

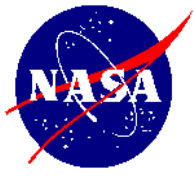
# Packaging Concerns/Techniques for Large Devices

## Seminar Topic

**Presentation Military and Aerospace Programmable Logic Devices (MAPLD)**

**NASA Goddard Space Flight Center  
August 31, 2009**

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# FPGAs- A Sampling of Challenges

*Can we “qualify” without breaking the bank?*

New Silicon

- 90nm CMOS
- new materials

New Connectors

- higher-speed, lower noise
- serial/parallel

New Board Material

- thermal coefficients
- material interfaces

New Architectures

- new interconnects
- new power distribution
- new frequencies



New Workmanship

- inspection, lead free
- stacking, double-sided
- signal integrity

New Design Flows/Tools

- programming algorithms, application
- design rules, tools, simulation, layout
- hard/soft IP instantiation

New Package

- Inspection
- Lead free

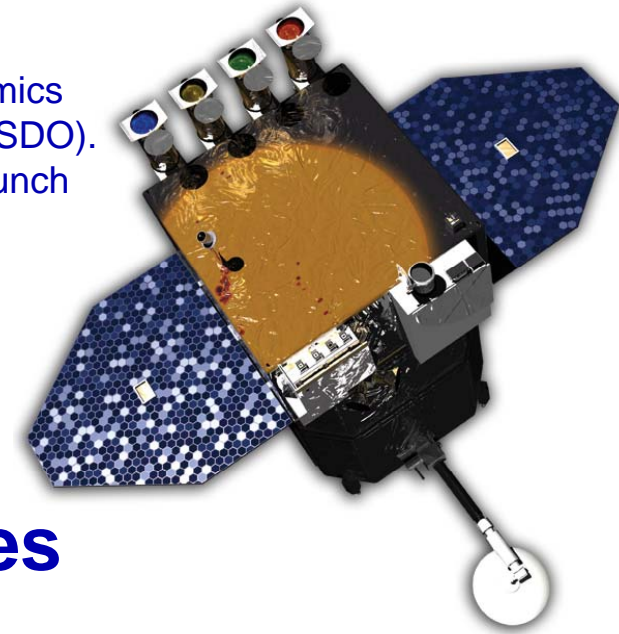
**Where we were**  
**©2006**



# Overview

- **Packaging Challenges**
- **Packaging Options**
- **Components of All Packages**
- **Commercial, Non-hermetic Packages**
- **Space Challenges to Packages**
- **A Non-hermetic, Complex Package for Space**
- **Hermeticity, Why Space Users Like It**
- **Non-hermetic, Complex Package Variations**
- **Class X**
- **Summary**

Solar Dynamics  
Observatory (SDO).  
Awaiting Launch



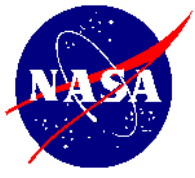


# Packaging Challenges

- **I/O s, increasing number, decreasing pitch**
- **Heat Dissipation, especially in space**
- **Manufacturability**
- **Materials**
- **Mechanical**
- **Installation**
- **Testability**
- **Inspectability**
- **Space Environment**
- **RoHS (Pb-free)**

