NASA-DOD Pb-free Electronics Rework Project: Effect of 1X and 2X Eutectic Solder Rework on Vibration Reliability

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Outline/Agenda

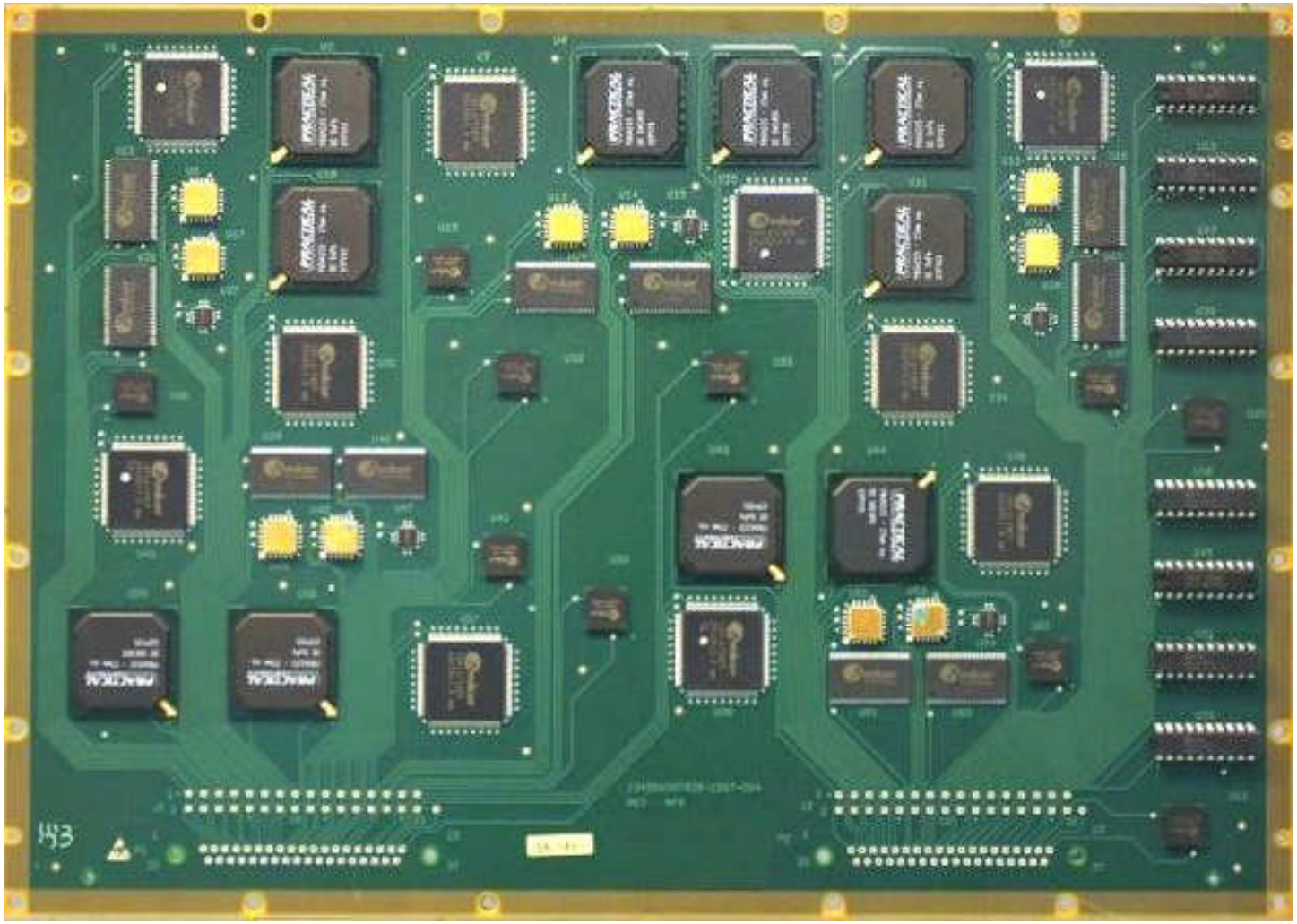
- Introduction: Crane Add-on
- Experimental Procedure
  - Test Vehicle
  - Rework Procedure
  - Vibration Test Procedure
  - Failure Analysis
- Results and Discussion
  - Comparison of Crane Data
    - As-Manufactured vs. Rework
    - 1X vs. 2X Rework
  - Comparison of Crane vs. Boeing Data
- Preliminary Conclusions

