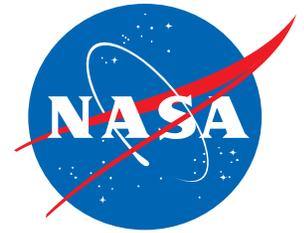


National Aeronautics and Space Administration



NASA-DoD Lead-Free Electronics Project

SMTA
International

October 28, 2010

www.nasa.gov

Resources

Project documents, test plans, test reports and other associated information will be available on the web:

➤ NASA-DoD Lead-Free Electronics Project:

http://www.teerm.nasa.gov/projects/NASA_DODLeadFreeElectronics_Proj2.html

Joint Test Protocol

Project Plan

Final Test Reports

Lead-Free Solder Alloys

SAC305 (Sn3.0Ag0.5Cu)

- Surface mount assembly

This alloy was chosen for reflow soldering because this particular solder alloy has shown the most promise as a primary replacement for tin-lead solder. The team decided that they wanted to select at least one “general purpose” alloy to be evaluated and it was determined that the SnAgCu solder alloy would best serve this purpose. {EnviroMark™ 907 from Kester.}

SN100C (Sn0.7Cu0.05Ni+Ge)

- Plated through hole

- Surface mount assembly

This alloy is commercially available and the general trend in industry has been switching to the nickel stabilized tin-copper alloy over standard tin-copper due to superior performance. In addition, this nickel-stabilized alloy does not require special solder pots and has shown no joint failures in specimens with over 4 years of service.

Components

BGA-225

- SAC405
- SnPb

CSP-100

- SAC105
- SnPb
- SN100C
 - ❑ Re-Balled

QFN

- Matte Sn
- SnPb

TSOP-50

- SnBi
- Sn
- SnPb

PDIP-20

- NiPdAu
- Sn
- SnPb

CLCC

- SAC305
 - ❑ Au finish then tinned
- SnPb
 - ❑ Au finish then tinned

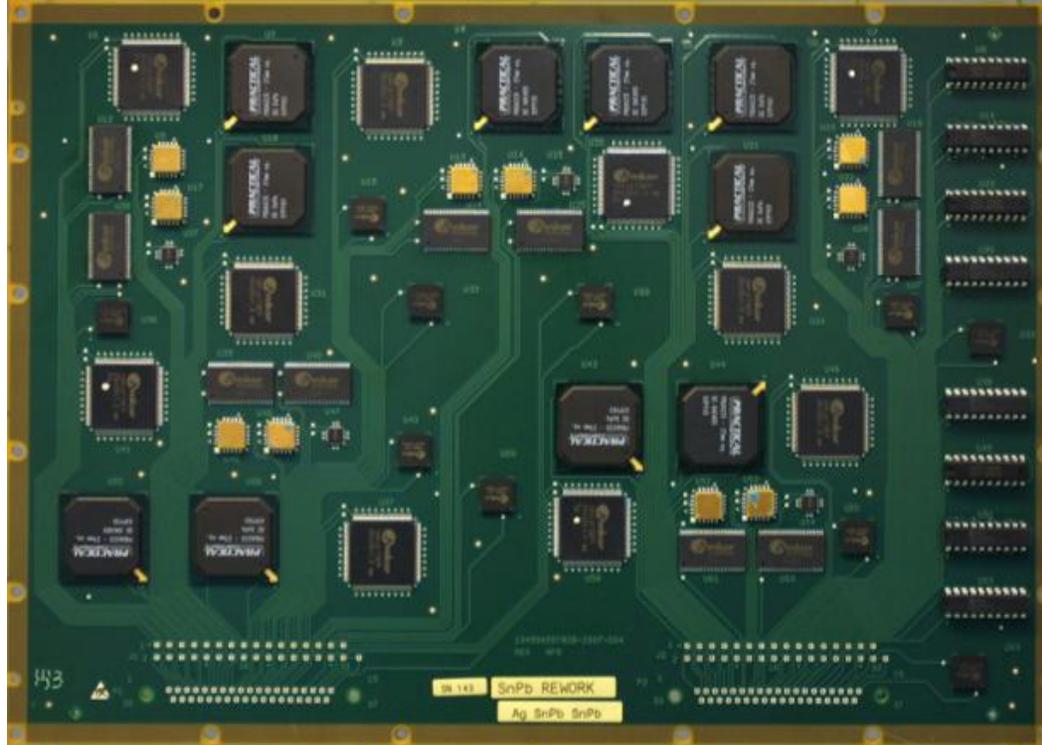
TQFP-144

- Matte Sn
- NiPdAu
- SAC305
 - ❑ Sn finish then tinned
- SnPb
 - ❑ Sn finish then tinned