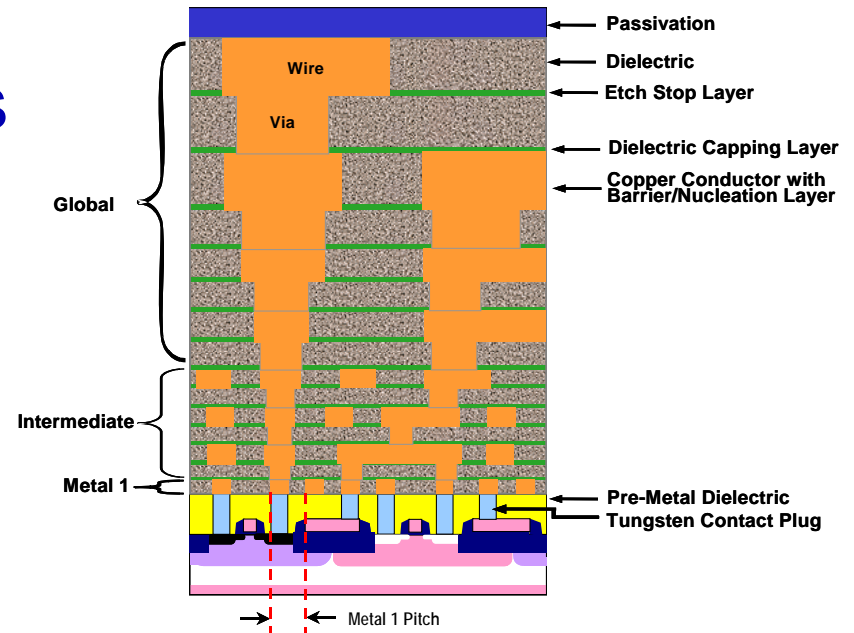


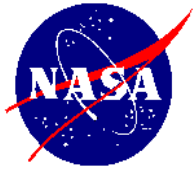
Lunar Reconnaissance Orbiter (LRO), Built at GSFC,  
Launched with LCROSS, June 18,2009



# Package Options – Hermetic?

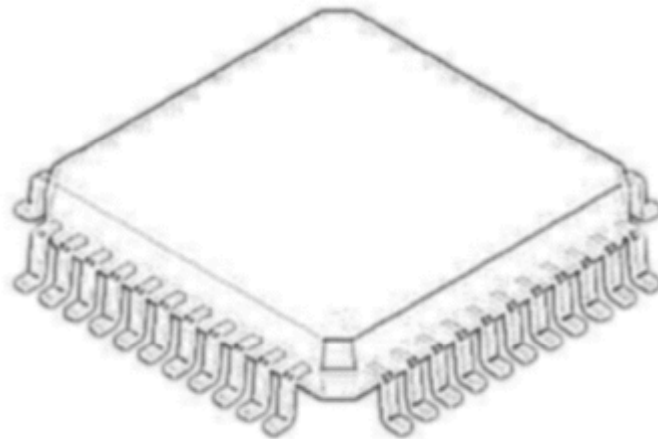
- Driven by consumer products
  - Low cost
  - High volume
  - Rapid turnover
  - “Green”
  - Minimized size
- Once, hermetic options existed for most package types
  - Now, few hermetic options for latest package technologies
  - Development of new hermetic options unattractive
    - » Very high NRE
    - » Very high technical difficulty
    - » Very low volume
    - » Demanding customers