Crane Add-on to NASA-DOD Lead-Free Electronics Project 2

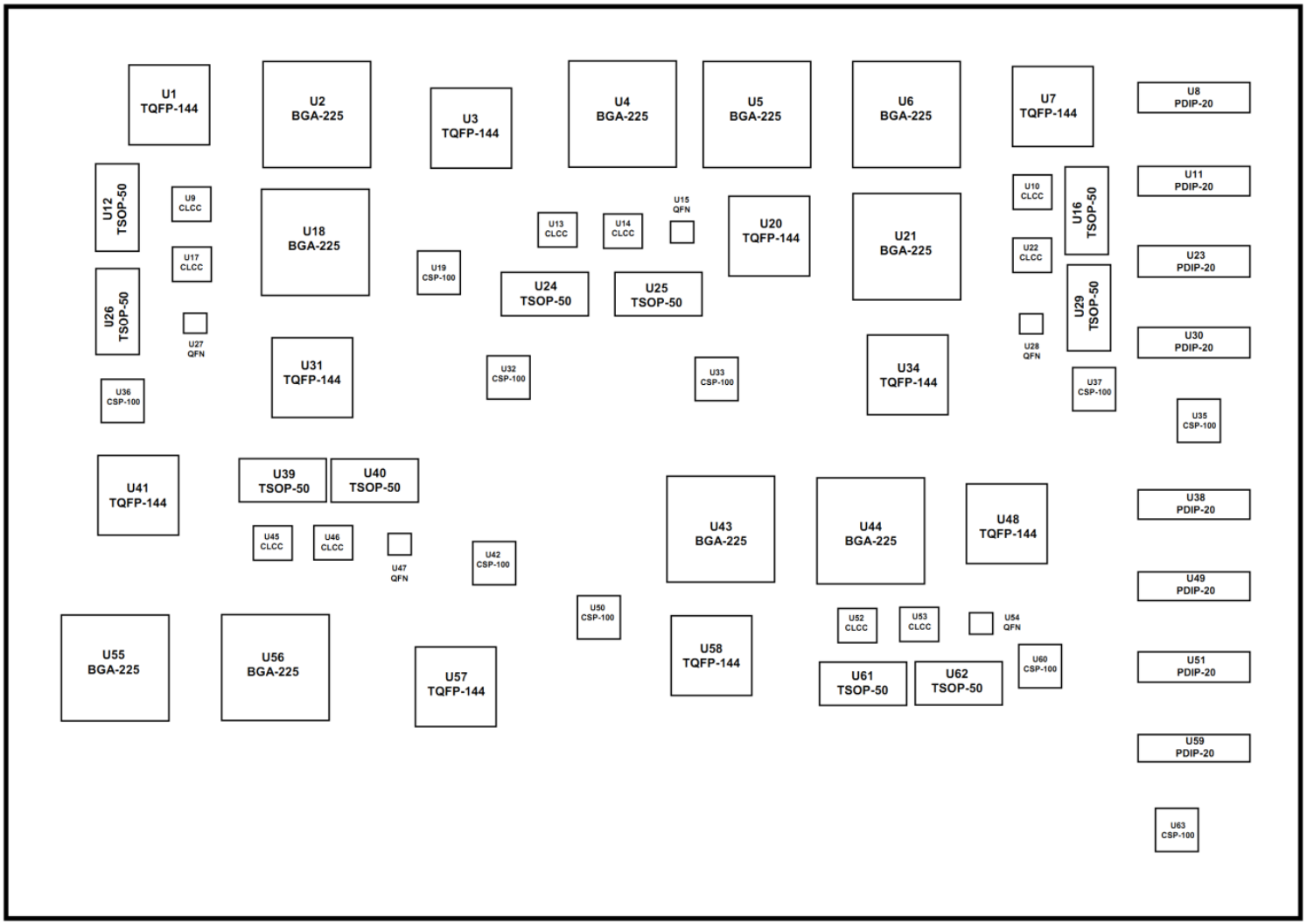
- 30 additional test vehicles
  - 9 Drop/Shock
  - 8 Thermal Cycling
  - **9 Vibration**
- Objective
  - Can a qualified rework facility with a capable process rework Pb-free boards with SnPb solder alloy and create solder joints that have a reliability comparable to as-manufactured Pb-free assemblies?

