NASA-DoD Lead-Free Electronics Project: Mechanical Shock Test

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NASA-DoD Lead-Free Electronics Project

- **Objective:** Formed to determine reliability of lead-free solders for military/aerospace. Effects of rework and solder mixing are being examined. Builds on the earlier JCAA/JG-PP Lead-Free Solder Project.

- **Testing**
  - Vibration (up to 28 Grms)
  - Mechanical Shock
  - Thermal Cycle (-55 to +125°C)
  - Thermal Cycle (-20 to +80°C)
  - Combined Vibration/Thermal Cycle
  - Copper Dissolution
  - IST Testing

- **Website**
  http://www.acqp2.nasa.gov/NASA_DODLeadFreeElectronics_Proj2.html

Mechanical Shock Testing

- **Solders tested:**
  - Sn3.0Ag0.5Cu (reflow) (SAC305)
  - Sn0.7Cu0.05%Ni (wave) (SN100C)
  - Sn4.0Ag0.5Cu (BGA balls)(SAC405)
  - Sn1.0Ag0.5Cu (CSP balls)(SAC105)
  - Sn37Pb as a control

- **Board finishes:** Immersion silver, ENIG
- **Board:** 6 layers,0.090 in.,FR4 (Tg of 170°C)

Mechanical Shock Testing

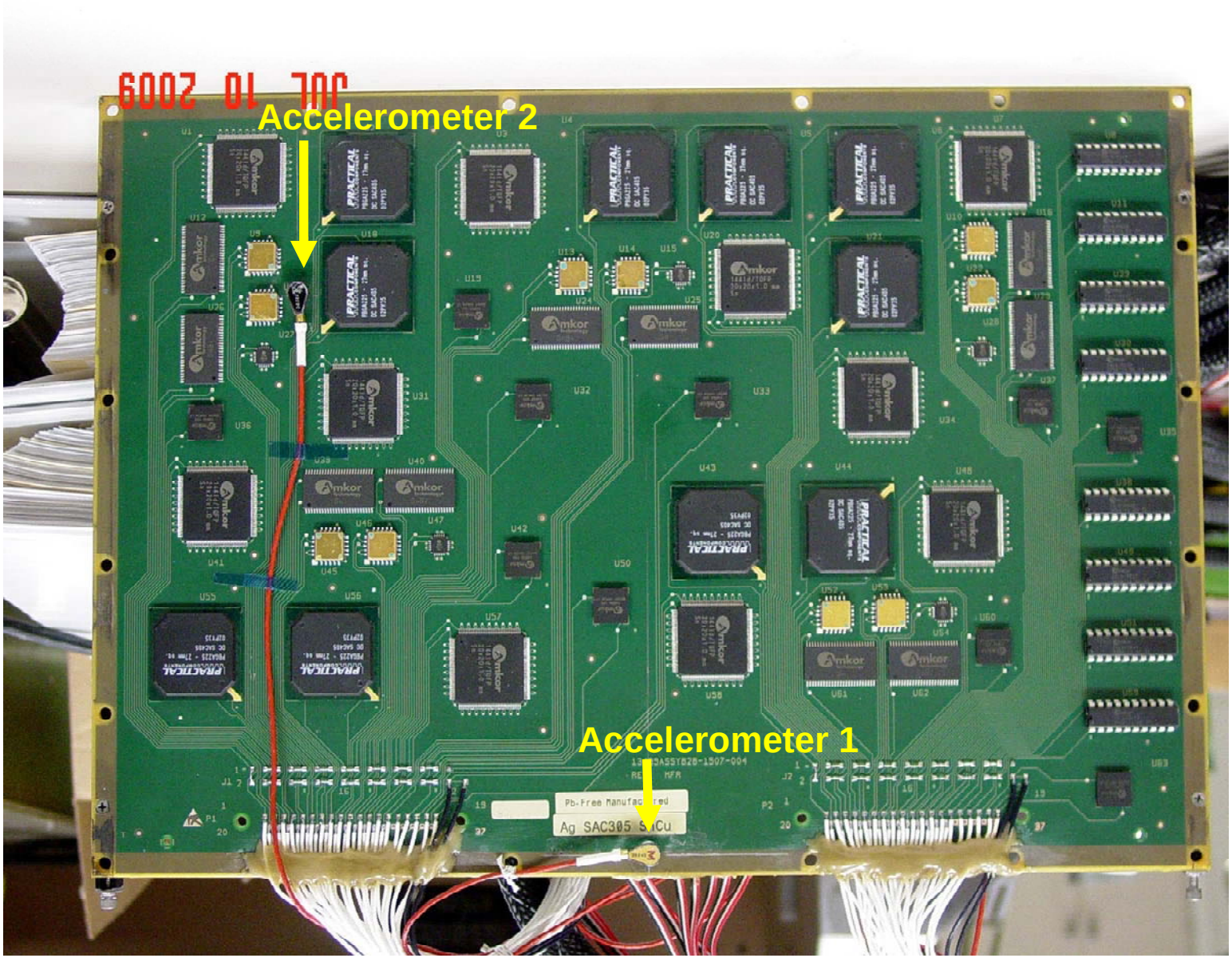
- **Components**
  - BGA-225
  - CSP-100
  - CLCC-20
  - QFN-20
  - PDIP-20
  - TQFP-144
  - Alloy 42 TSOP-50

- Two types of test vehicles

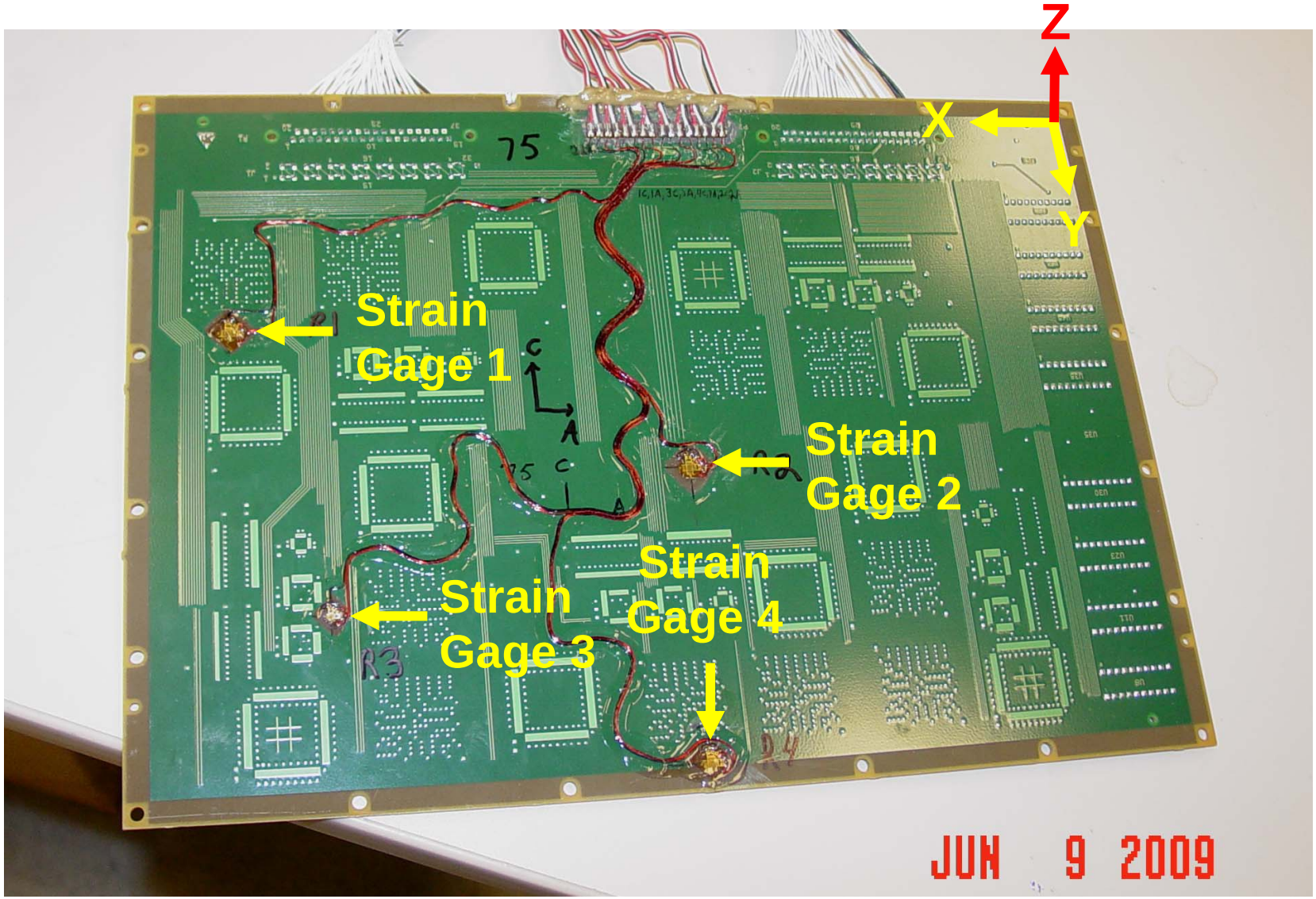
  - **"Manufactured"** – 5 SnPb; 5 lead-free

  - **"Rework"** – 6 SnPb; 5 lead-free. Reworked six BGA's; six CSP's; two PDIP's; and four TSOP's. Also mixed SnPb/lead-free. One SnPb test vehicle had an ENIG finish.