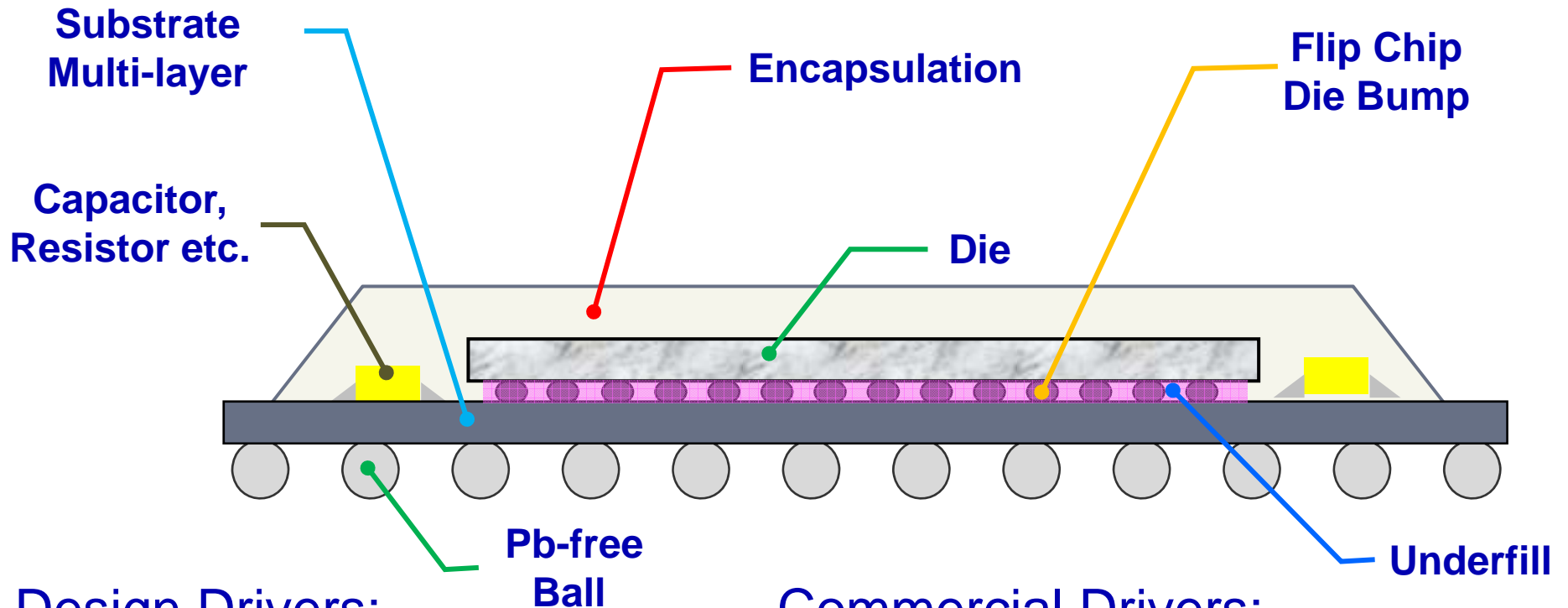
# The “General” Package

- Typically, packages consist of the same basic features but achieve them in many ways:
  - Functional elements - active die, passives etc.
  - Interconnects between elements (2 or more elements)
  - A substrate
  - Interconnects to the external I/O of the package
  - A protective package
  - Interconnects to the next higher level of assembly





# Commercial, Non-hermetic Package (PBGA)

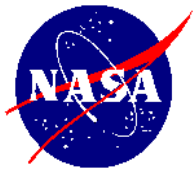


## Design Drivers:

- High I/O count
- Large die
- Environmental protection
- Performance/Speed
- Ancillary parts

## Commercial Drivers:

- Low cost
- High volume
- Limited life
- Automated installation
- Compact



# Space Challenges for Complex Non-hermetic Packages

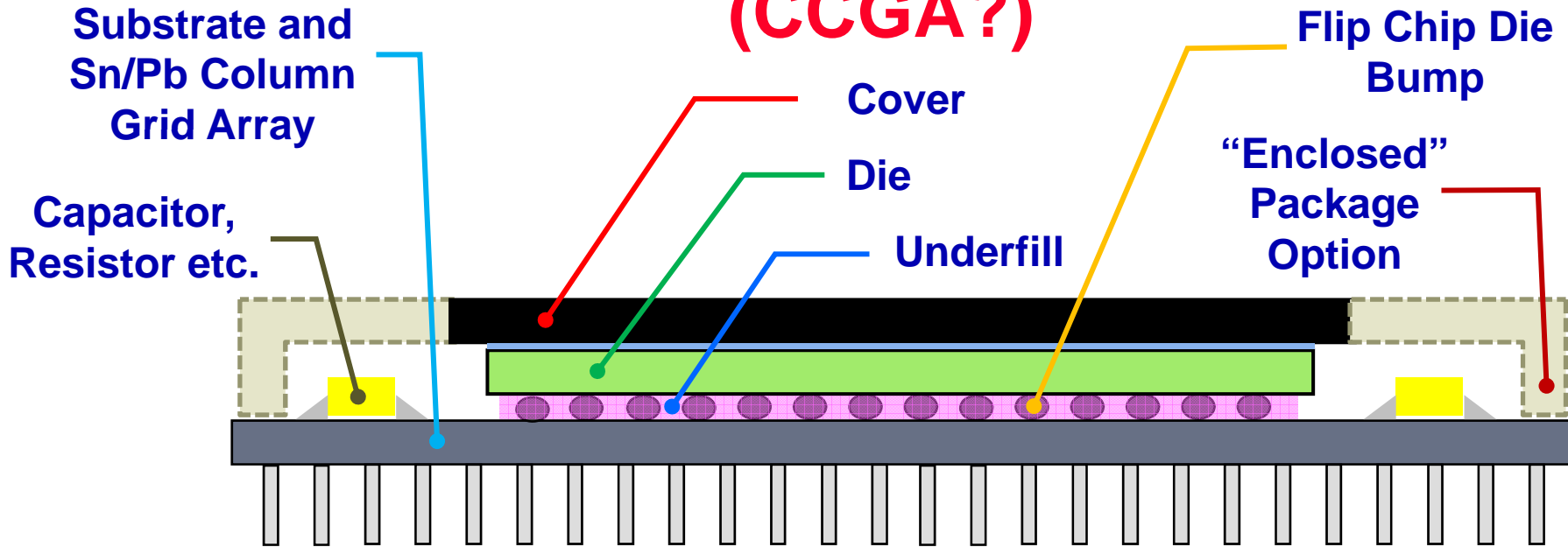
- **Vacuum:**
  - Outgassing, offgassing, property deterioration
- **Foreign Object Debris (FOD)**
  - From the package threat to the system, or a threat to the package
- **Shock and vibration**
  - During launch, deployments and operation
- **Thermal cycling**
  - Usually small range; high number of cycles in Low Earth Orbit (LEO)
- **Thermal management**
  - Only conduction and radiation transfer heat
- **Thousands of interconnects**
  - Opportunities for opens, intermittent - possibly latent
- **Low volume assembly**
  - Limited automation, lots of rework
- **Long life**
  - Costs for space are high, make the most of the investment
- **Novel hardware**
  - Lots of “one offs”
- **Rigorous test and inspection**
  - To try to find the latent threats to reliability