Experimental procedure

Test Vehicle



Schematic of Test Vehicle

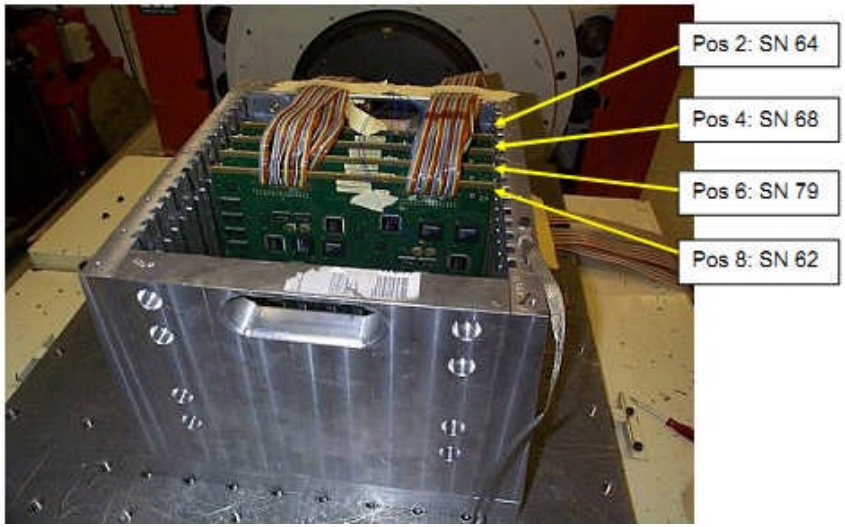


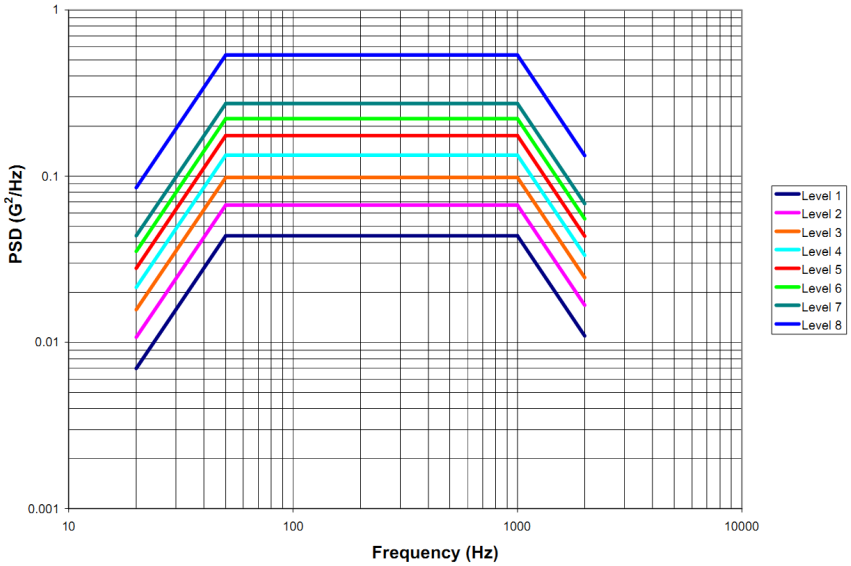
Rework Procedure

- PDIP, TSOP, TQFP, and CLCC component types
  - SnPb 1X and 2X on SAC 305 (24 boards) and Sn100C (6 boards)
  - Standard: IPC-7711 (built to Navy 2M)
  - Total of 1072 components removed and replaced with new components
- Complete details in paper

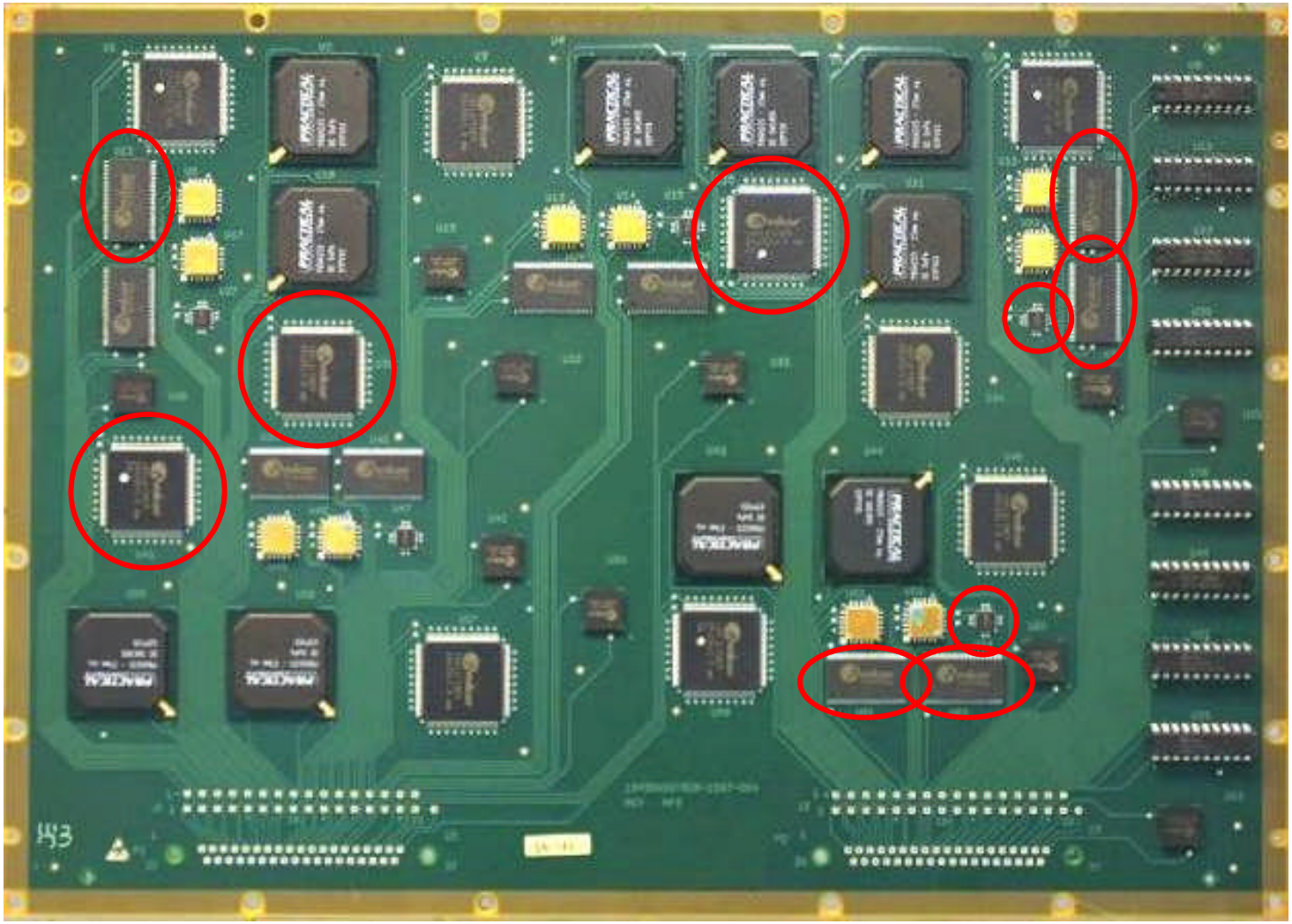
Vibration Test Procedure

- Conducted by Celestica
  - Intent to duplicate Boeing test procedure
- 8 Grms for 1 hour, followed by 2 Grms increase every hour until 20 Grms, then 28 Grms
- Components electrically monitored for failure