Test Vehicles

Assembled by BAE Systems - Irving, Texas

- 120 = “Manufactured”
- 73 = “Rework”
 - ❑ 14.5”X 9”X 0.09”
 - ❑ 6 layers of 0.5 ounce copper
 - ❑ FR4 per IPC-4101/26 with a minimum Tg of 170°C (Isola 370HR)
 - ❑ Most Immersion Ag & Some ENIG
 - ❑ Pho-Tronics



Test Vehicles

Batch	Test Vehicle Type	Reflow	Wave
		Solder	Solder
A	Lead-Free Rework	SAC305	SN100C
	All Test Vehicles		
B	SnPb Rework*	SnPb*	SnPb*
	All Test Vehicles		
C	SnPb Manufactured Test Vehicles	SnPb	SnPb
	Thermal Cycle and Combined Environments		
D	SnPb Manufactured Test Vehicles	SnPb	SnPb
	Vibration, Mechanical Shock and Drop		
E	Lead-Free Manufactured Test Vehicles	SAC305	SN100C
	Thermal Cycle and Combined Environments		
F	Lead-Free Manufactured Test Vehicles	SAC305	SN100C
	Vibration, Mechanical Shock and Drop		
G	Lead-Free Manufactured Test Vehicles	SN100C	SN100C
	Thermal Cycle and Combined Environments		
H	Lead-Free Manufactured Test Vehicles	SN100C	SN100C
	Vibration, Mechanical Shock and Drop		
I	Lead-Free Manufactured Test Vehicles	SN100C	SN100C
	Crane Rework Effort		

* NOTE: Lead-Free profiles will be used for reflow and wave soldering

Test Vehicles

Lead-Free Rework (Batch A)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U18, U43, U06, U02, U21, U56	BGA-225	SAC405	SAC305	
U04, U55, U05, U44	BGA-225	SnPb	SAC305	
U09, U13, U22, U46, U53, U10, U14, U17, U45, U52	CLCC-20	SnPb	SAC305	
U33, U50, U19, U37, U42, U60, U36	CSP-100	SAC105	SAC305	
U32, U35, U63	CSP-100	SnPb	SAC305	
U08, U23, U49, U59, U30, U38, U11, U51	PDIP-20	Sn		SN100C
U15, U27, U28, U47, U54	QFN	SnPb	SAC305	
U03, U31, U34, U48, U57	TQFP-144	NiPdAu	SAC305	
U01, U07, U20, U41, U58	TQFP-144	SAC 305 Dip	SAC305	
U12, U25	TSOP-50	Sn	SAC305	
U29, U39, U61, U24, U26	TSOP-50	SnBi	SAC305	
U16, U40, U62	TSOP-50	SnPb	SAC305	

Testing

- Thermal Cycling: -55°C to +125°C
- Thermal Cycling: -20°C to +80°C
- Vibration
- Combined Environments Testing
- Drop Testing
- Mechanical Shock
- Extra Boards
- Test Vehicle Characterization

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = SAC305
 - Preheat = 60-120 seconds @150-190°C
 - Peak temperature target = 243°C
 - Reflow: ~20 seconds above 230°C
 - ~30-90 seconds above 220°C
- Wave Soldering
- Location – Scorpio Solutions
- Wave Profile = SN100C
 - Solder Pot Temperature = 265°C
 - Preheat Board T = 134°C
 - Peak Temperature = 155°C to 175°C
 - Speed: 90 cm/min

