Jet Propulsion Laboratory
National Aeronautics & Space Administration
California Institute of Technology

Reliability of Commercially Available Ball Grid Array Packages for Aerospace Applications

by

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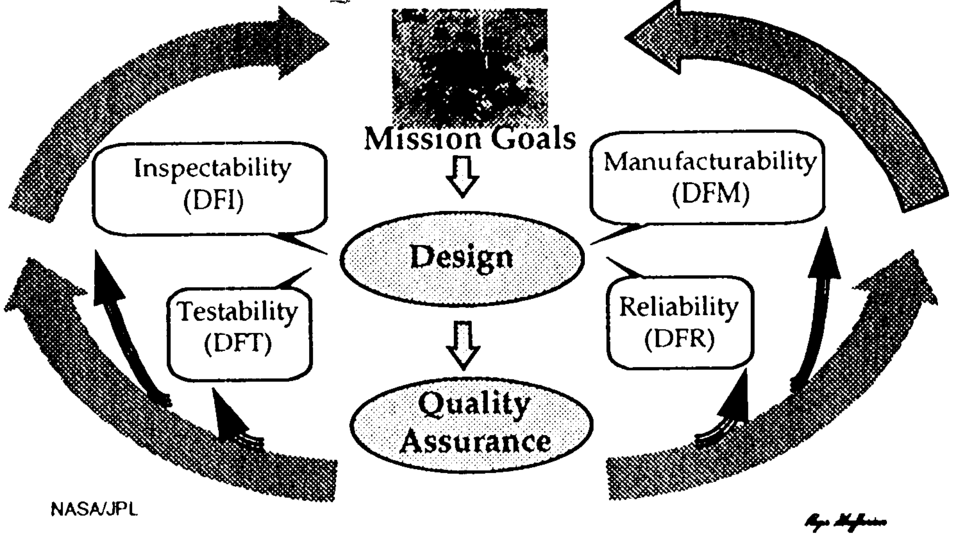
OUTLINE

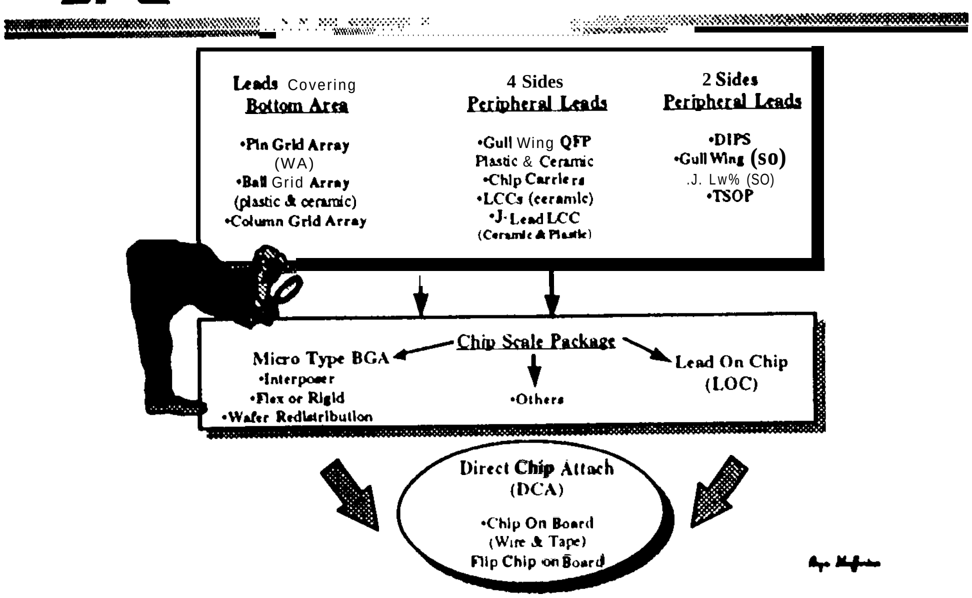
- QA Precative Approach
- SM Package Trends
- Introduction on Ball Grid Array
  - o Why BGA
  - o JPL-led BGA consortium
  - o Test Matrix- Design of Experiment
    - Test Vehicle using commercially available BGA packages
- Environmental Test
  - o Results on CBGA and PBGA
  - o Failure Mechanisms
- Conclusions