**ONE  
STRIKE AND  
YOU'RE OUT!**





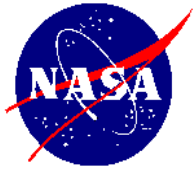
# Non-hermetic Package, With "Space" Features (CCGA?)



## Space Challenge

## Some Defenses

Space Challenge	Some Defenses
Vacuum	Low out/off-gassing materials. Ceramics vs polymers.
Shock and vibration	Compliant / robust interconnects - wire bonds, solder balls, columns, conductive polymer
Thermal cycling	Compliant/robust interconnects, matched thermal expansion coefficients
Thermal management	Heat spreader in the lid and/or substrate, thermally conductive materials
Thousands of interconnects	Process control, planarity, solderability, substrate design
Low volume assembly	Remains a challenge
Long life	Good design, materials, parts and process control
Novel hardware	Test, test, test
Rigorous test and inspection	Testability and inspectability will always be challenges



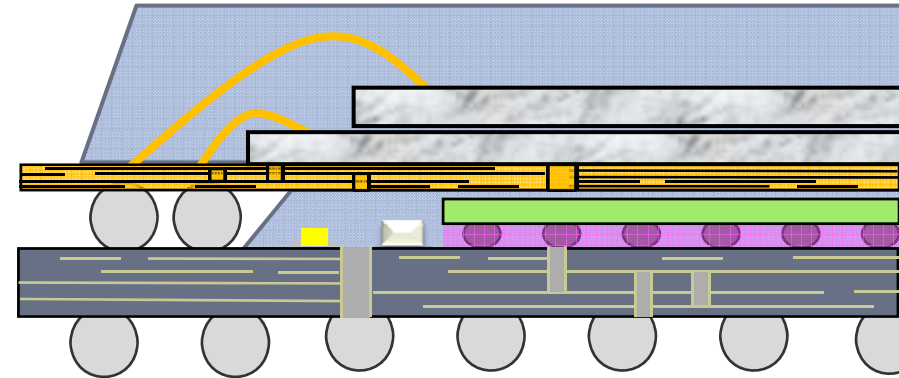
# Hermeticity

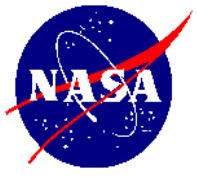
- NASA prefers hermetic packages for critical applications
- Hermeticity is measureable, assuring package integrity
- Only 3 tests provide assurance for hermetic package integrity:
  - Hermeticity – nothing bad can get in
  - Residual or Internal gas analysis – nothing bad is inside
  - Particle Impact Noise Detection – no FOD inside
- **NON-HERMETIC PACKAGE INTEGRITY IS HARD TO ASSESS - NO 3 BASIC TESTS**