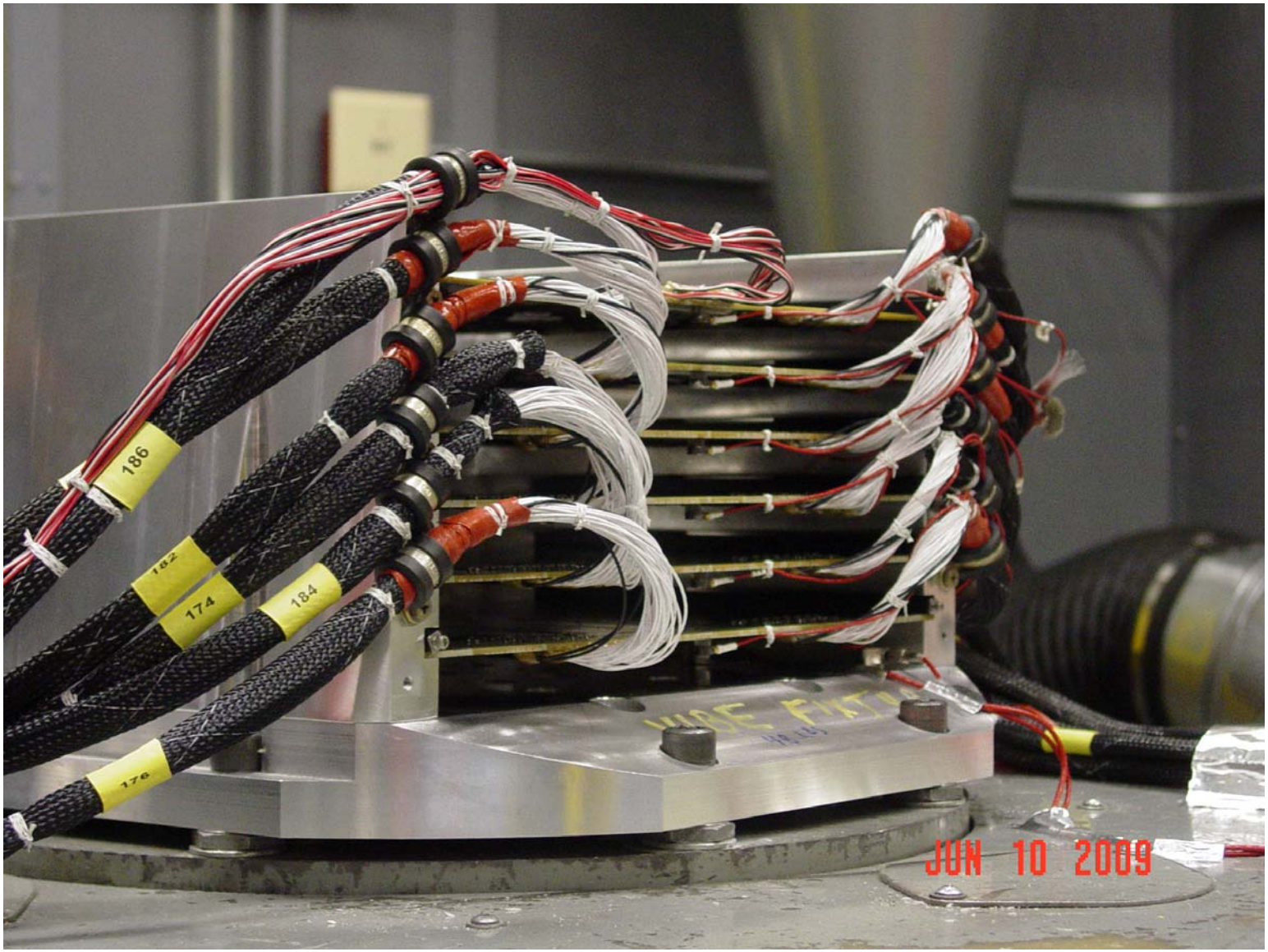
NASA-DoD Test Vehicle



Strain Gages Applied to One Test Vehicle

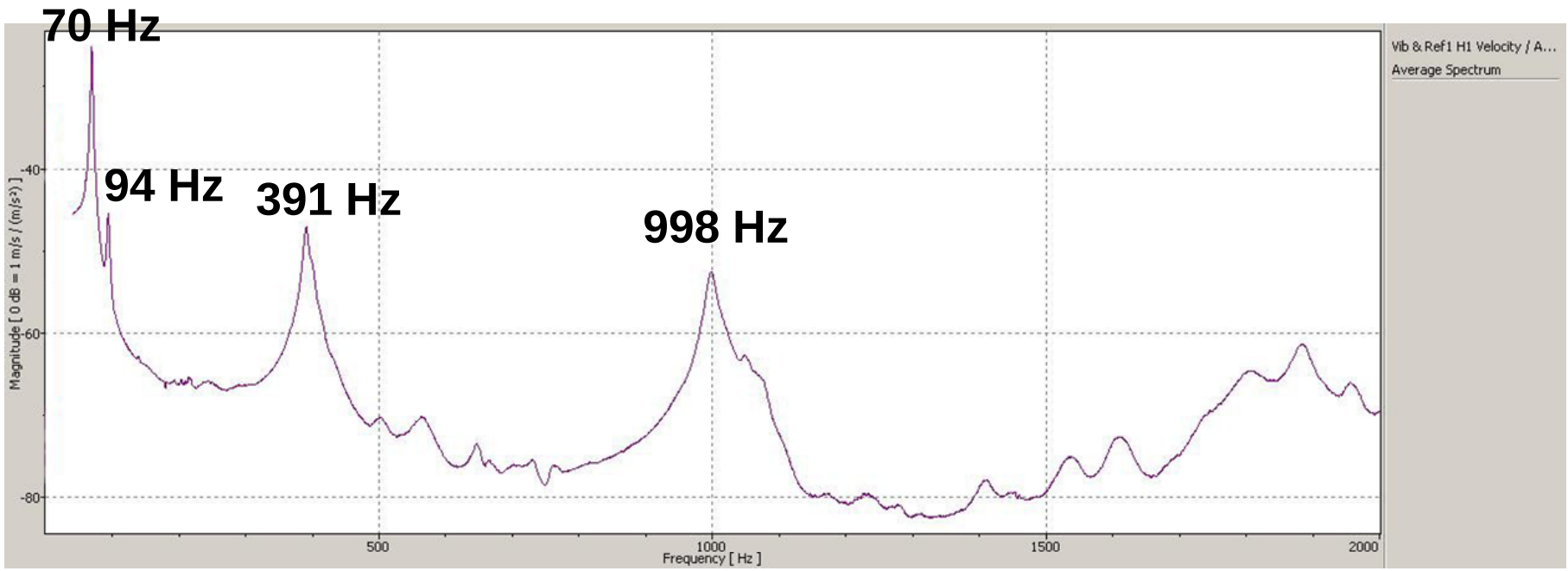


Test Vehicles in Fixture



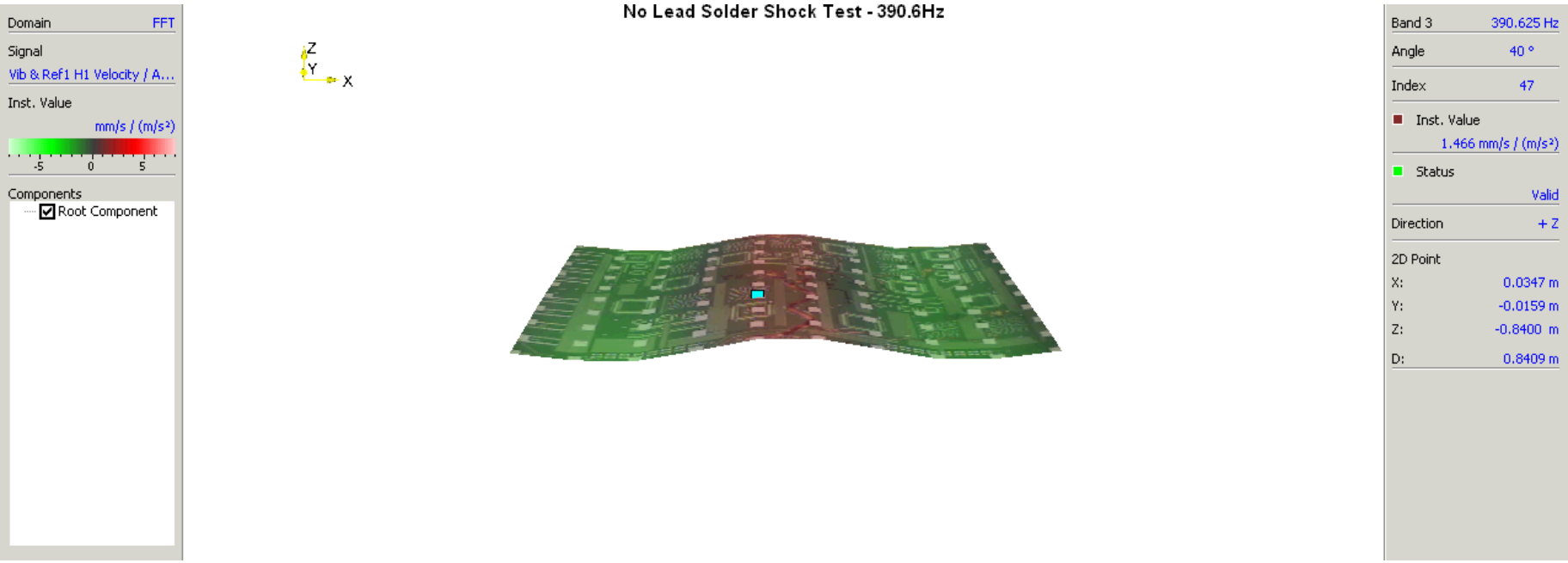
Laser Vibrometer
Mounted Over Fixture

Modal Analysis of Test Vehicle Using the Laser Vibrometer and Random Excitation

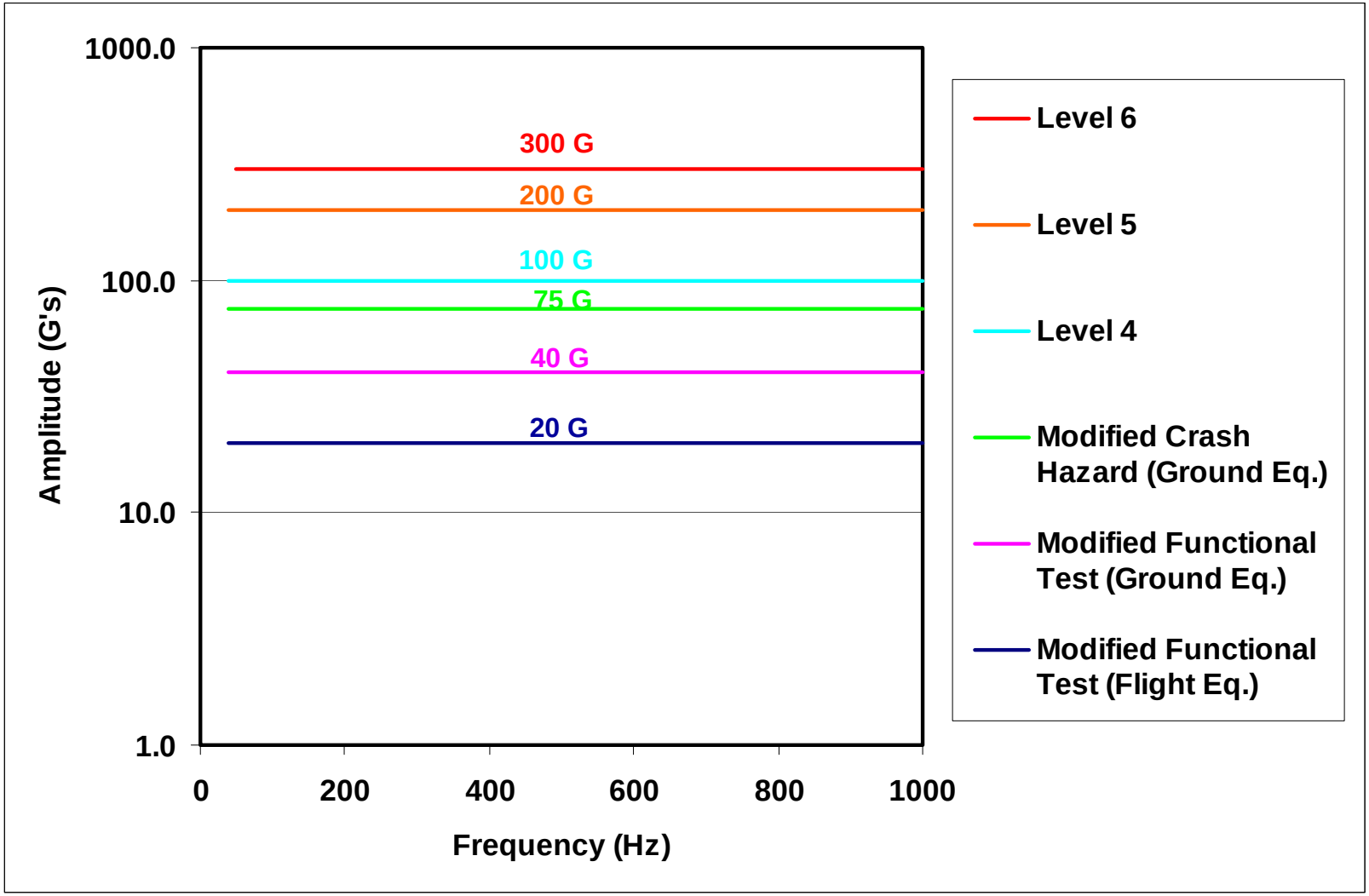


Mode Shape at 70 Hz

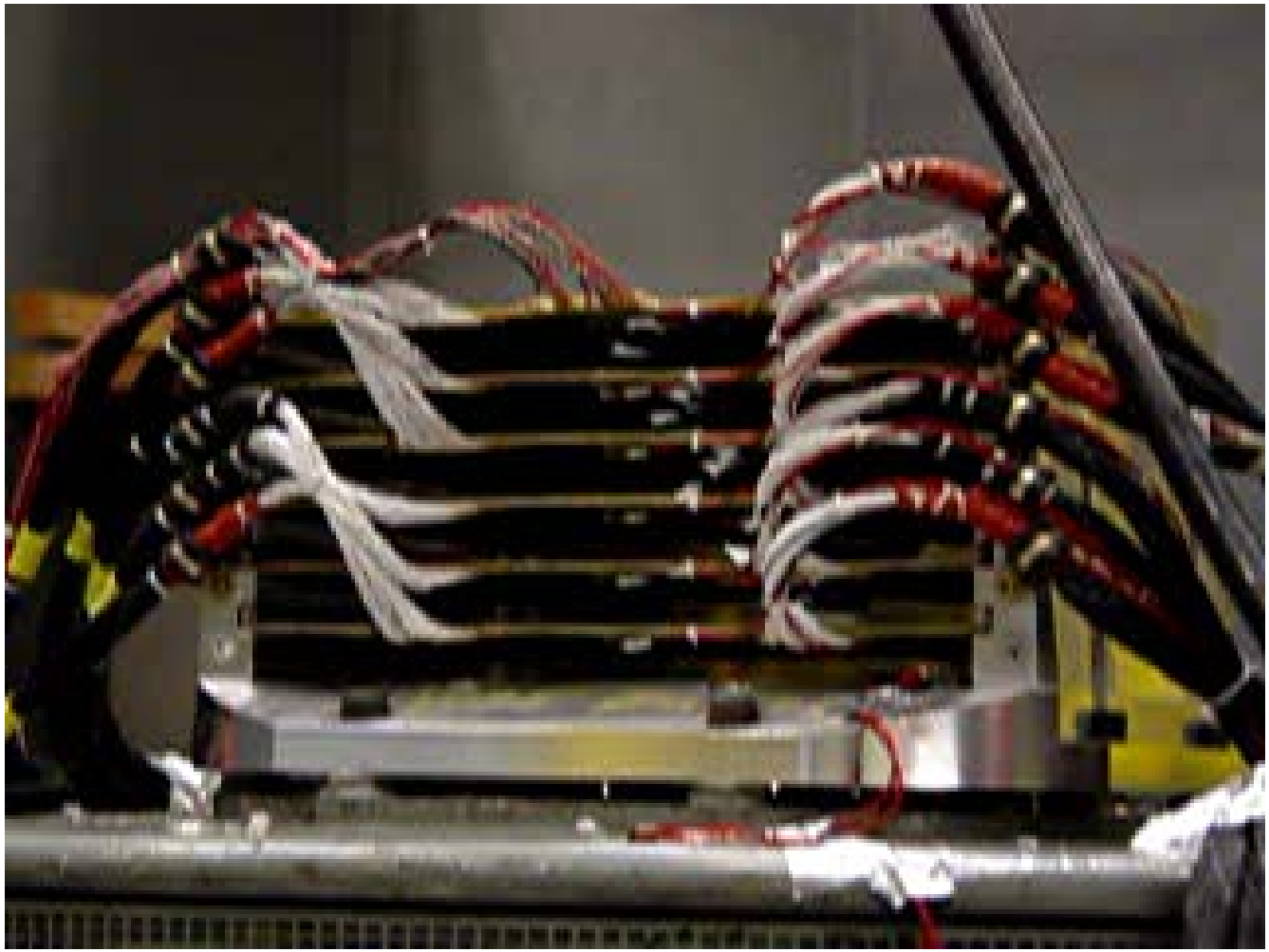
Mode Shape at 391 Hz



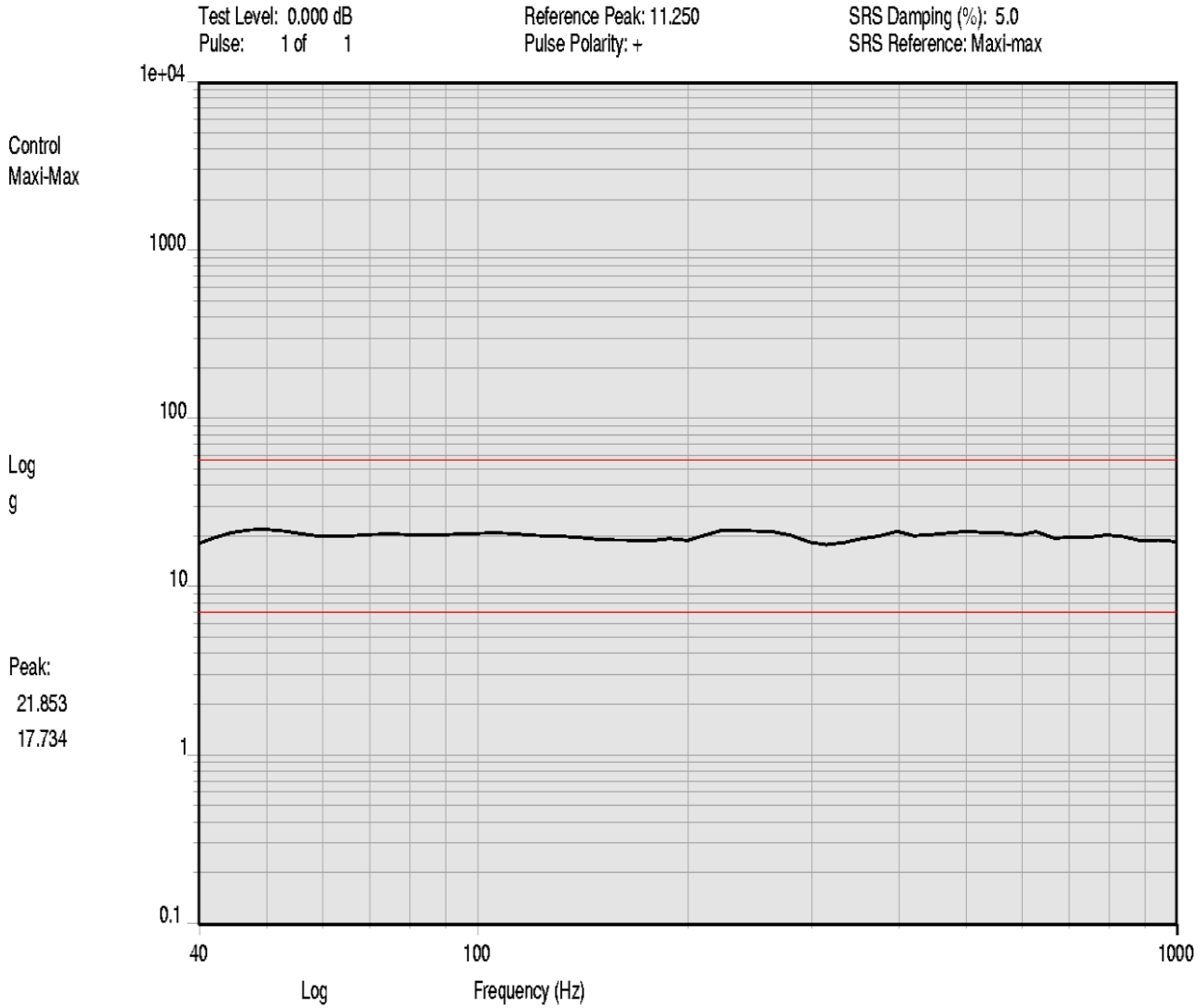