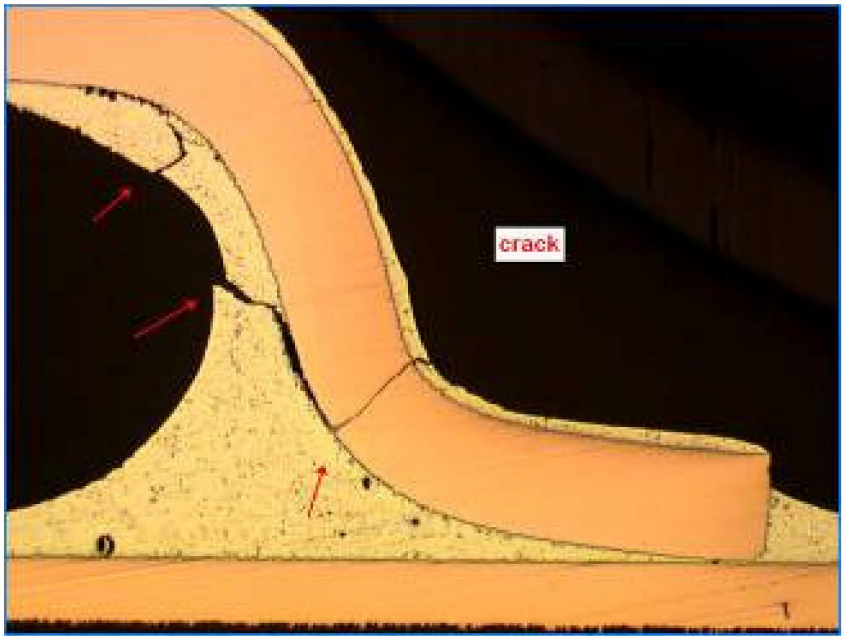


Failure Analysis

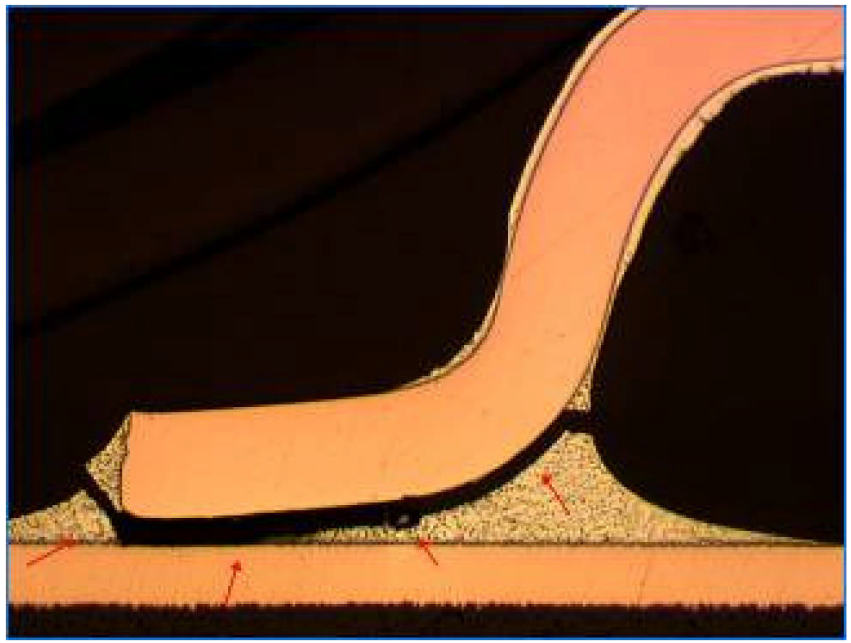


TQFP-144 Cross Sections

SN61, U20, No Rework
(SAC 305 Solder)



SN67, U31, 2X SnPb Rework
(SnPb Solder)



Results and Discussion

Analysis of Results

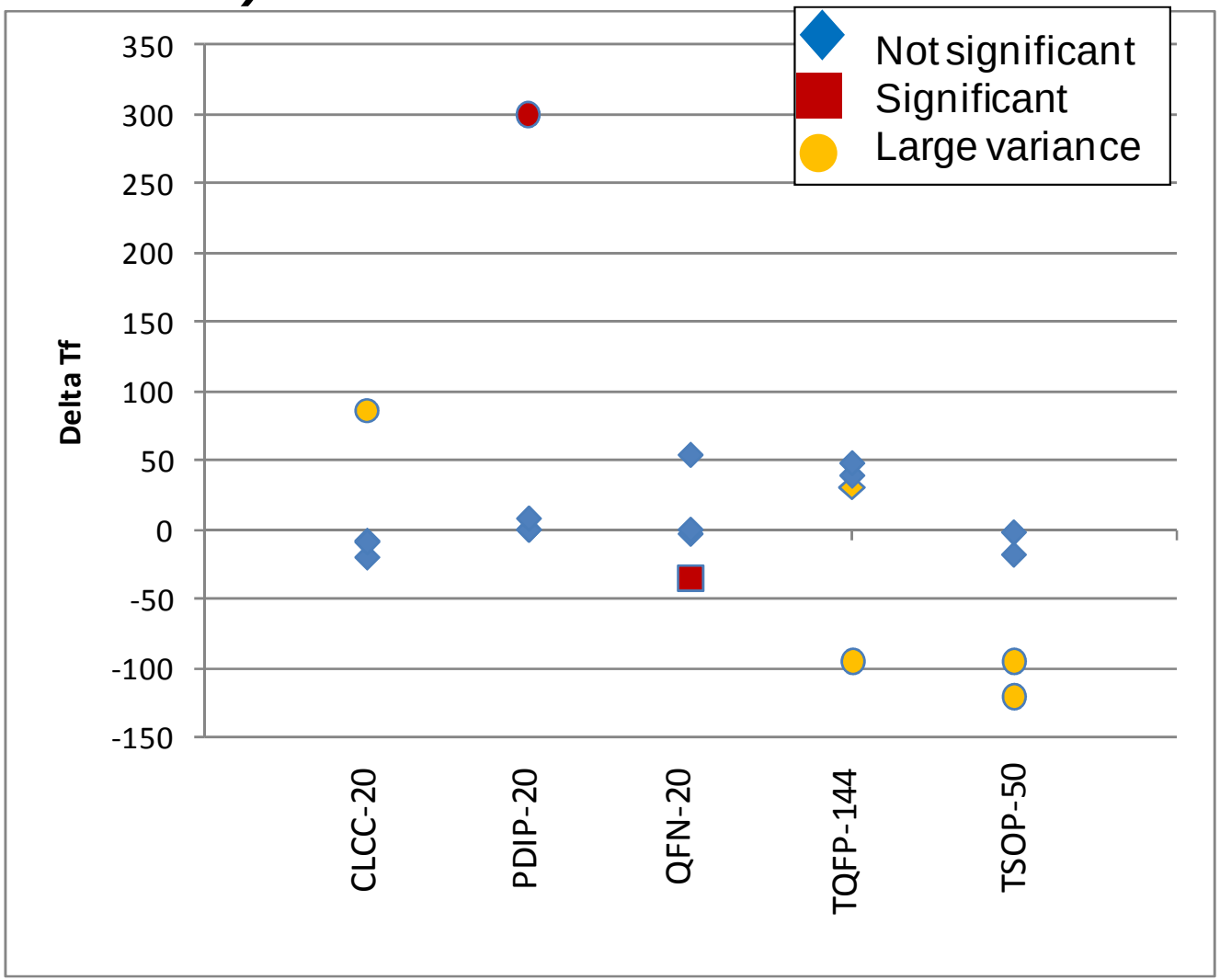
- Statistical Analysis
  - No differentiation with respect to board location
  - Average time to failure T_f (test minutes)
  - Standard deviation of T_f
  - Survivors assigned T_f of 480 minutes
- F-Test
  - Determines if there is a significant shift between the means of several test group
  - Performed on data to determine significant changes between two conditions
    - 0X vs. 1X, 1X vs. 2X
  - P-value < 0.05 significant at the 95% level
- Variance Check
  - Checks to see if all test groups have similar variances