QUALITY ASSURANCE

Code U, PROACTIVE APPROACH



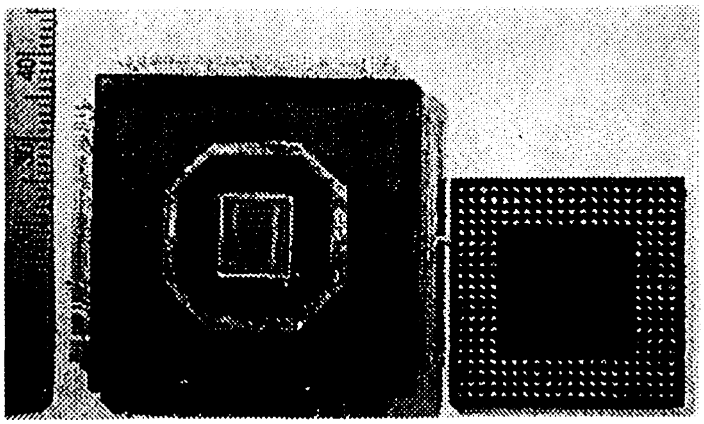
SM PACKAGE MINIATURIZATION TRENDS



WHY BGA

- Advantages
  - o Capable of high pin counts
  - o Manufacturing robustness
  - o Higher package densities
  - o Faster circuitry speed than QFP
  - o Better heat dissipation
  - 0
- Challenges
  - o Inspection
  - o Multiple processes and double sided assemblies
  - o Routing for high pin count
  - o Rework

BGA & QFP



BGAS ARE ROBUST IN MANUAFACTURING

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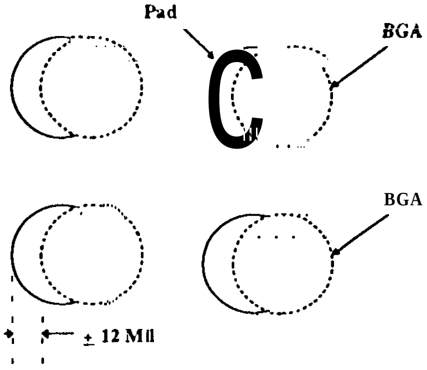
BGAs Are Robust

- Placement accuracy: ±12 mil
- Vision Not Required
- BGA Self-Center during Reflow Process



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OBJECTIVES

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Demonstrate robustness and quality & reliability of Ball Grid Arrays (BGAs) interconnects

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Support the development of industrial infrastructure in BGA product assurance

- Inspection methodology development, especially for assembly level
- Optimal package configuration- Full vs. peripheral
- Reliability characterization of CBGA/PBGA
  - o 1/0 & Environmental dependency
- Reworking techniques

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APPROACH

- Formed core consortium teams (JPL, Hughes, Boeing, RIT)
  - o Reviewed literature and defined critical variables

- Workshop at JPL to understand industry's needs
  - o Trends data from ITRI & SEMATECH, and input from others
  - o Design of Experiment (DOE) test matrix used for efficiency

- Assemble more than 200 Test Vehicles
  - o 300& 6001/0s packages, FR-4, Polyimide, 3 solder volume, 2 flux types, 2 manufacturing sites, 2 temp. cycling ranges, power cycling, and limited other variables

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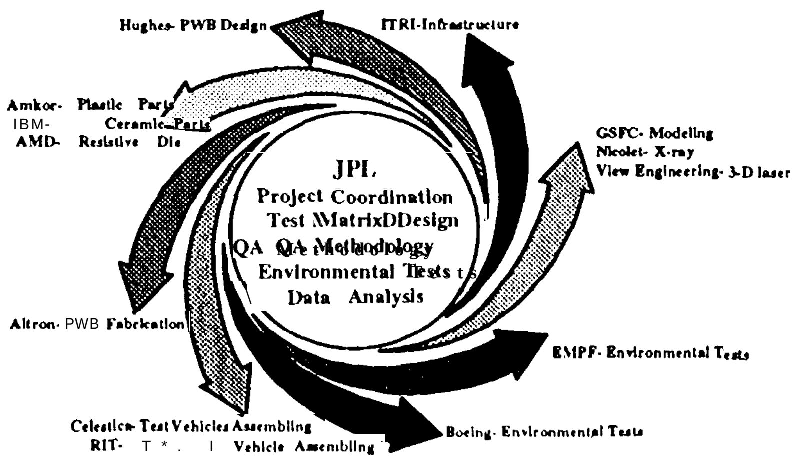
CONSORTIUM



