
    - Class D
    - CAE/Design Rules
    - JC-13.7 MIL-PRF-38535 Class Y for Organic Substrates

- Organizations
  - Georgia Tech Packaging Research Center
  - NEPP Packaging
  - SRHEC Tech & Dev WG Packaging WG
  - DoD T&AM/MSSEC Advanced Packaging & Test
  - UC Santa Barbara Optoelectronics Technology Center
  - JPL Microdevices Laboratory
  - Vanderbilt Institute Space and Defense Electronics

Heterogeneous Integration technologies
- Reliability as function of mission class
- Space Rad Hard HI Packaging Design Kit

= ETW topic
Space RH HI Design Kit

- University and Industry CAPEX investments have made small lot, custom developments possible
- University tool sets near-equal some industry tools -> enables real technology transfer
- CAD design rules are physics/materials science based to support space requirements
- Leverage and supports workforce development with modern software experience base
- Begin to leverage development in infrastructure to make unique NASA HI parts – not reliant on COTS systems architectures where you have to qualify many additional part types (support)
- Heterogenous integration - unique to NASA mission requirements
  - Mixture of rad hard and not so rad hard
  - Different power requirements
  - Old and new technologies
  - Electrical and optical
- Goal moving forward to enable NASA to leverage and benefit from the HI packaging revolution