Test Vehicles

SnPb Rework (Batch B)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U04, U55, U05, U44	BGA-225	SAC405	SnPb	
U18, U43, U06, U02, U21, U56	BGA-225	SnPb	SnPb	
U09, U13, U22, U46, U53, U10, U14, U17, U45, U52	CLCC-20	SAC305	SnPb	
U32, U35, U63, U36	CSP-100	SAC105	SnPb	
U33, U50, U19, U37, U42, U60	CSP-100	SnPb	SnPb	
U08, U23, U49	PDIP-20	NiPdAu		SnPb
U59, U30, U38	PDIP-20	Sn		SnPb
U11, U51	PDIP-20	SnPb		SnPb
U15, U27, U28, U47, U54	QFN	Matte Sn	SnPb	
U03, U31, U34, U48, U57	TQFP-144	NiPdAu	SnPb	
U01, U07, U20, U41, U58	TQFP-144	SnPb Dip	SnPb	
U29, U39, U61	TSOP-50	Sn	SnPb	
U16, U40, U62	TSOP-50	SnBi	SnPb	
U12, U25, U24, U26	TSOP-50	SnPb	SnPb	

Testing

- Thermal Cycling: -55°C to +125°C
- Thermal Cycling: -20°C to +80°C
- Vibration
- Combined Environments Testing
- Drop Testing
- Mechanical Shock
- Extra Boards
- Test Vehicle Characterization

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = SAC305
 - Preheat = 60-120 seconds @150-190°C
 - Peak temperature target = 243°C
 - Reflow: ~20 seconds above 230°C
 - ~30-90 seconds above 220°C
- Wave Soldering
- Location – Scorpio Solutions
- Wave Profile = SN100C
 - Solder Pot Temperature = 265°C
 - Preheat Board T = 134°C
 - Peak Temperature = 155°C to 175°C
 - Speed: 90 cm/min

Test Vehicles

SnPb Manufactured (Batch C)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U18, U43, U04, U06, U55	BGA-225	SAC405	SnPb	
U02, U05, U21, U44, U56	BGA-225	SnPb	SnPb	
U09, U13, U22, U46, U53	CLCC-20	SAC305	SnPb	
U10, U14, U17, U45, U52	CLCC-20	SnPb	SnPb	
U32, U33, U35, U50, U63	CSP-100	SAC105	SnPb	
U19, U36, U37, U42, U60	CSP-100	SnPb	SnPb	
U08, U23, U49, U59	PDIP-20	NiPdAu		SnPb
U11, U30, U38, U51	PDIP-20	Sn		SnPb
U15, U27, U28, U47, U54	QFN	Matte Sn	SnPb	
U01, U07, U20, U41, U58	TQFP-144	Matte Sn	SnPb	
U03, U31, U34, U48, U57	TQFP-144	SnPb Dip	SnPb	
U12, U25, U29, U39, U61	TSOP-50	SnBi	SnPb	
U16, U24, U26, U40, U62	TSOP-50	SnPb	SnPb	

Testing

- Thermal Cycling: -55°C to +125°C
- Thermal Cycling: -20°C to +80°C
- Combined Environments Testing
- Extra Boards
- Test Vehicle Characterization

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = SnPb
 - Preheat = ~ 120 seconds @140-183°C
 - Solder joint peak temperature = 225°C
 - Time above reflow = 60-90 sec
 - Ramp Rate = 2-3 °C/sec
- Wave Soldering
- Location – BAE Systems Irving, Texas
- Wave Profile = SnPb
 - Solder Pot Temperature = 250°C
 - Preheat Board T = 101°C
 - Peak Temperature = 144°C
 - Speed: 110 cm/min

Test Vehicles

SnPb Manufactured (Batch D)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U18, U43, U04, U06, U55, U02, U05, U21, U44, U56	BGA-225	SnPb	SnPb	
U09, U13, U22, U46, U53, U10, U14, U17, U45, U52	CLCC-20	SnPb	SnPb	
U32, U33, U35, U50, U63, U19, U36, U37, U42, U60	CSP-100	SnPb	SnPb	
U08, U23, U49, U59, U30, U38, U11, U51	PDIP-20	SnPb		SnPb
U15, U27, U28, U47, U54	QFN	SnPb	SnPb	
U01, U07, U20, U41, U58, U03, U31, U34, U48, U57	TQFP-144	Matte Sn	SnPb	
U12, U25, U29, U39, U61, U16, U24, U26, U40, U62	TSOP-50	SnPb	SnPb	

Testing

- Vibration
- Drop Testing
- Mechanical Shock
- Extra Boards
- Test Vehicle Characterization

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = SnPb
 - Preheat = ~ 120 seconds @140-183°C
 - Solder joint peak temperature = 225°C
 - Time above reflow = 60-90 sec
 - Ramp Rate = 2-3 °C/sec
- Wave Soldering
- Location – BAE Systems Irving, Texas
- Wave Profile = SnPb
 - Solder Pot Temperature = 250°C
 - Preheat Board T = 101°C
 - Peak Temperature = 144°C
 - Speed: 110 cm/min