Comparison of Crane Data

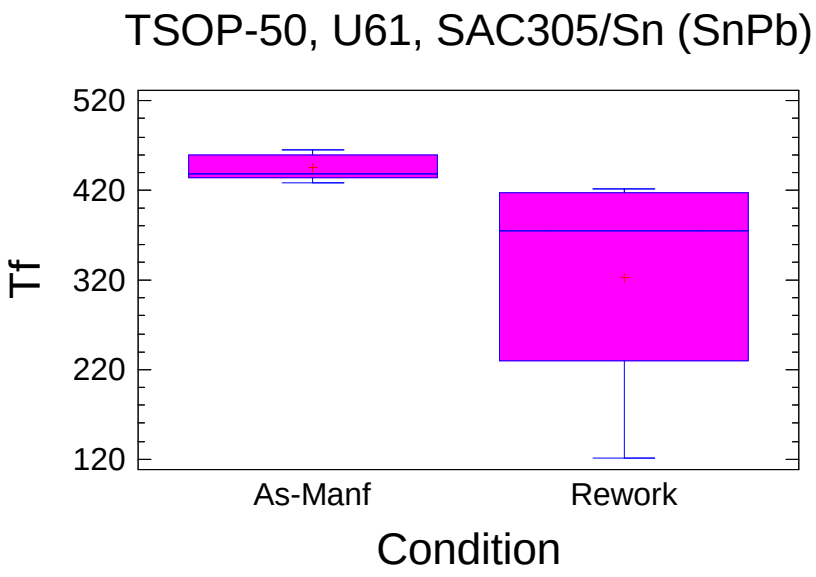
Comparison: As-Manufactured to Reworked (0X vs. 1X)