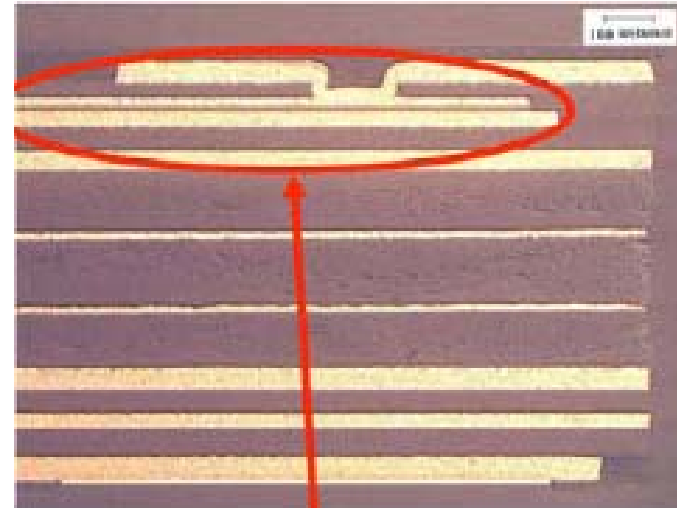
# Non-hermetic Package Variations

- Current and future package options mix and match elements in almost infinite combinations
- Elements include:
  - Wire bonds
  - Ball interconnects
  - Solder joints
  - Conductive epoxies
  - Vias
  - Multi-layer substrates
  - Multiple chips, active and passive (hybrid?)
  - Stacking of components
  - Embedded actives and passives
  - Polymers
  - Ceramics
  - Enclosures/encapsulants
  - Thermal control features

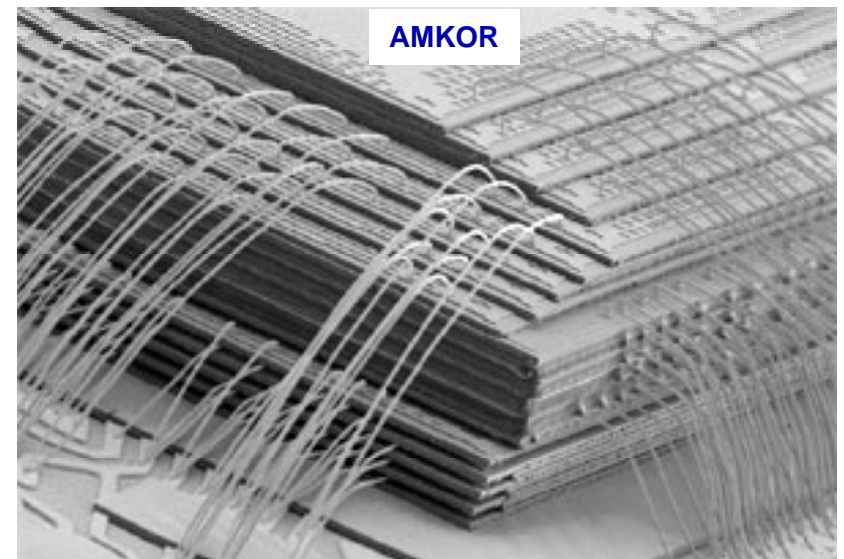
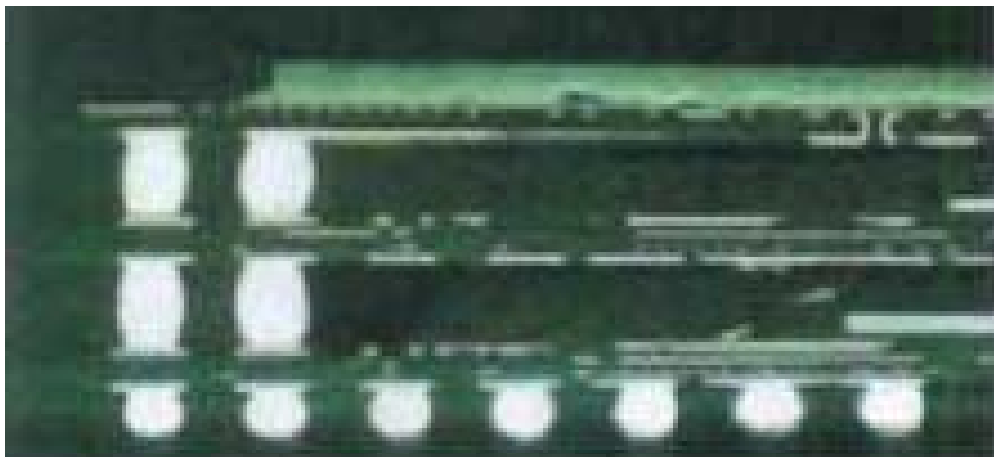