Test Vehicles

Lead-Free Manufactured (Batch E)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U02, U05, U21, U44, U56	BGA-225	SAC405	SAC305	
U18, U43, U04, U06, U55	BGA-225	SnPb	SAC305	
U10, U14, U17, U45, U52	CLCC-20	SAC305	SAC305	
U09, U13, U22, U46, U53	CLCC-20	SnPb	SAC305	
U19, U36, U37, U42, U60	CSP-100	SAC105	SAC305	
U32, U33, U35, U50, U63	CSP-100	SnPb	SAC305	
U08, U23, U49, U59	PDIP-20	NiPdAu		SN100C
U11, U30, U38, U51	PDIP-20	Sn		SN100C
U15, U27, U28, U47, U54	QFN	Matte Sn	SAC305	
U03, U31, U34, U48, U57	TQFP-144	Matte Sn	SAC305	
U01, U07, U20, U41, U58	TQFP-144	SnPb Dip	SAC305	
U16, U24, U26, U40, U62	TSOP-50	SnBi	SAC305	
U12, U25, U29, U39, U61	TSOP-50	SnPb	SAC305	

Testing

- Thermal Cycling: -55°C to +125°C
- Thermal Cycling: -20°C to +80°C
- Combined Environments Testing
- Extra Boards
- Test Vehicle Characterization

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = SAC305
 - Preheat = 60-120 seconds @150-190°C
 - Peak temperature target = 243°C
 - Reflow: ~20 seconds above 230°C
 - ~30-90 seconds above 220°C
- Wave Soldering
- Location – Scorpio Solutions
- Wave Profile = SN100C
 - Solder Pot Temperature = 265°C
 - Preheat Board T = 134°C
 - Peak Temperature = 155°C to 175°C
 - Speed: 90 cm/min

Test Vehicles

Lead-Free Manufactured (Batch F)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U18, U43, U04, U06, U55, U02, U05, U21, U44, U56	BGA-225	SAC405	SAC305	
U09, U13, U22, U46, U53, U10, U14, U17, U45, U52	CLCC-20	SAC305	SAC305	
U32, U33, U35, U50, U63, U19, U36, U37, U42, U60	CSP-100	SAC105	SAC305	
U08, U23, U49	PDIP-20	NiPdAu		SN100C
U59, U30, U38, U11, U51	PDIP-20	Sn		SN100C
U15, U27, U28, U47, U54	QFN	Matte Sn	SAC305	
U01, U07, U20, U41, U58, U03, U31, U34, U48, U57	TQFP-144	Matte Sn	SAC305	
U12, U25, U29, U39, U61	TSOP-50	Sn	SAC305	
U16, U24, U26, U40, U62	TSOP-50	SnBi	SAC305	

Testing

- Vibration
- Drop Testing
- Mechanical Shock
- Extra Boards
- Test Vehicle Characterization

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = SAC305
 - Preheat = 60-120 seconds @150-190°C
 - Peak temperature target = 243°C
 - Reflow: ~20 seconds above 230°C
 - ~30-90 seconds above 220°C
- Wave Soldering
- Location – Scorpio Solutions
- Wave Profile = SN100C
 - Solder Pot Temperature = 265°C
 - Preheat Board T = 134°C
 - Peak Temperature = 155°C to 175°C
 - Speed: 90 cm/min

Test Vehicles

Lead-Free Manufactured (Batch G)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U02, U05, U21, U44, U56	BGA-225	SAC405	SN100C	
U18, U43, U04, U06, U55	BGA-225	SnPb	SN100C	
U10, U14, U17, U45, U52	CLCC-20	SAC305	SN100C	
U09, U13, U22, U46, U53	CLCC-20	SnPb	SN100C	
U19, U36, U37, U42, U60	CSP-100	SAC105	SN100C	
U32, U33, U35, U50, U63	CSP-100	SnPb	SN100C	
U08, U23, U49, U59	PDIP-20	NiPdAu		SN100C
U11, U30, U38, U51	PDIP-20	Sn		SN100C
U15, U27, U28, U47, U54	QFN	Matte Sn	SN100C	
U03, U31, U34, U48, U57	TQFP-144	Matte Sn	SN100C	
U01, U07, U20, U41, U58	TQFP-144	SnPb Dip	SN100C	
U16, U24, U26, U40, U62	TSOP-50	SnBi	SN100C	
U12, U25, U29, U39, U61	TSOP-50	SnPb	SN100C	