JPL DESIGN OF EXPERIMENT

- 2- Level toggled parameters
  - o **Package type - CBGA and PBGA**
  - o **Package 1/0s - "300" and "600**
  - o **PWB materials - FR-4 and Polyimide**
  - ❑ **Flux type - RMA and Water soluble**
  - o **Environmental test- two temperature ranges**
  - o **Manufacturing sites- Mature (Celestica) and startup (RIT)**
- 3- Level toggled parameters
  - O **Solder volume**
  - o **Surface finish- OSP, limited HASL and electroless Ni/Au immersion**
- Others
  - o **Power cycling and vibration toggled with PWB materials**
  - o **Mixed technologies- Manufacturing robustness of BGA and 16 mil pitch QFP**

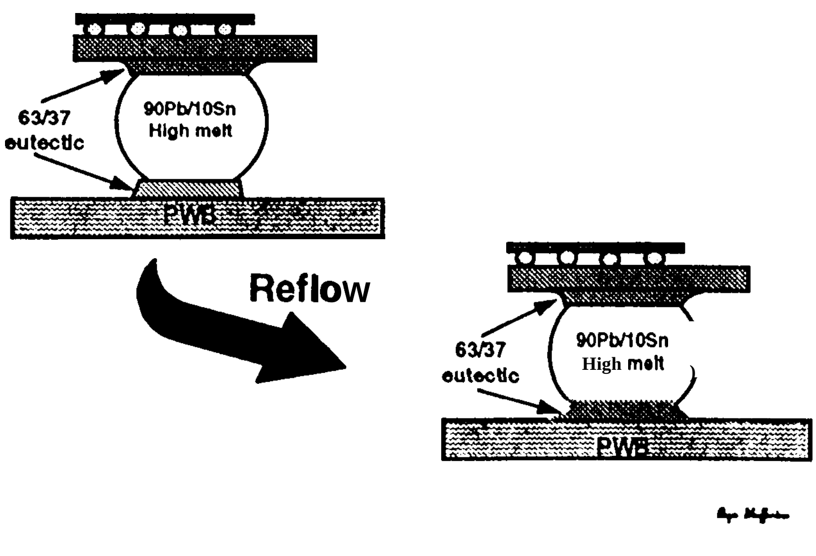
JPL PACKAGE/ASSEMBLY CRITICAL VARIABLES

- **BGA PACKAGE TYPE& I/O**
  - o Package type - CBGA and PBGA with die
  - o Package 1/0s - "300" and "600", Package planarity
  - o PWB materials - FR-4 and Polyimide
- **MANUFACTURING**
  - o Process optimization
  - o Mixed technology- Robustness of BGA and 16 mil QFP
  - o Solder volume, Flux type - RMA, Water soluble, no clean
  - o Surface finish- OSP, HASL and electroless Ni/Au immersion
- **, ENVIRONMENTAL CONDITION**
  - o Temperature cycle
  - o Power cycle, vibration, etc.

PACKAGE PLANARITY

- CBGA625 <.004” & CBGA361< .002
  - Coplanarity is critical
    - **High melt solder ball and no collapse in reflow**
- SuperBGA 560 & 352<.006 or higher
- OMPAC<.006
  - Coplanarity is not as critical as CBGA
    - **Solder balls collapse during reflow**
- 3-D Laser
  - Fast and accurate for planarity, warpage, and through position measurements

CERAMIC BGA SOLDER BALLS CONTROL HEIGHT



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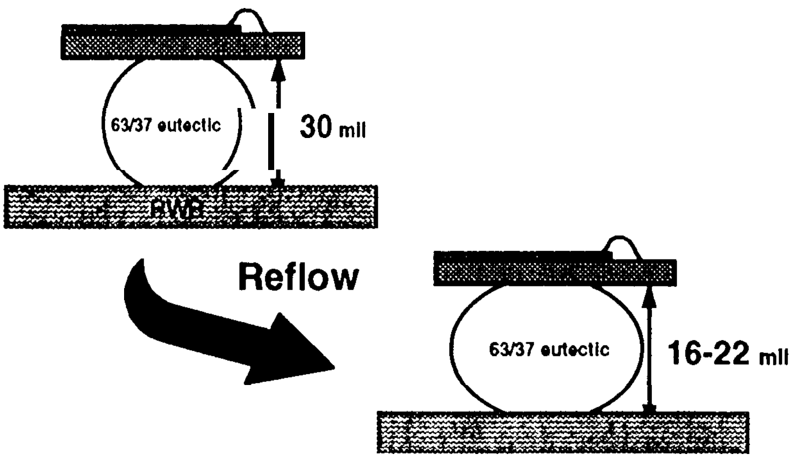
PLASTIC BGA SOLDER BALLS COLLAPSE