Mechanical Shock SRS Test Levels



Levels 1 through 5: 100 shock pulses per level
Level 6: 400 shock pulses



20 G SRS Input (Accelerometer on Fixture)



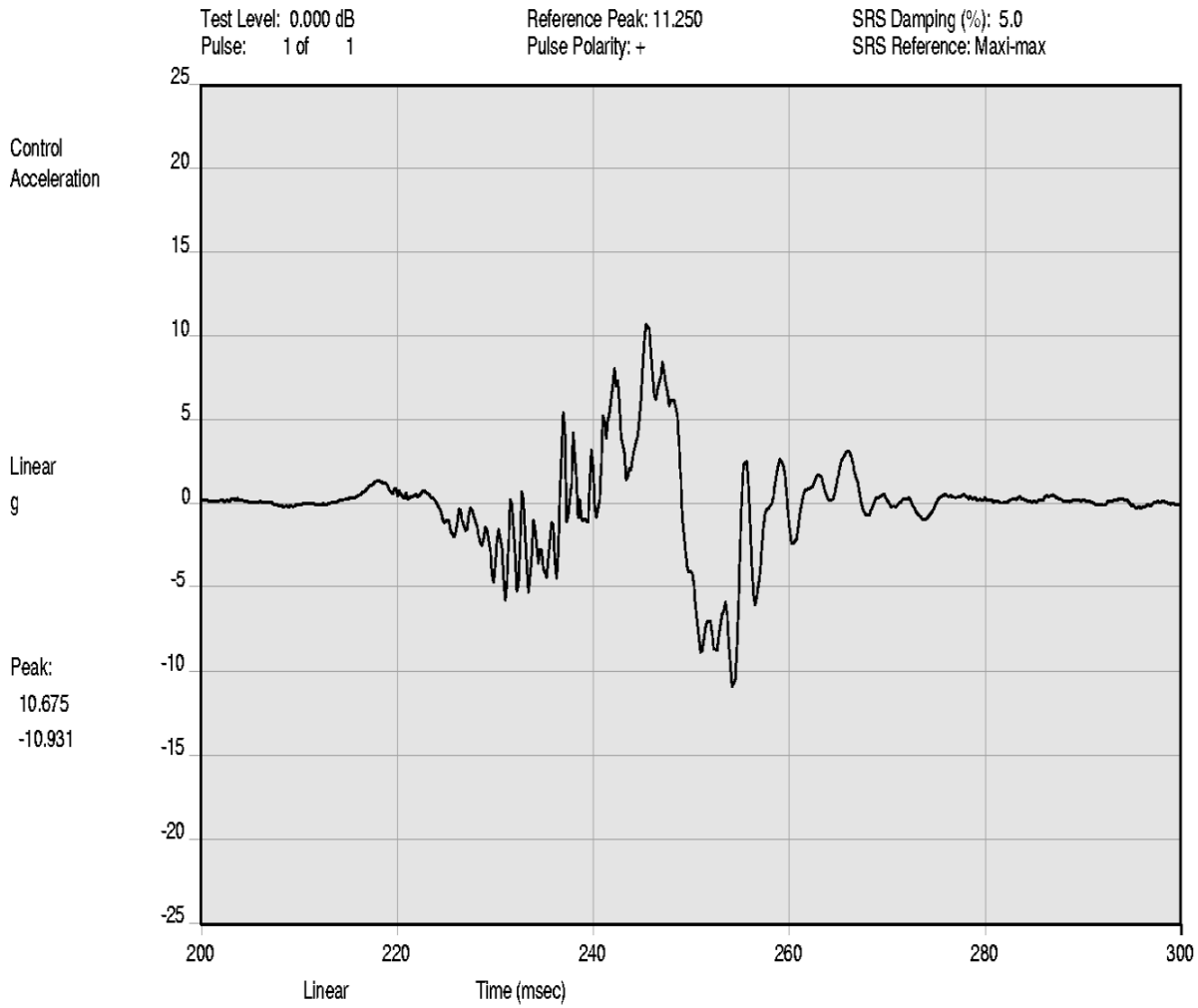
#1Z, Control base outboard by wall

16:28:03.3
Tue Jun 02 2009

CITAP 907 No Lead, Circuit Boards: #30,31,88,89 Pulse #10
Run #5 Z-axis, Level#1 20g, 40-1000Hz

Shock Synthesis Test Name: tn2122_shock_20g-40hz_a.003

Pulse Used to Create 20 G SRS Input (Accelerometer on Fixture)