Testing

- Thermal Cycling: -55°C to +125°C
- Thermal Cycling: -20°C to +80°C
- Combined Environments Testing
- Extra Boards
- Test Vehicle Characterization

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = **SN100C**:
 - Preheat = 60-120 seconds @150-190°C
 - Peak temperature target = 243°C
 - Reflow: ~20 seconds above 230°C
 - ~30-90 seconds above 220°C
- Wave Soldering
- Location – Scorpio Solutions
- Wave Profile = SN100C:
 - Solder Pot Temperature = 265°C
 - Preheat Board T = 134°C
 - Peak Temperature = 155°C to 175°C
 - Speed: 90 cm/min

Test Vehicles

Lead-Free Manufactured (Batch H)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U18, U43, U04, U06, U55, U02, U05, U21, U44, U56	BGA-225	SAC405	SN100C	
U09, U13, U22, U46, U53, U10, U14, U17, U45, U52	CLCC-20	SAC305	SN100C	
U32, U33, U35, U50, U63, U19, U36, U37, U42, U60	CSP-100	SAC105	SN100C	
U08, U23, U49	PDIP-20	NiPdAu		SN100C
U59, U30, U38, U11, U51	PDIP-20	Sn		SN100C
U15, U27, U28, U47, U54	QFN	Matte Sn	SN100C	
U01, U07, U20, U41, U58, U03, U31, U34, U48, U57	TQFP-144	Matte Sn	SN100C	
U12, U25, U29, U39, U61	TSOP-50	Sn	SN100C	
U16, U24, U26, U40, U62	TSOP-50	SnBi	SN100C	

Testing

- Vibration
- Drop Testing
- Mechanical Shock
- Extra Boards
- Test Vehicle Characterization

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = **SN100C**:
 - Preheat = 60-120 seconds @150-190°C
 - Peak temperature target = 243°C
 - Reflow:~20 seconds above 230°C
 - ~30-90 seconds above 220°C
- Wave Soldering
- Location – Scorpio Solutions
- Wave Profile = SN100C:
 - Solder Pot Temperature = 265°C
 - Preheat Board T = 134°C
 - Peak Temperature = 155°C to 175°C
 - Speed: 90 cm/min

Test Vehicles

Lead-Free Manufactured (Batch I)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U18, U43, U04, U06, U55, U02, U05, U21, U44, U56	BGA-225	SAC405	SN100C	
U09, U13, U22, U46, U53, U10, U14, U17, U45, U52	CLCC-20	SAC305	SN100C	
U32, U33, U35, U50, U63, U19, U36, U37, U42, U60	CSP-100	SN100C	SN100C	
U08, U23, U49	PDIP-20	NiPdAu		SN100C
U59, U30, U38, U11, U51	PDIP-20	Sn		SN100C
U15, U27, U28, U47, U54	QFN	Matte Sn	SN100C	
U01, U07, U20, U41, U58, U03, U31, U34, U48, U57	TQFP-144	Matte Sn	SN100C	
U12, U25, U29, U39, U61	TSOP-50	Sn	SN100C	
U16, U24, U26, U40, U62	TSOP-50	SnBi	SN100C	