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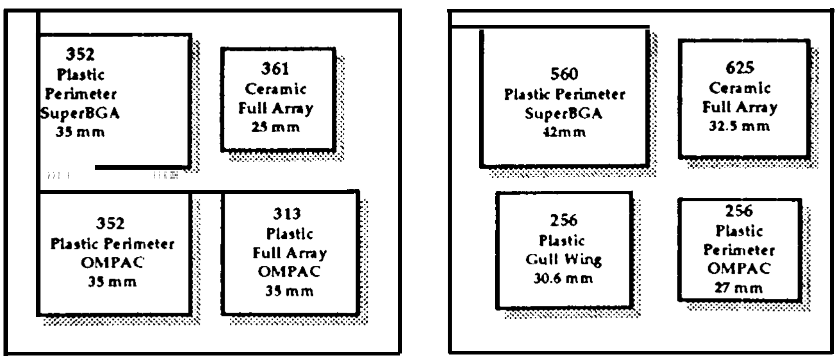
TEST VEHICLES



Type 1 "300" I/Os

Type 2 "600" I/Os

JPL THERMAL CYCLING

- THERMAL CYCLING
  - o Military (-55 to 125 'C)
  - 0 Others, majority (-30 **to 1000** C), few NASA cycle (-55 to 100 'C) for baseline

- . TESTING TIME (estimated using Motorola data)
  - o Type 1 -CBGA 361 for Boeing cycle- **low** -400 and No- 800 cycles
    PBGA 361- **low -1800 and average 3,255**
  - **0** Type 2- CBGA 625- **low 150, No- 200**

Due to larger CTE mismatch of CBGA packages on FR-4/Polyimide, time to failures for CBGA assemblies are much shorter than PBGAs

JPL DELIVERABLES

- Weibull Reliability Plots
  - o Results for DOE matrix variables
- Coffin-Manson Relationship
  - o Increase in package 1/0 & Change in temperature ranges
- Manufacturing defect
  - o Frequency of defects for BGA and mixed technology
- Correlation
  - o Mfg. defect and cycles to failure and crack propagation mapping
- Guidelines Documentation

FAILURE DISTRIBUTIONS

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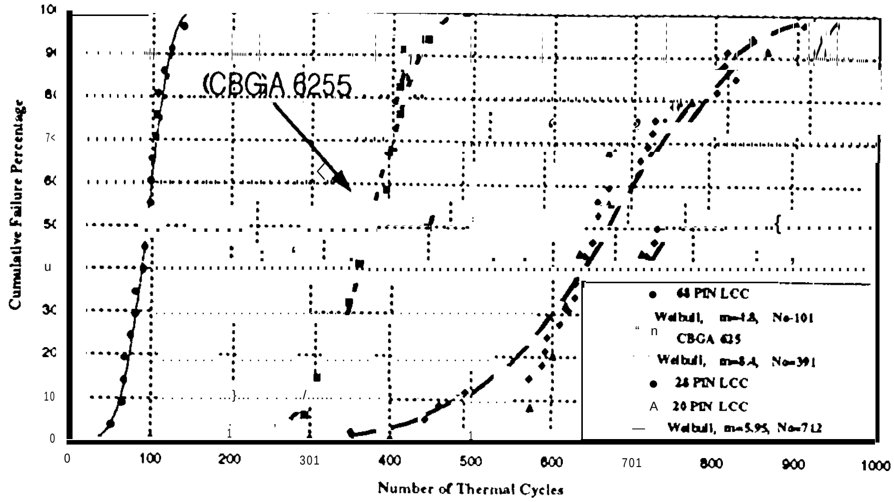
CBGA 625 & 20-, 2s-, 68-PIN LCCS