#1Z, Control base outboard by wall

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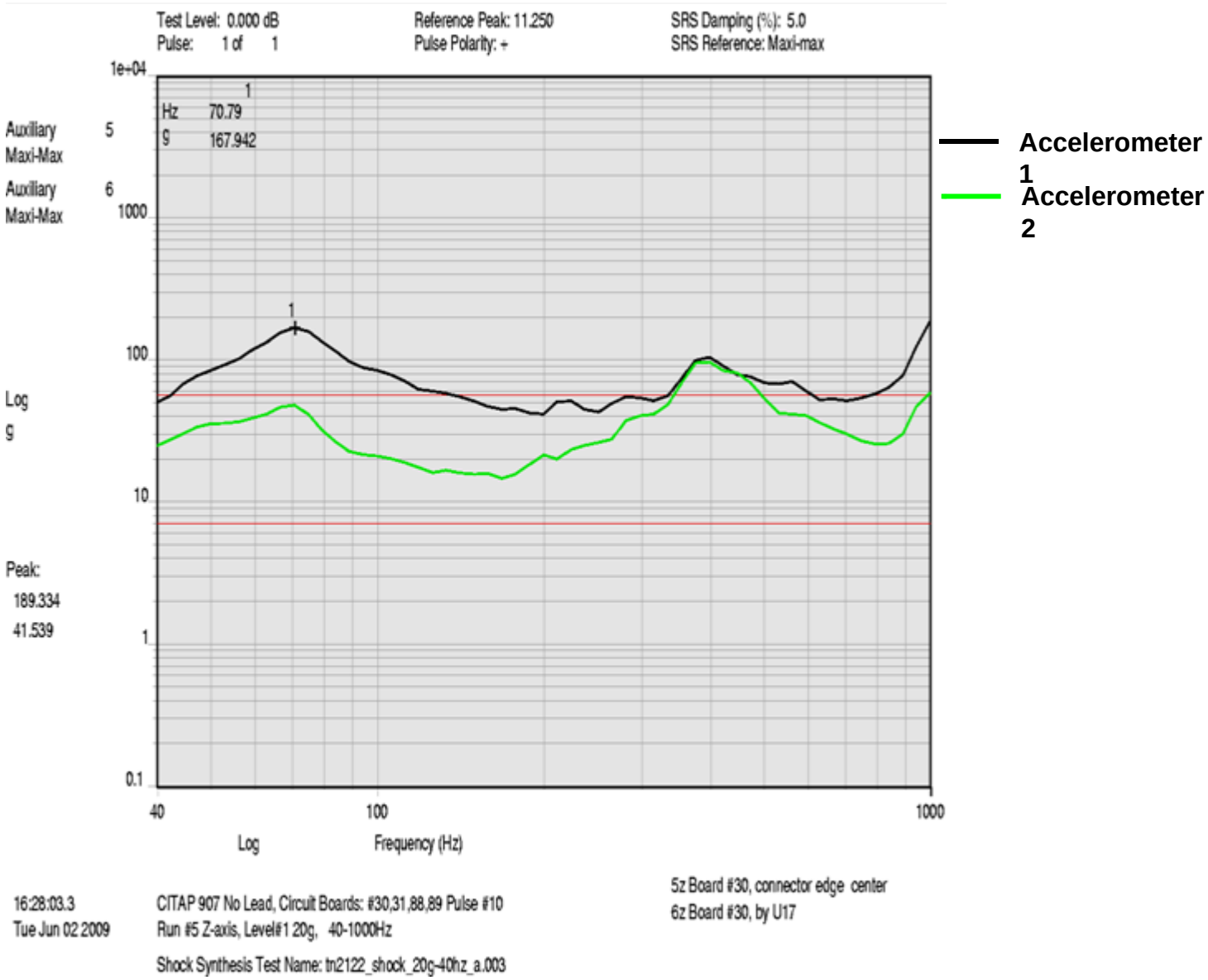
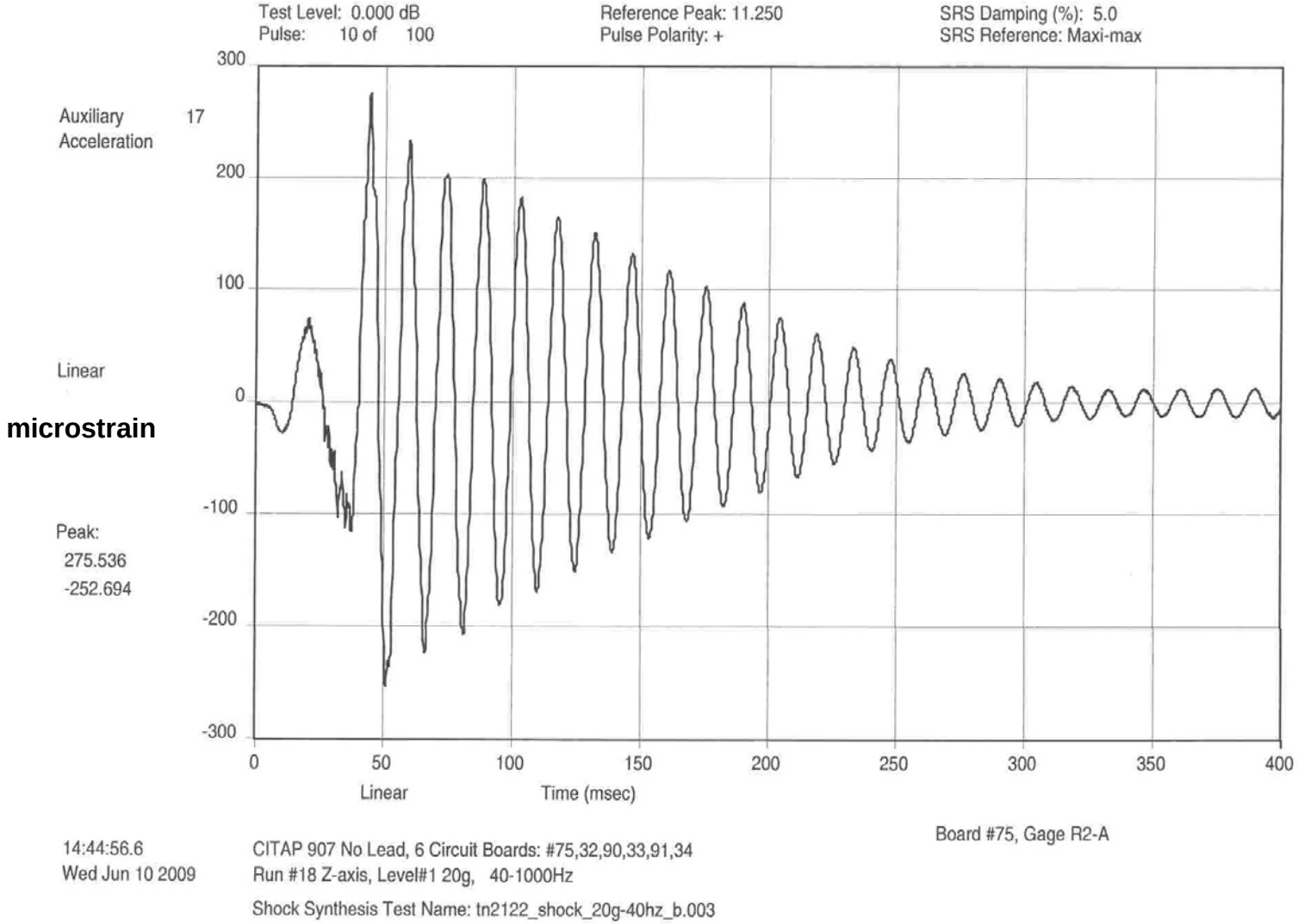
CITAP 907 No Lead, Circuit Boards: #30,31,88,89 Pulse #10
Run #5 Z-axis, Level#1 20g, 40-1000Hz

Shock Synthesis Test Name: tn2122_shock_20g-40hz_a.003

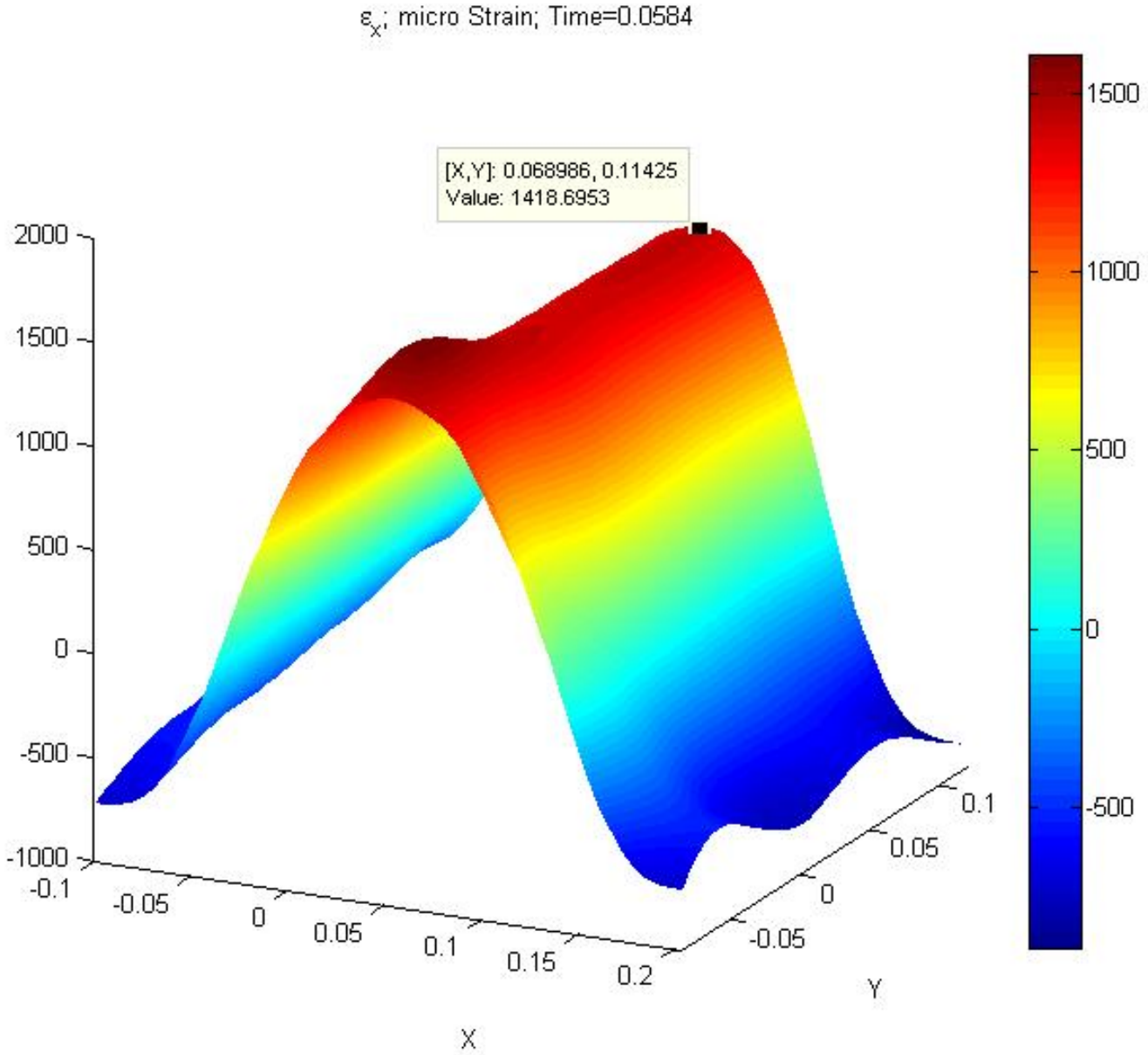
Test Vehicle SRS Response to 20 G SRS Input