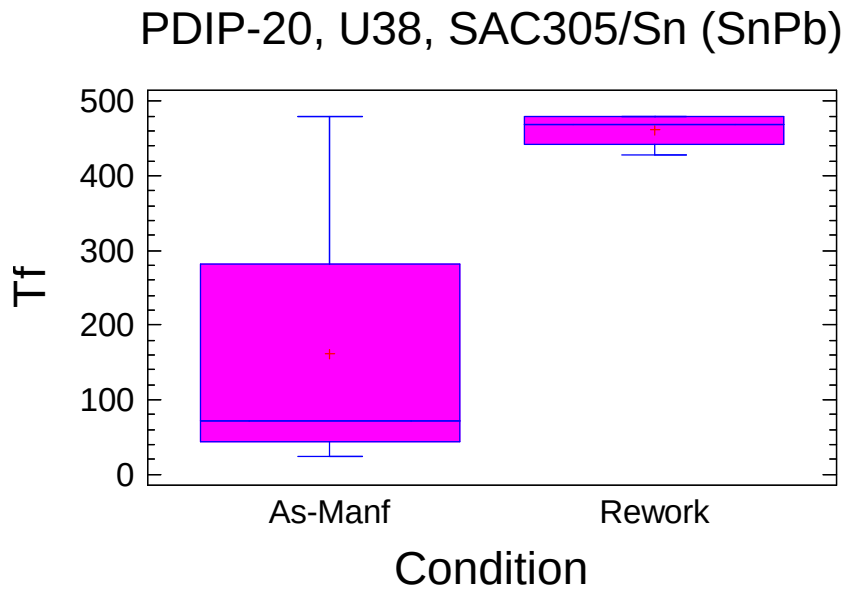
	Conditions				Results with samples which did not fail						
					As-Manufactured		1st SnPb Rework		Statistics		
	Site	Solder	Lead	Board	Average Tf	Standard Deviation	Average Tf	Standard Deviation	F-Test	P-Value	Variance Check
CLCC-20	U52	SAC305	SAC305	ImAg	360	162	446	19	1.39	0.2763	0.001
	U45	SAC305	SAC305	ImAg	465	25	457	27	0.2	0.6654	0.9
	U46	SAC305	SAC305	ImAg	451	26	431	54	0.56	0.4793	0.215
	U53	SAC305	SAC305	ImAg	465	12	456	29	0.39	0.5533	
PDIP-20	U59	SN100C	NiPdAu	ImAg	480	0	480	0	NA	NA	NA
	U23	SN100C	Sn	ImAg	480	0	480	0	NA	NA	NA
	U30	SN100C	Sn	ImAg	150	197	158	91	0.01	0.9378	0.237
	U38	SN100C	Sn	ImAg	162	213	462	25	7.78	0.0316	0.005
QFN-20	U47	SAC305	Sn	ImAg	347	48	401	39	1.3	0.2762	0.632
	U27	SAC305	Sn	ImAg	480	0	477	4.5	1.3	0.2924	NA
	U28	SAC305	Sn	ImAg	480	0	445	32	5.47	0.047	NA
	U54	SAC305	Sn	ImAg	480	0	480	0	NA	NA	NA
TQFP-144	U57	SAC305	Sn	ImAg	271	101	310	21	0.74	0.4172	0.012
	U58	SAC305	Sn	ImAg	220	54	251	35	0.96	0.359	0.462
	U48	SAC305	Sn	ImAg	439	5	344	111	3.83	0.0914	0.00005
	U41	SAC305	Sn	ImAg	392	56	440	32	2.54	0.1553	0.352
TSOP-50	U61	SAC305	Sn	ImAg	445	5	421	111	3.87	0.0899	0.002
	U39	SAC305	Sn	ImAg	457	20	439	29	1.18	0.313	0.566
	U62	SAC305	SnBi	ImAg	472	11	351	158	0.1284	2.97	0.0002
	U26	SAC305	SnBi	ImAg	362	55	360	53	0	0.9571	0.709

Differences in Average T_f (0X vs. 1X)



Differences in T_f Distribution (0X vs. 1X)