Failure in CBGA 625

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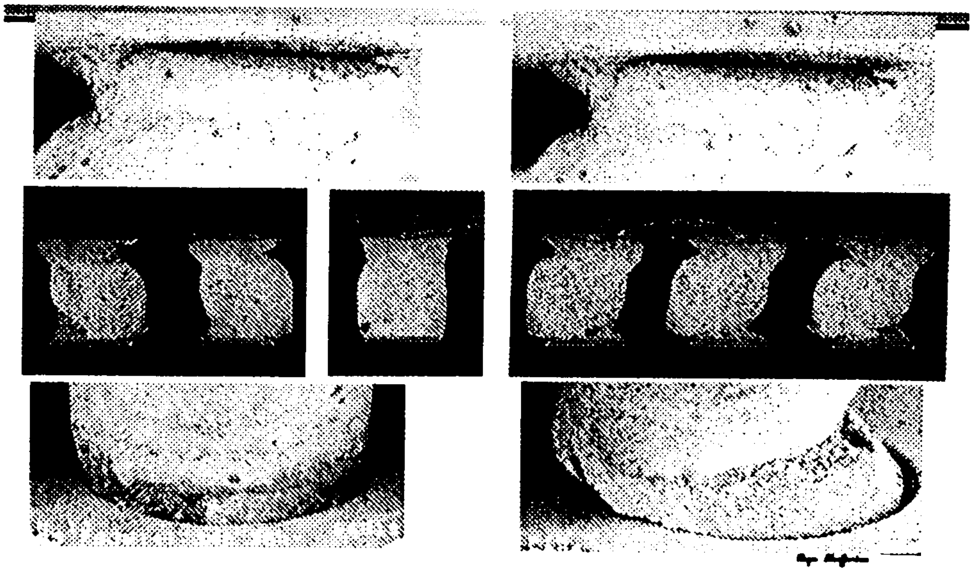
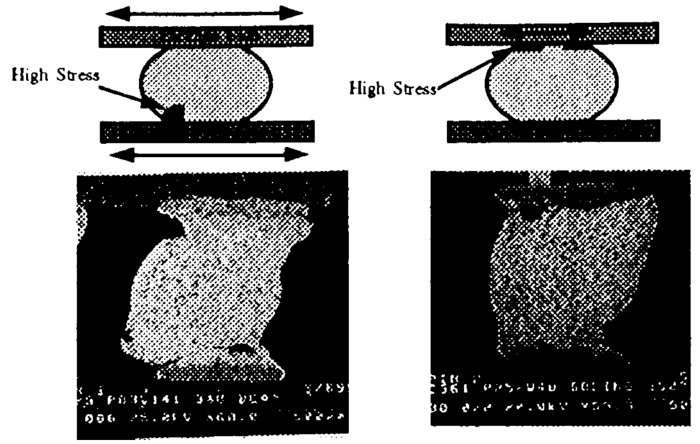
(-30"C to 100"C)



Failure Mechanism
JPL Cycling Condition

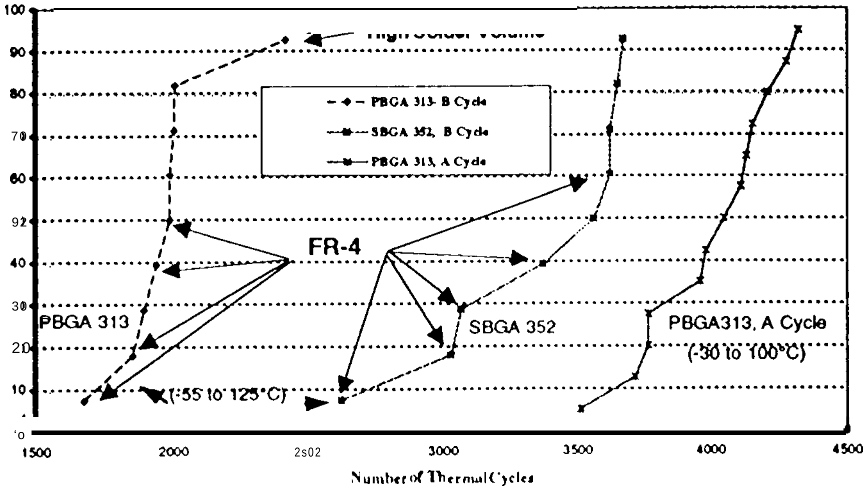


Global CTE Mismatch
-3 0”C0100”C

Local CTE Mismatch
-55°C⇔125°C

FAILURE DISTRIBUTION

JPL PBGAs- (55°C to 125°C, 6S minutes, B; -30°C to 100°C, 82 minutes, A)



CONCLUSIONS

- CBGA 6251/0s were first to fail under different cycling ranges than
  - o CBGA 361
  - o SBGA 560, SBGA 352, OMPAC 352, and PBGA 256 when cycled to different temperature ranges
- PBGAs 313 **1/0,** depopulated full arrays, were first among the PBGAs to fail
- SBGA 352 with no solder balls under the die showed much higher cycles to failure than the PBGA 313

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