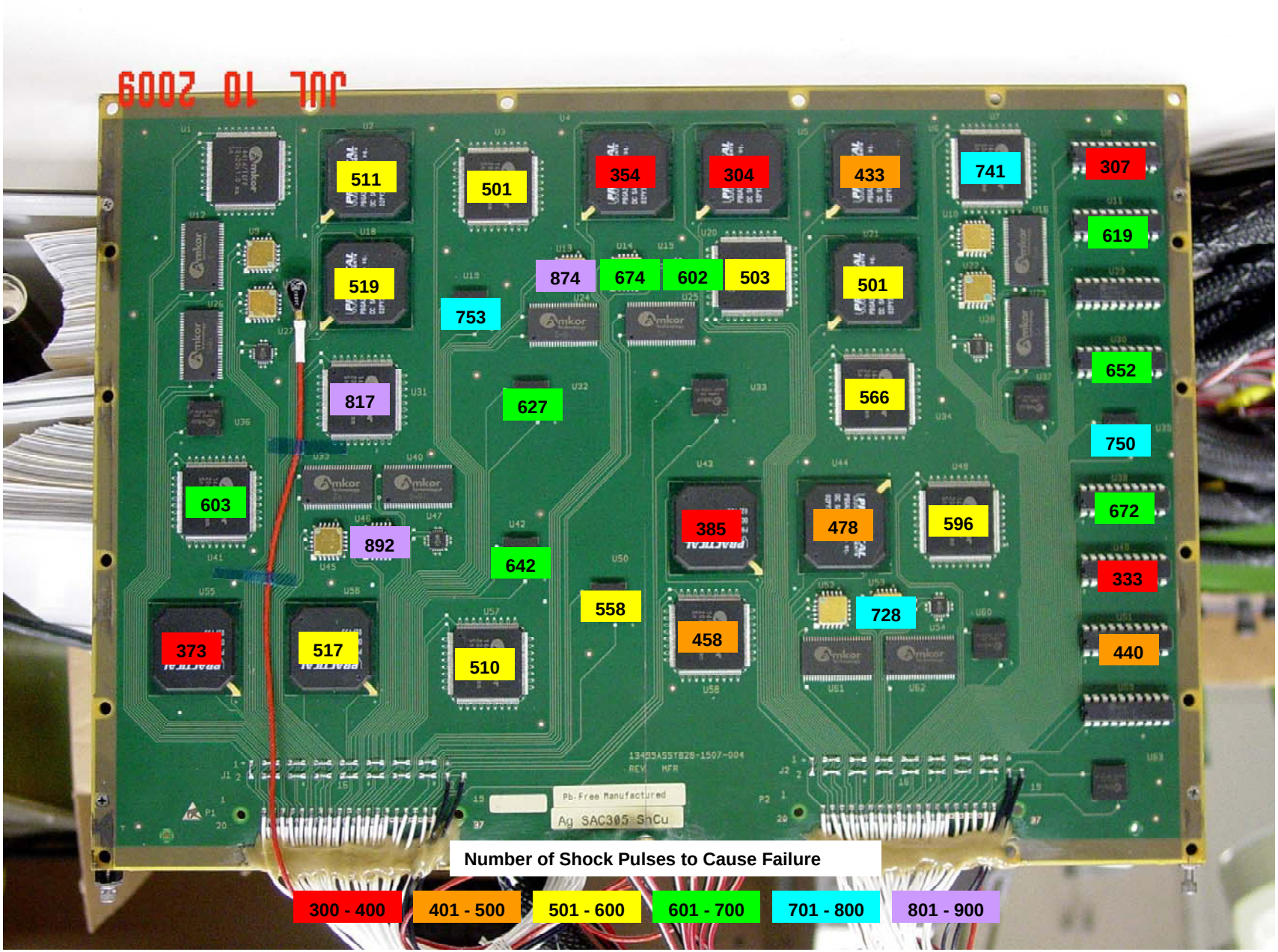
Test Vehicle Time History Strain Response to 20 G SRS Input (x-Direction)



Peak Strains during 100 G Shock Pulse from All Modes Combined (in microstrain)



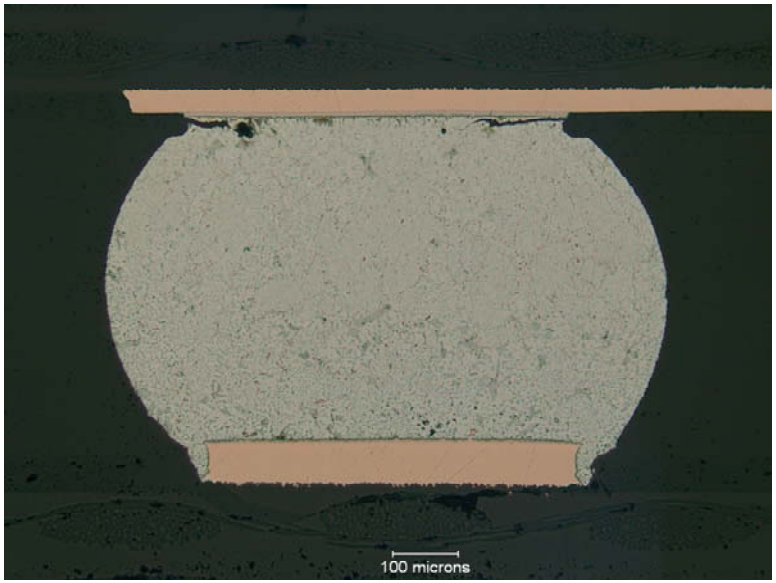
Number of Shocks Required to Fail Components

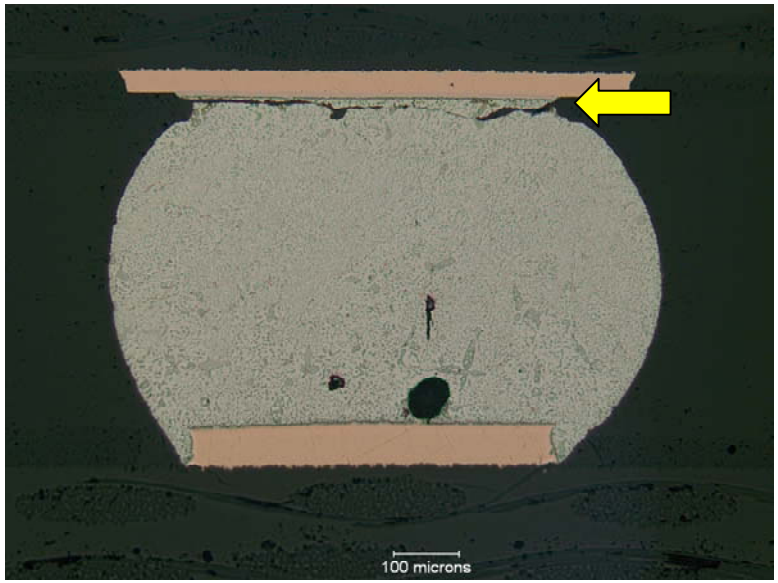


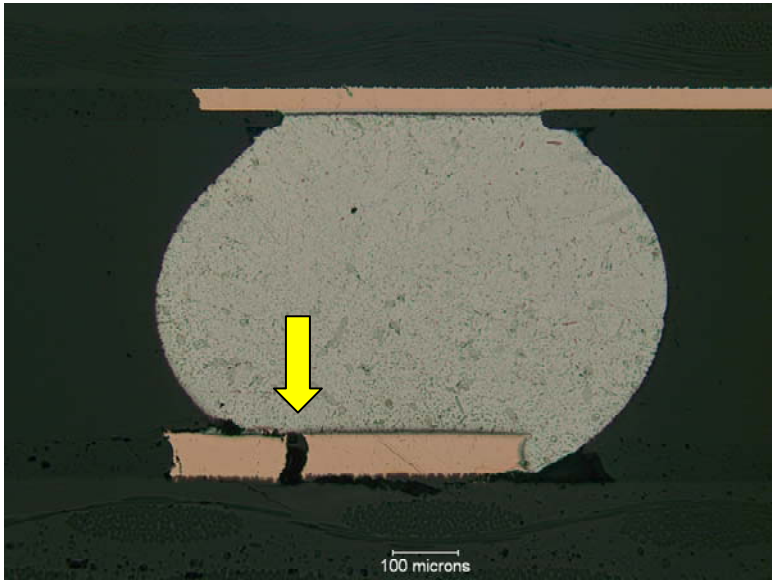
QFN's and TSOP's Were Resistant to Failure

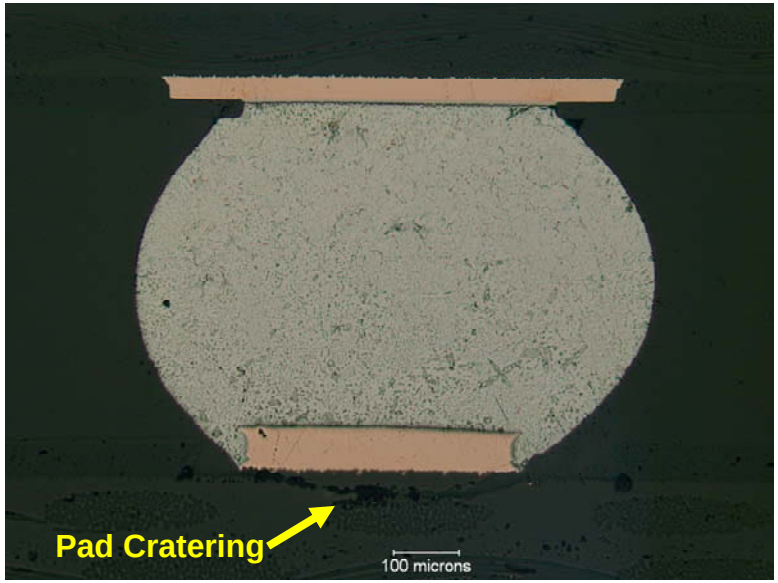
	% of Components Failed During Mechanical Shock Testing			
	"Manufactured" Test Vehicles		"Rework" Test Vehicles	
	SnPb	Pb-Free	SnPb	Pb-Free
Component				
BGA-225	94	96	95	100
CLCC-20	22	30	22	30
CSP-100	32	26	42	38
PDIP-20	53	73	54	58
QFN-20	0	10	0	0
TQFP-144	70	62	68	80
TSOP-50	4	0	22	20

Test Vehicle 34 - Four Corner Balls of BGA U6 (SnPb Solder/SnPb Balls)
Microsections were not useful in determining which failure mechanism occurred first