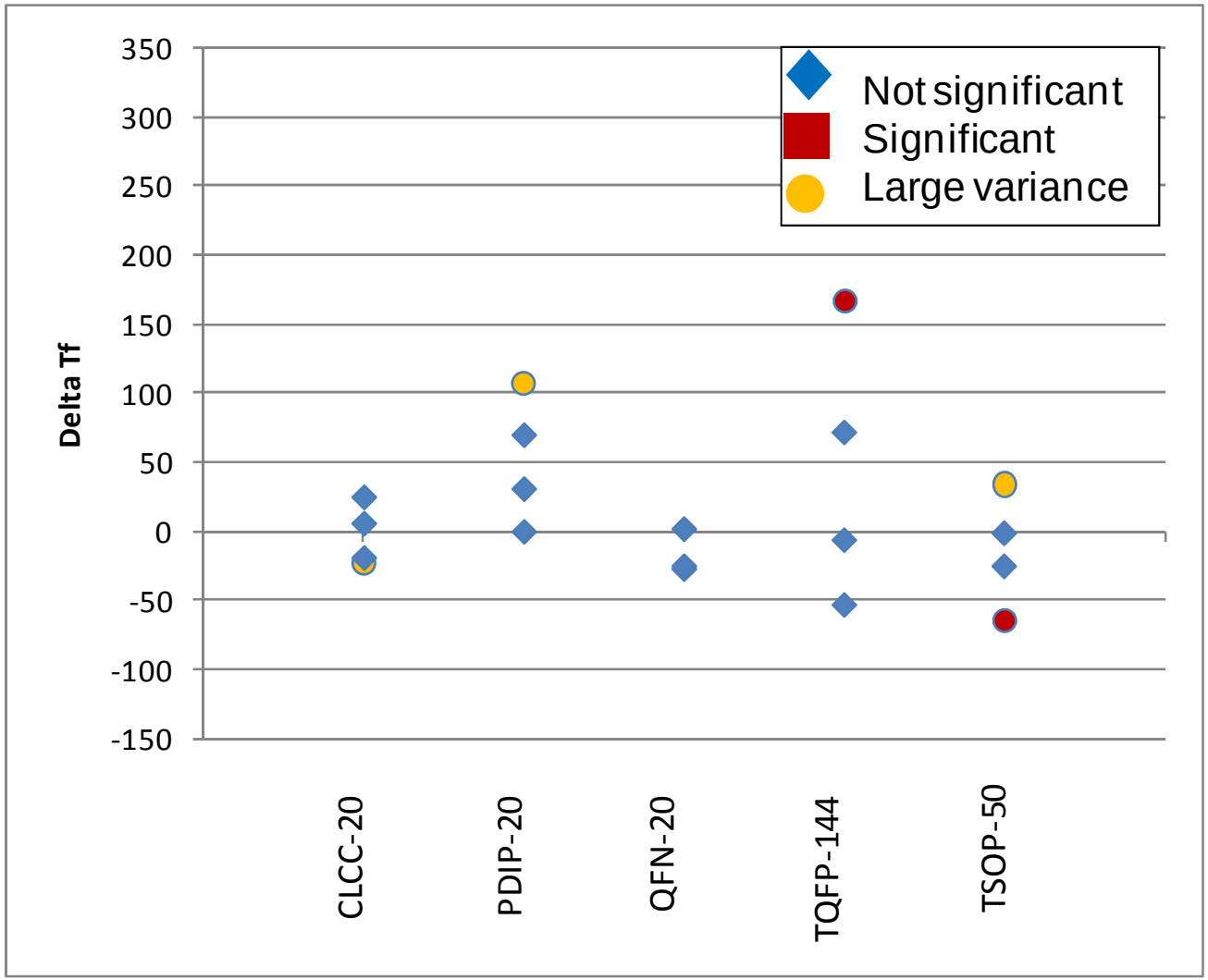




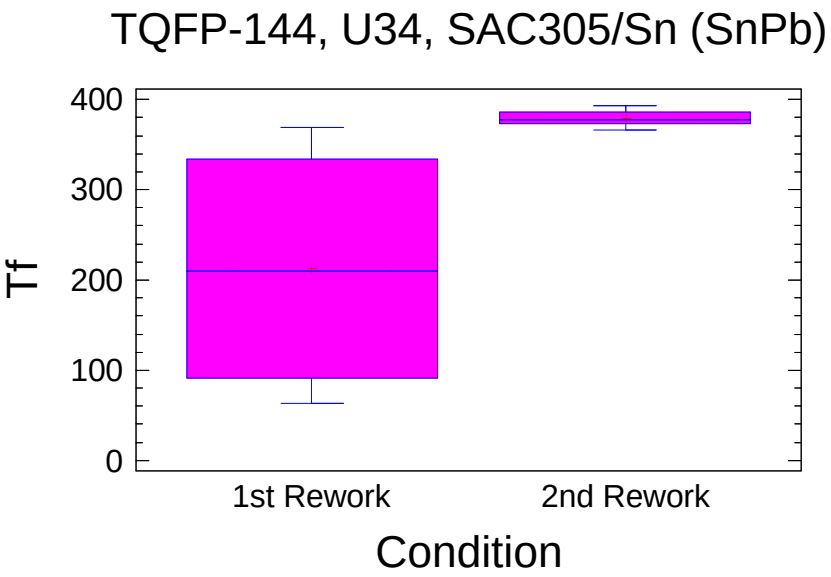
Comparison: 1X vs. 2X Rework

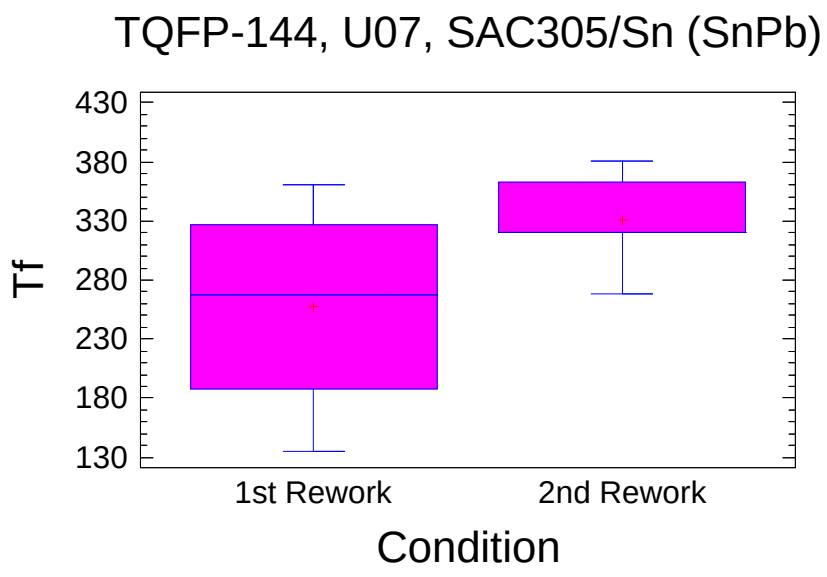
	Conditions				Results with samples which did not fail						
					1st Rework		2nd Rework		Statistics		
	Site	Solder	Component	Board	Average Tf	Standard Deviation	Average Tf	Standard Deviation	F-Test	P-Values	Variance Check
CLCC-20	U10	SAC305	SAC305	ImAg	407	44	413	72	0.02	0.8849	0.404
	U22	SAC305	SAC305	ImAg	421	45	446	37	0.86	0.3821	0.75
	U09	SAC305	SAC305	ImAg	417	10	394	69	0.44	0.532	0.011
	U17	SAC305	SAC305	ImAg	480	0	461	38	1.3	0.294	NA
PDIP-20	U51	SN100C	NiPdAu	ImAg	323	190	393	128	0.31	0.5989	0.57
	U08	SN100C	Sn	ImAg	368	223	475	9	0.92	0.3746	0.0003
	U11	SN100C	Sn	ImAg	480	0	480	0	NA	NA	NA
	U49	SN100C	Sn	ImAg	75	87	106	124	0.13	0.7303	0.63
QFN-20	U15	SAC305	Sn	ImAg	117	48	90	49	0.67	0.4386	0.979
	U27	SAC305	Sn	ImAg	478	5	480	0	1.3	0.2924	NA
	U28	SAC305	Sn	ImAg	446	33	421	36	1.19	0.3116	0.867
TQFP-144	U07	SAC305	Sn	ImAg	258	95	330	44	2.36	0.1681	0.185
	U31	SAC305	Sn	ImAg	422	42	416	27	0.07	0.8049	0.472
	U34	SAC305	Sn	ImAg	213	145	380	11	6.78	0.0375	0.0002
	U01	SAC305	Sn	ImAg	377	33	324	73	2.13	0.1877	0.174
TSOP-50	U25	SAC305	Sn	ImAg	170	14	145	43	1.56	0.2517	0.07
	U29	SAC305	Sn	ImAg	394	71	428	17	1.07	0.3344	0.023
	U40	SAC305	SnBi	ImAg	381	12	317	46	7.15	0.0318	0.048
	U16	SAC305	SnBi	ImAg	386	28	385	34	0	0.9681	0.755