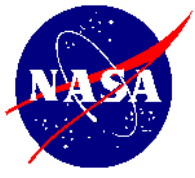


# Some Large Device Package Options

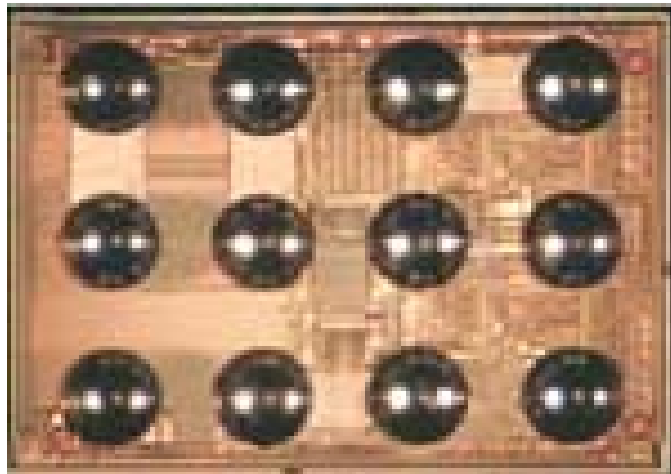


Embedded Capacitor





# Some Large Device Package Options



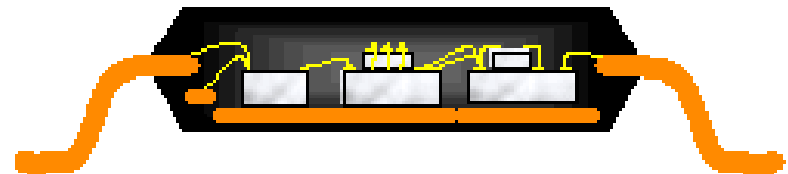
**2 Die Stack**



**3 Die Stack**



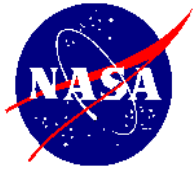
**6 Die Multi-Chip Module  
Stacked Die ePad LQFP**



From Amkor's Website <http://www.amkor.com/go/packaging>

# Why MIL Spec. for Space ?

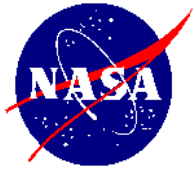
- **Space users like MIL spec. parts because:**
  - There are technical “rules” that apply equally to all suppliers
  - Qualification to recognized requirements
  - Visibility of change control
  - Required tests and inspections reduce or eliminate the need for the space user to do post-procurement tests
  - Transparent government process for reacting to performance issues
  - Space level participation provides an opportunity to do continuous improvement of the MIL supply chain for Class S (space grade) microelectronics
  - Our experience says They Work



## Class X

- **Proposed new class for MIL-PRF-38535**
- **Class X will be for Space level non-hermetic**
- **Class V will be defined as hermetic only**
- **Addition to Appendix B, “Space Application”**
- **Package-specific “package integrity” test requirements proposed by manufacturer, approved by DSCC and government space**
- **The Package Integrity Test Plan must address:**
  - **Potential materials degradation**
  - **Interconnect reliability**
  - **Thermal management**
  - **Resistance to processing stresses**
  - **Thermo-mechanical stresses**

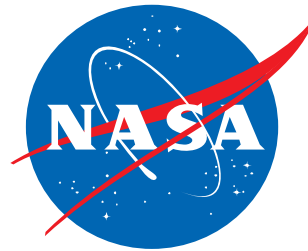
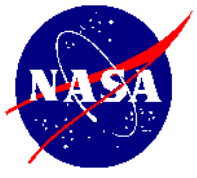




## Summary

- **NASA is going to have to accept the use of non-hermetic packages for complex devices**
- **There are a large number of packaging options available**
- **Space application subjects the packages to stresses that they were probably not designed for (vacuum for instance)**
- **NASA has to find a way of having assurance in the integrity of the packages**
- **There are manufacturers interested in qualifying non-hermetic packages to MIL-PRF-38535 Class V**
- **Government space users are agreed that Class V should be for hermetic packages only**
- **NASA is working on a new Class for non-hermetic packages for M38535 Appendix B, "Class X"**
- **Testing for package integrity will be required but can be package specific as described by a Package Integrity Test Plan**
- **The plan is developed by the manufacturer and approved by DSCC and government space**





<http://nepp.nasa.gov>