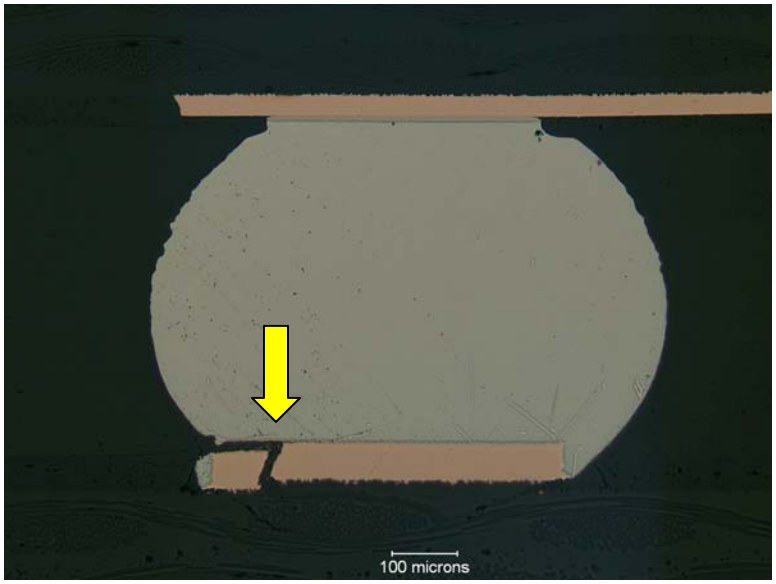


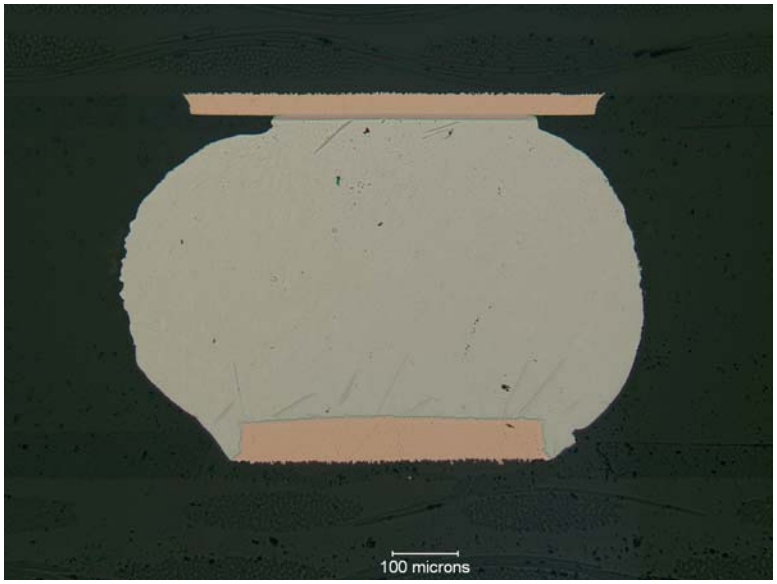


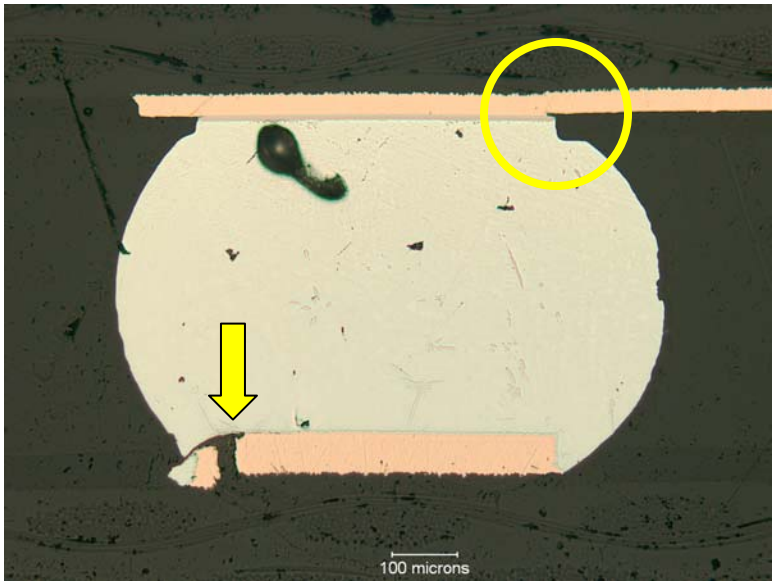


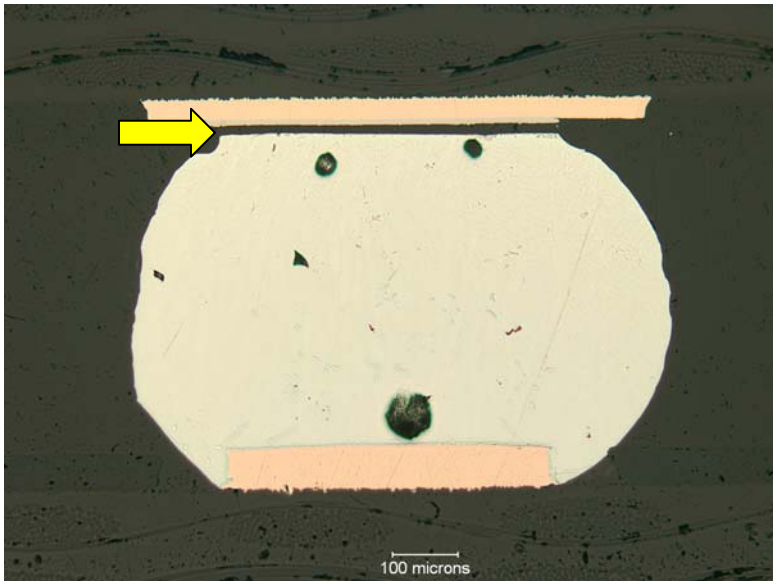


Test Vehicle 89 - Four Corner Balls of BGA U2 (SAC305 Solder/SAC405 Balls)
Microsections were not useful in determining which failure mechanism occurred first

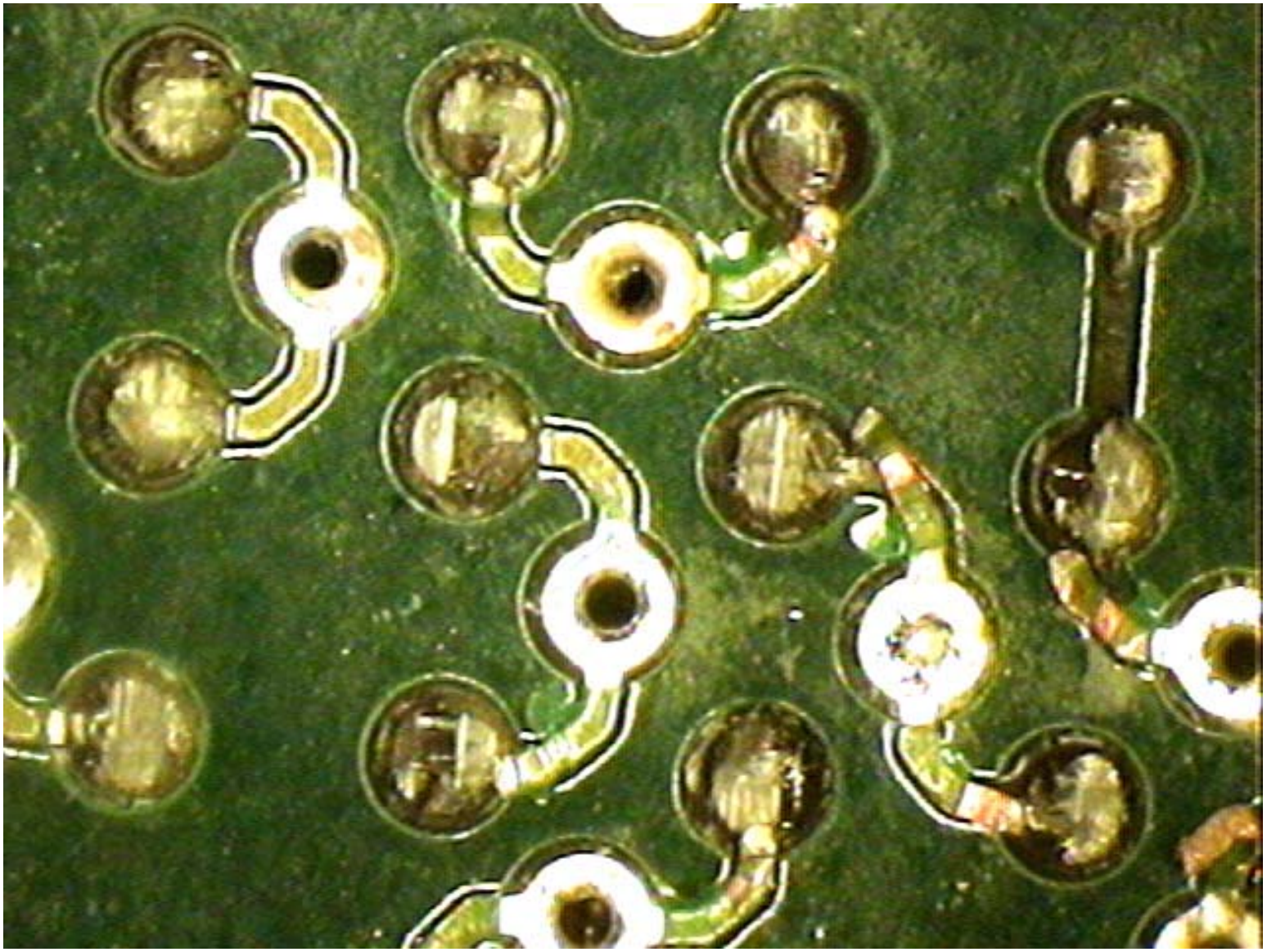




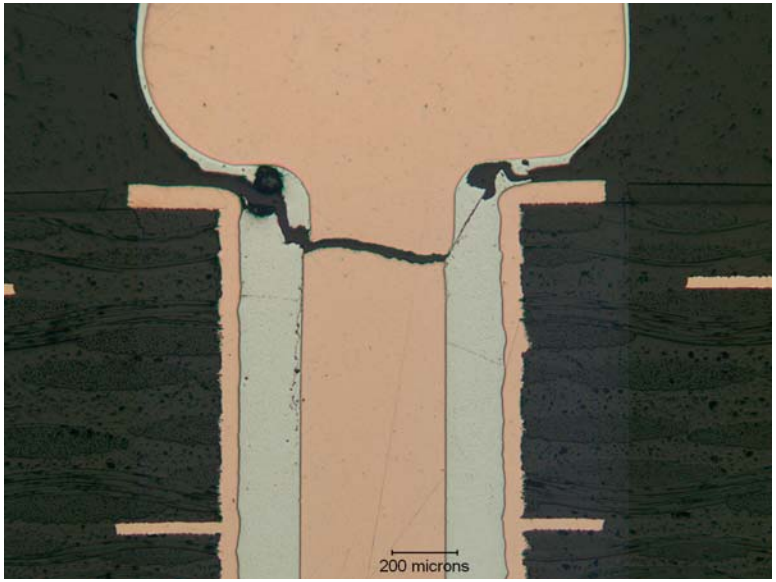


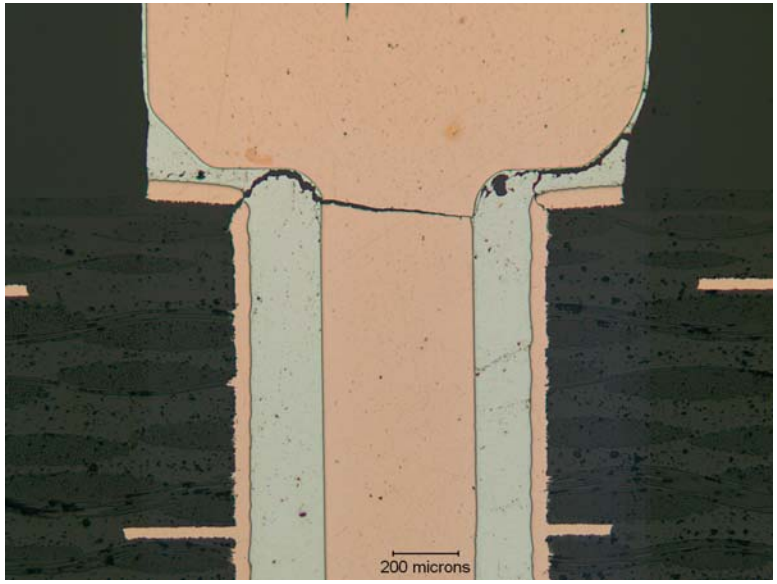


SnPb and Lead-Free BGA's that Fell Off Exhibited Pad Cratering



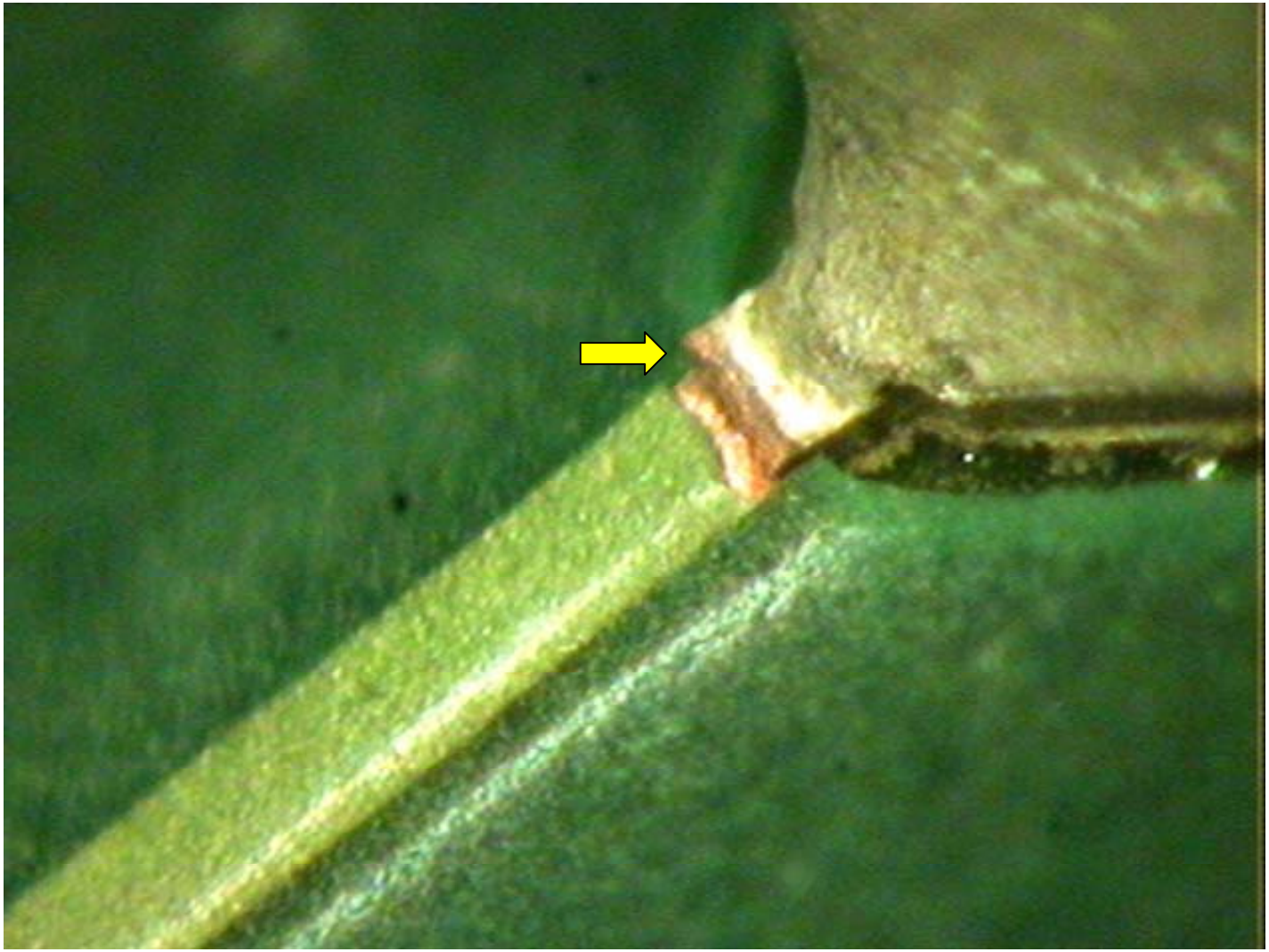
PDIP Corner Leads
(SN100C Solder/Sn Finish)