Differences in Average T_f (1X vs. 2X)



Differences in T_f Distribution (1X vs. 2X)





Comparison of Crane vs. Boeing Data

Boeing Rework vs. Crane Rework

Boeing Rework

- BGAs reworked
- SnPb and SAC 305 used in rework

Crane Rework

- No BGAs reworked
- All rework with SnPb

Crane vs. Boeing Vibration Results

- Some differences were seen in the test results obtained at Boeing vs Crane
  - Boeing and Crane obtained similar results on TSOPs and CLCCs
  - Boeing obtained longer times to failure on BGAs and TQFPs
- Times to failure on components reworked once at Boeing were significantly less than the as-manufactured boards on
  - 83% of BGAs (10 of 12)
  - 33% of TSOPs (2 of 6)
  - 16% of CSP (2 of 12)

Comparison of Crane and Boeing: As-Manufactured

Pagkage	Site	Solder	Lead	Result
BGA-225	U5	SAC305	SAC405	Boeing higher
BGA-225	U43	SAC305	SAC405	Same
BGA-225	U44	SAC305	SAC405	Same
BGA-225	U02	SAC305	SAC405	Boeing higher
BGA-225	U06	SAC305	SAC405	Boeing higher
BGA-225	U18	SAC305	SAC405	Boeing higher
BGA-225	U21	SAC305	SAC405	Boeing higher
BGA-225	U56	SAC305	SAC405	Boeing higher
BGA-225	U55	SAC305	SAC405	Crane higher
CLCC-20	U13	SAC305	SAC305	Same
CLCC-20	U14	SAC305	SAC305	Same
CLCC-20	U52	SAC305	SAC305	Same
CLCC-20	U45	SAC305	SAC305	Same
CLCC-20	U46	SAC305	SAC305	Same
CLCC-20	U53	SAC305	SAC305	Same
TQFP-144	U03	SAC305	Sn	Boeing higher
TQFP-144	U20	SAC305	Sn	Boeing higher
TQFP-144	U57	SAC305	Sn	Same
TQFP-144	U58	SAC305	Sn	Same
TQFP-144	U48	SAC305	Sn	Boeing higher
TQFP-144	U41	SAC305	Sn	Same
TSOP-50	U61	SAC305	Sn	Same
TSOP-50	U39	SAC305	Sn	Same
TSOP-50,	U12	SAC305	Sn	Same

Trouble spots:

BGA's

TQFP's

Comparison of Boeing Data: 0X vs. 1X

Package	Site	Solder	Lead	Rework	Result
TSOP-50	U25	SAC305	Sn	SnPb	Rwk Worse
TSOP-50	U12	SAC305	Sn	SnPb	Same
TSOP-50	U24	SnPb	SnBi	SnPb	Rwk Worse
TSOP-50	U25	SnPb	SnBi	SnPb	Same
TSOP-50	U12	SnPb	SnBi	SnPb	Same
TSOP-50	U26	SnPb	SnBi	SnPb	Same
CSP-100	U19	SAC305	SAC105	Flux	Same
CSP-100	U33	SAC305	SAC105	SnPb	Rwk Worse
CSP-100	U42	SAC305	SAC105	SnPb	Same
CSP-100	U50	SAC305	SAC105	Flux	Rwk Worse
CSP-100	U60	SAC305	SAC105	Flux	Same
CSP-100	U37	SAC305	SAC105	Flux	Same
CSP-100	U19	SnPb	SnBi	Flux	Same
CSP-100	U33	SnPb	SnBi	SnPb	Same
CSP-100	U42	SnPb	SnBi	SnPb	Same
CSP-100	U50	SnPb	SnBi	Flux	Same
CSP-100	U60	SnPb	SnBi	SnPb	Same
CSP-100	U37	SnPb	SnBi	Flux	Same
BGA-225	U43	SAC305	SAC405	SnPb	Same
BGA-225	U02	SAC305	SAC405	Flux	Rwk Worse
BGA-225	U06	SAC305	SAC405	SnPb	Rwk Worse
BGA-225	U18	SAC305	SAC405	SnPb	Rwk Worse
BGA-225	U21	SAC305	SAC405	Flux	Rwk Worse
BGA-225	U56	SAC305	SAC405	Flux	Rwk Worse
BGA-225	U43	SnPb	SnBi	SnPb	Rwk Worse
BGA-225	U02	SnPb	SnBi	Flux	Rwk Worse
BGA-225	U06	SnPb	SnBi	SnPb	Rwk Worse
BGA-225	U18	SnPb	SnBi	SnPb	Same
BGA-225	U21	SnPb	SnBi	Flux	Rwk Worse
BGA-225	U56	SnPb	SnBi	Flux	Rwk Worse

Preliminary Conclusions

Preliminary Conclusions

- Significant amount of variation
  - Vibration batch
  - Test location (Boeing vs. Celestica)
- Crane rework *did not* appear to impair reliability
- Boeing rework *did* appear to impair reliability
  - Different reworked components

Ongoing Work

- Outliers and suspect data
- Differences between testers
- Final report will be available on TEERM website soon
  - http://teerm.nasa.gov/NASA_DODLeadFreeElectronics_Proj2.html

Acknowledgements

- Co-authors and collaborators
- Consortia members

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