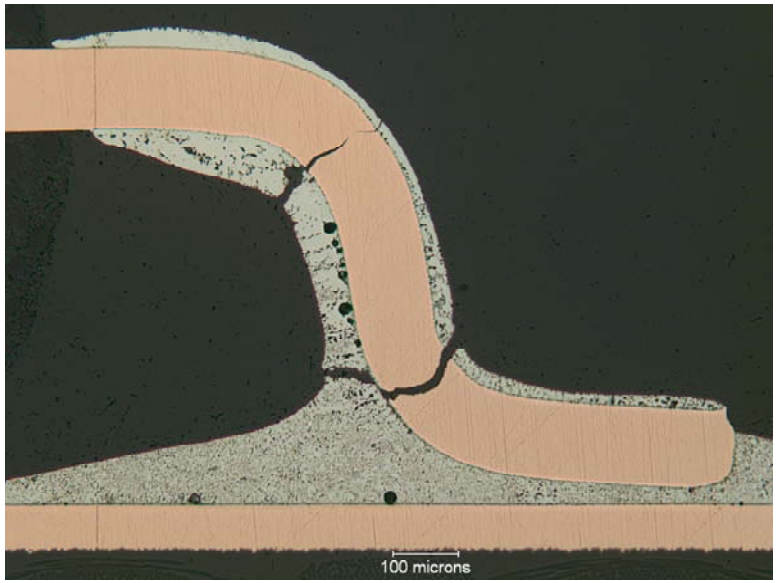


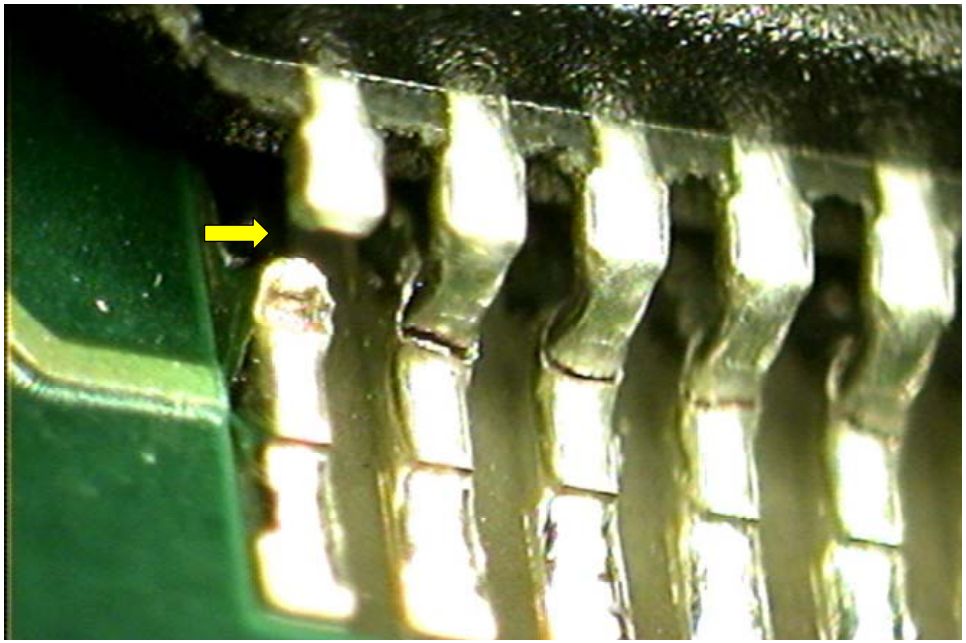
PDIP U38 (Cracked Trace, SN100C)

This was a common failure mechanism seen on Pb-free but not SnPb test vehicles

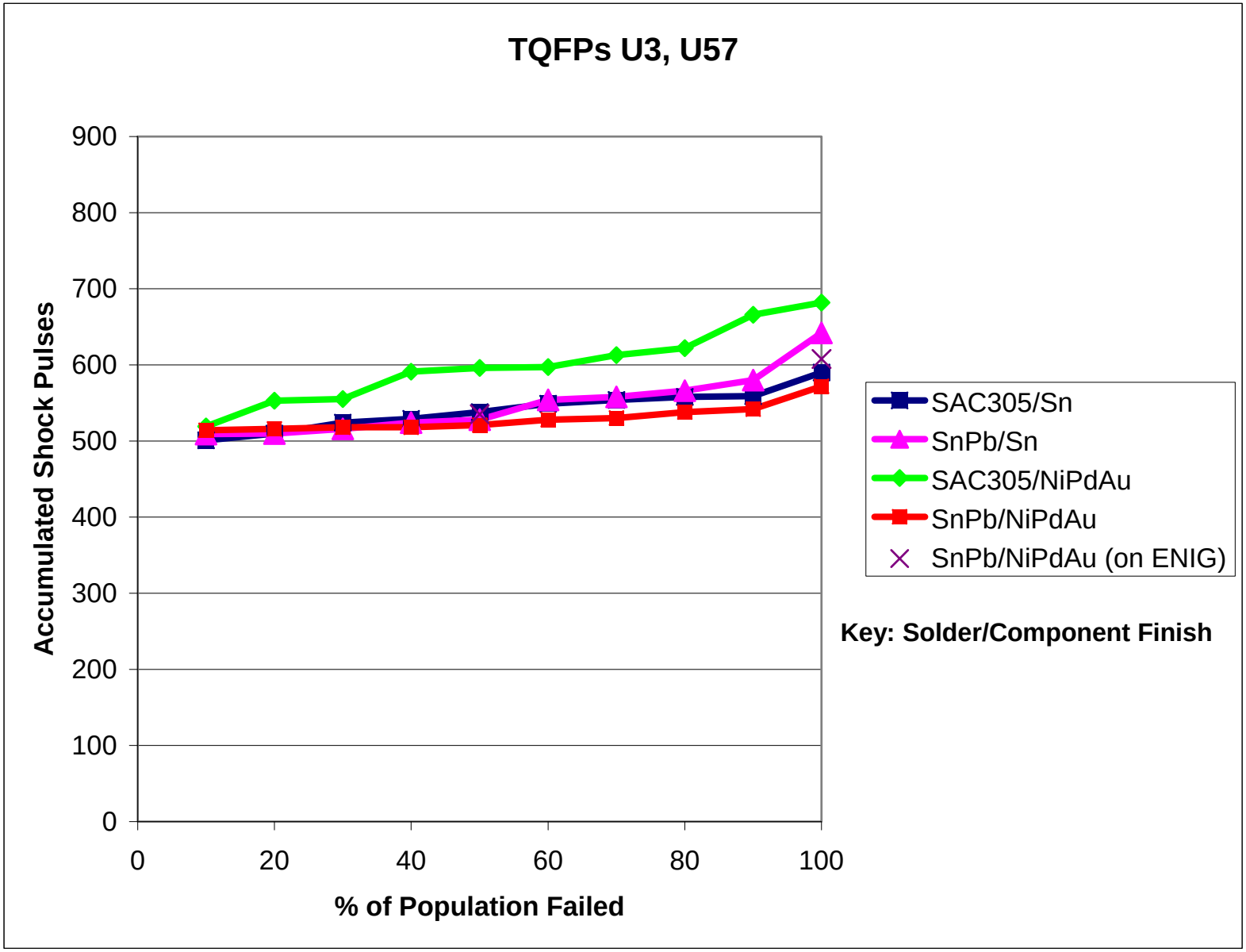


TQFP-144, Corner Leads (SnPb Solder/Sn Finish)

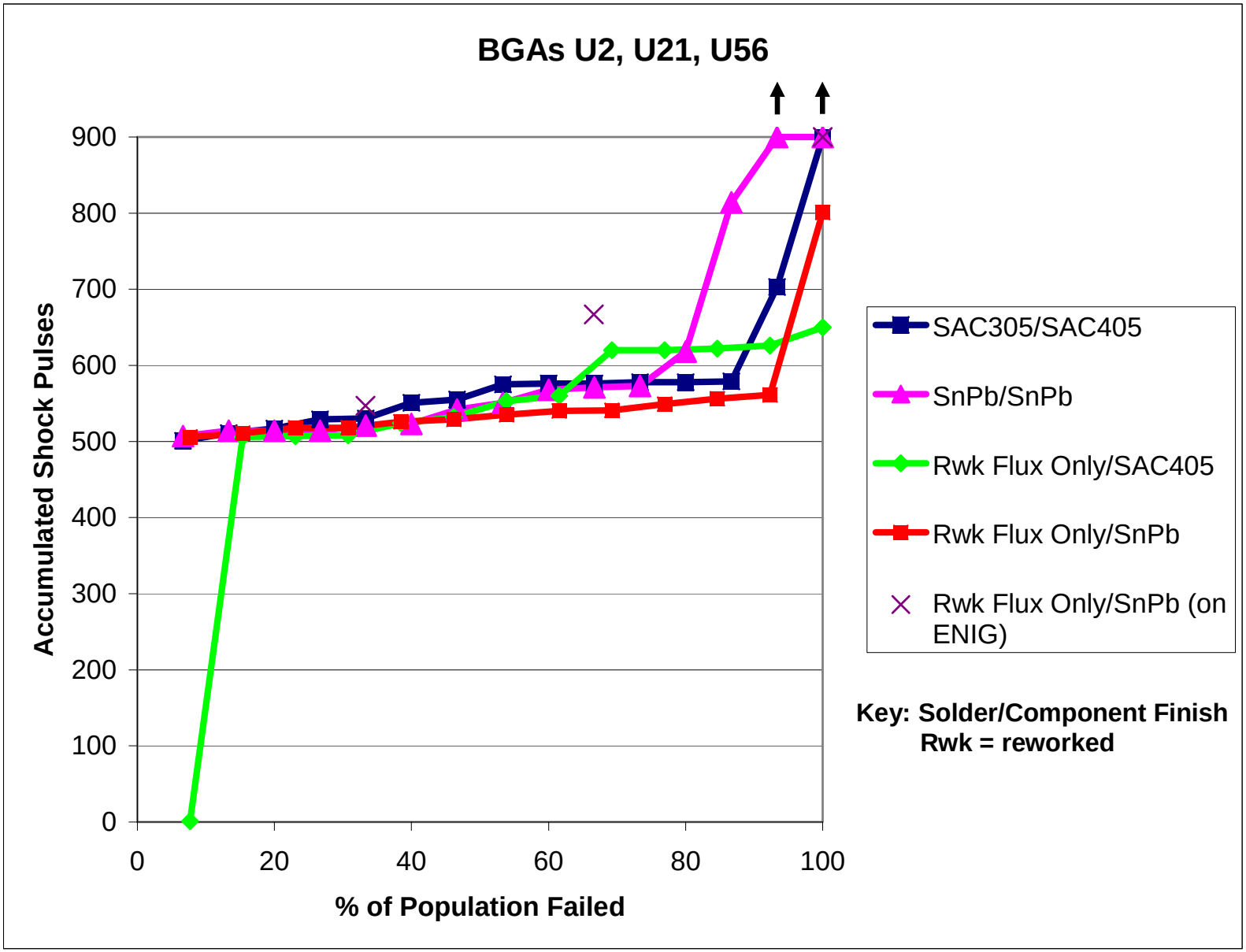




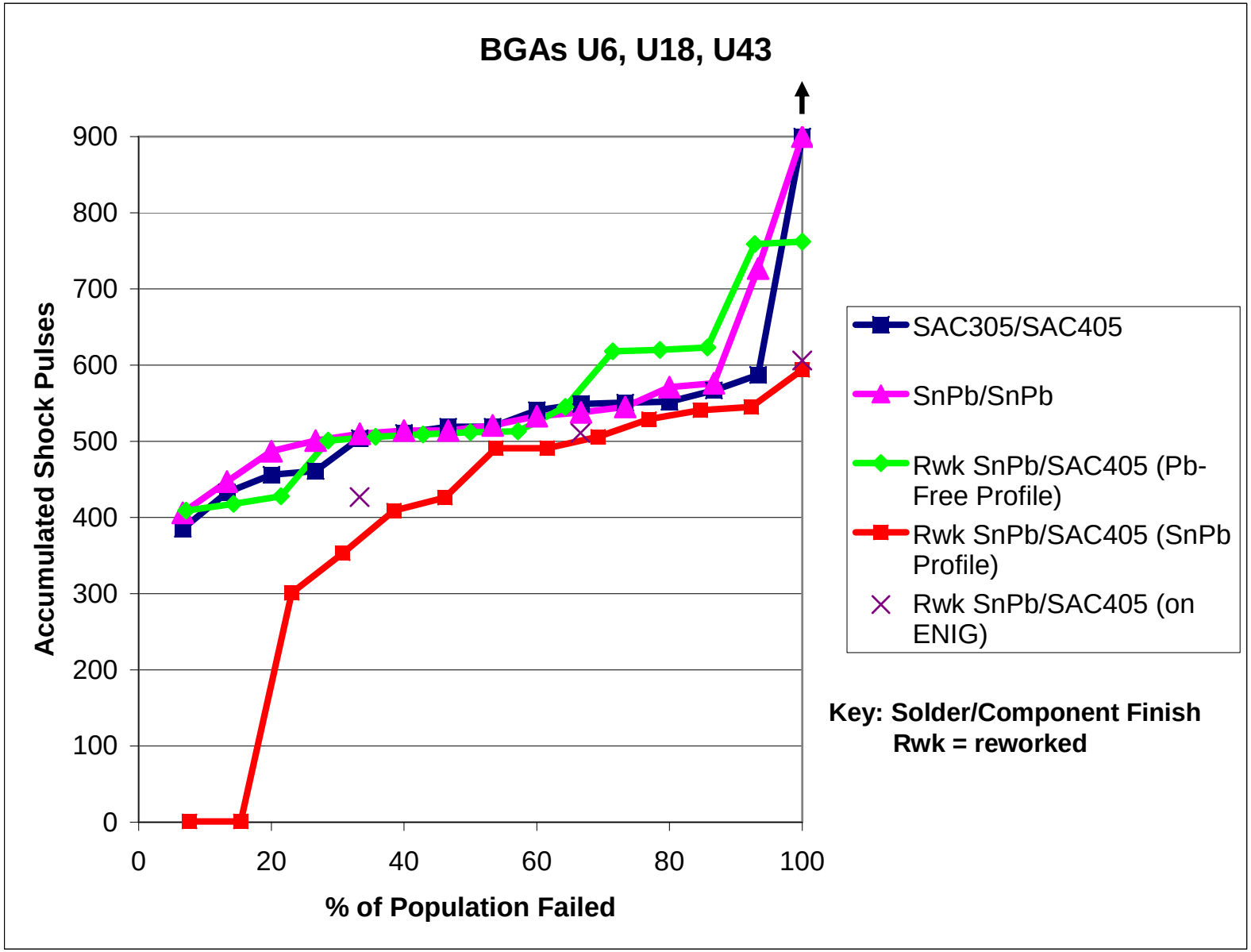
Combined Data from TQFP's U3 and U57



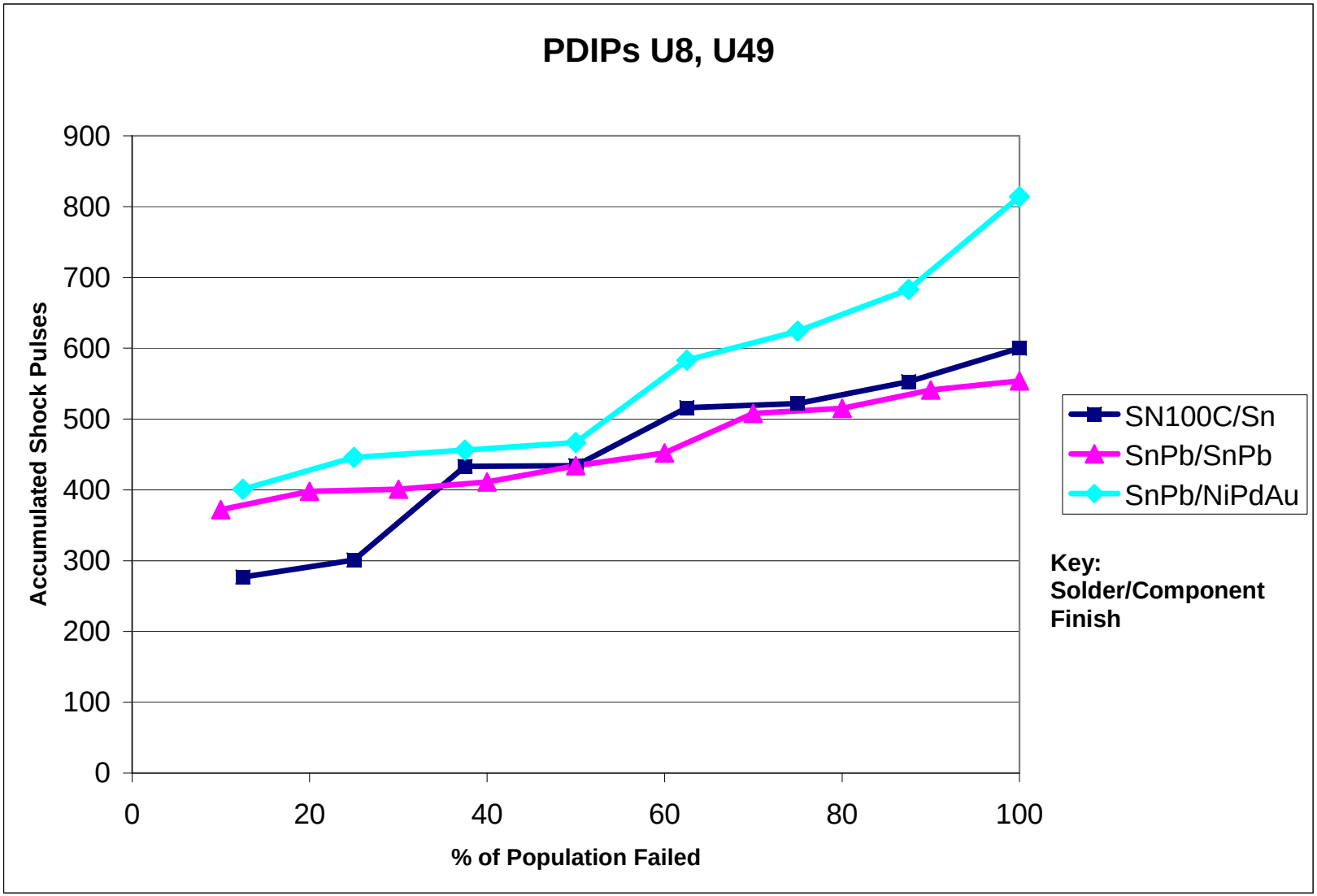
Combined Data from BGA's U2, U21, and U56



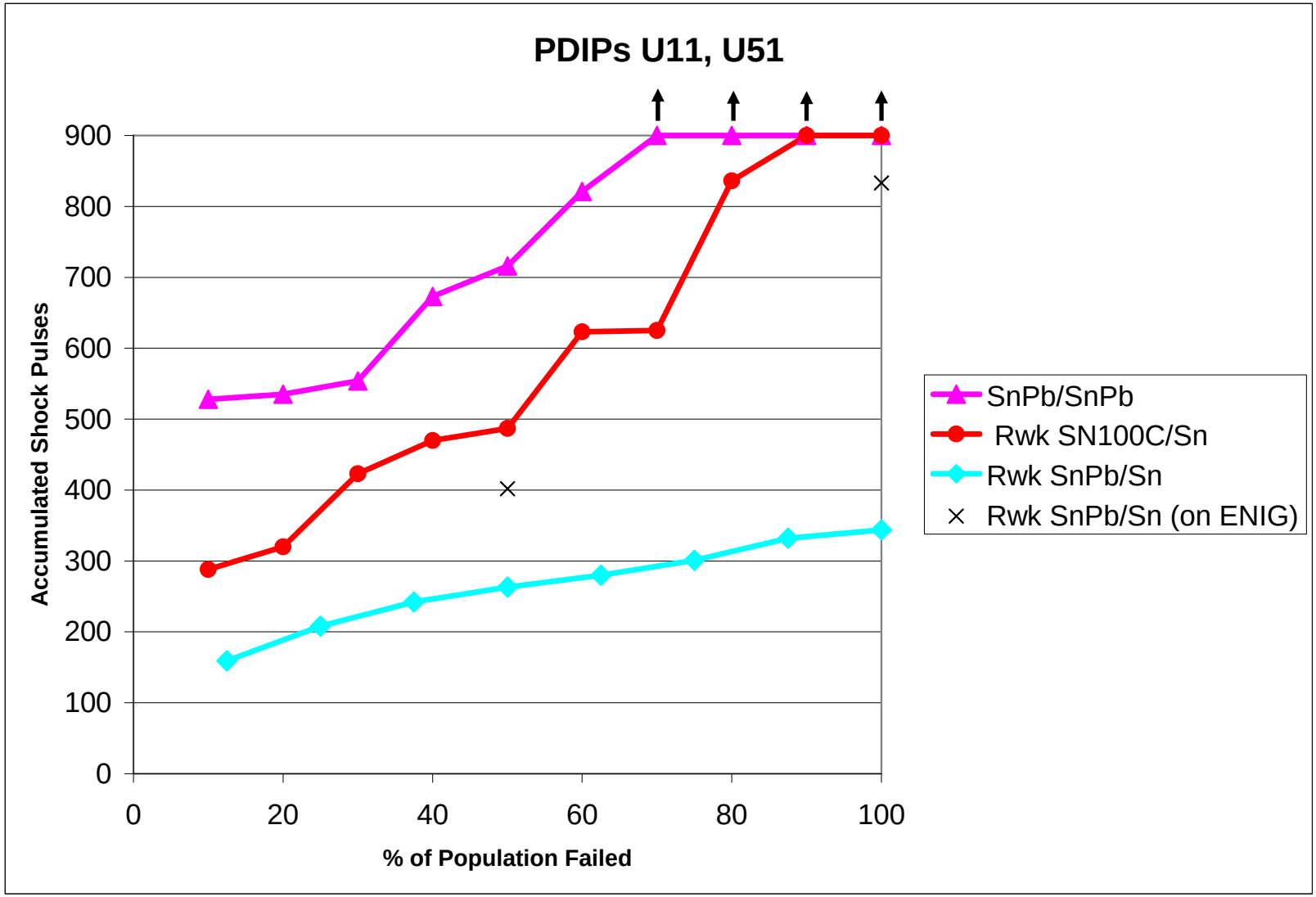
Combined Data from BGA's U6, U18, and U43



Combined Data from PDIP's U8 and U49



Combined Data from PDIP's U11 and U51



Summary

- Most of the components tested (including reworked components) successfully passed the tests defined in MIL-STD-810G 33 times each no matter which solder was used. These tests are:
  - Functional Test (Flight Equipment)
  - Functional Test (Ground Equipment)
  - Crash Hazard Test (Ground Equipment).

- These results suggest that the Pb-free solders tested can be used on designs that will be exposed to mechanical shock and will perform as well as currently used eutectic SnPb solder under many use conditions.

Acknowledgements

- Thanks to Nihon Superior and the Boeing PSS Domain for funding this study.

Questions?