Testing

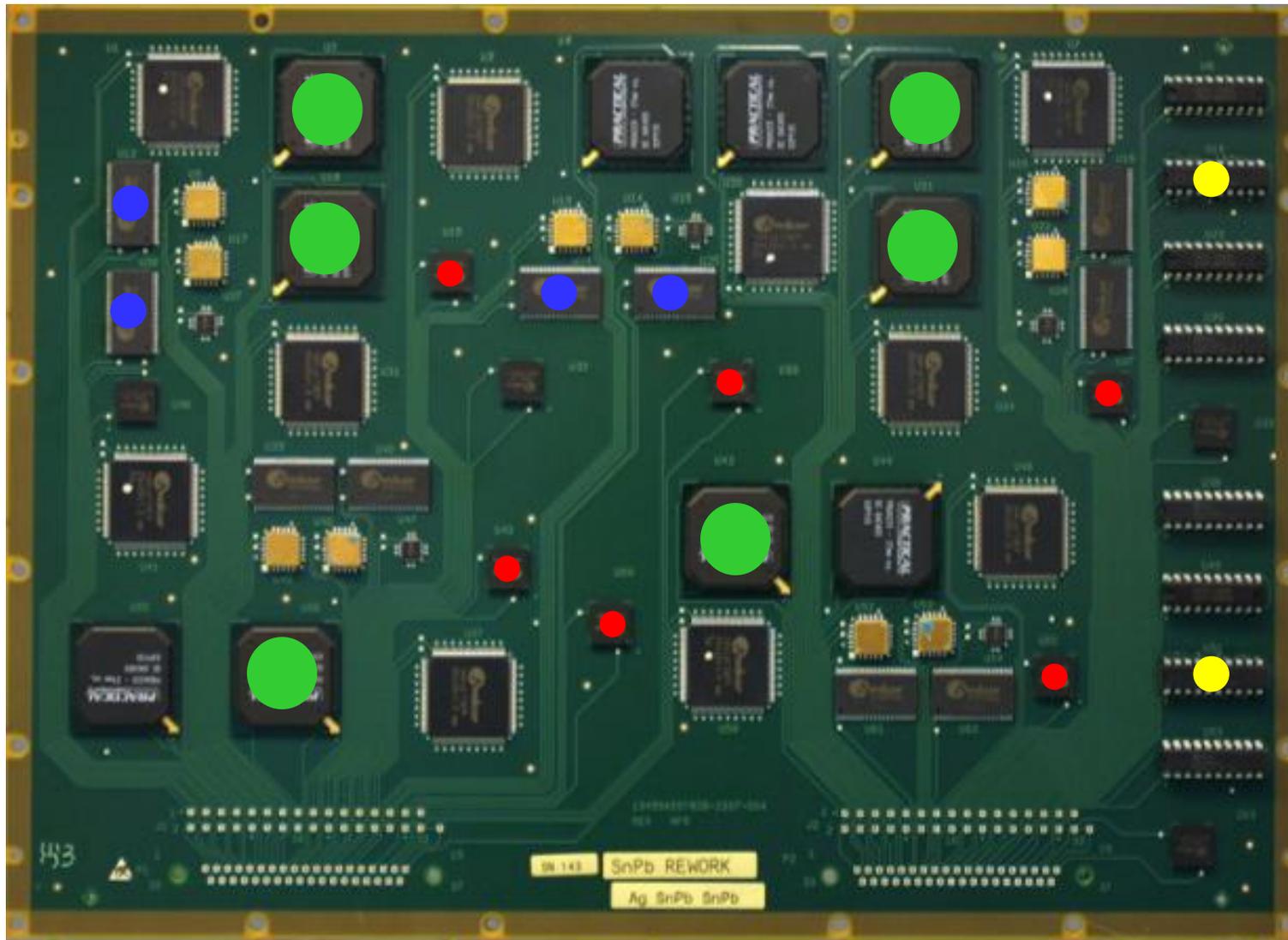
- Thermal Cycling: -55°C to +125°C
- Thermal Cycling: -20°C to +80°C
- Vibration
- Combined Environments Testing
- Drop Testing
- Mechanical Shock
- Extra Boards
- Test Vehicle Characterization

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = **SN100C**:
 - Preheat = 60-120 seconds @150-190°C
 - Peak temperature target = 243°C
 - Reflow: ~20 seconds above 230°C
 - ~30-90 seconds above 220°C
- Wave Soldering
- Location – Scorpio Solutions
- Wave Profile = SN100C:
 - Solder Pot Temperature = 265°C
 - Preheat Board T = 134°C
 - Peak Temperature = 155°C to 175°C
 - Speed: 90 cm/min

“Rework” Test Vehicles

Reworked Components



U18 – BGA-225
U43 – BGA-225
U06 – BGA-225
U02 – BGA-225
U21 – BGA-225
U56 – BGA-225

U33 – CSP-100
U50 – CSP-100
U19 – CSP-100
U37 – CSP-100
U42 – CSP-100
U60 – CSP-100

U11 – PDIP-20
U51 – PDIP-20

U12 – TSOP-50
U25 – TSOP-50
U24 – TSOP-50
U26 – TSOP-50

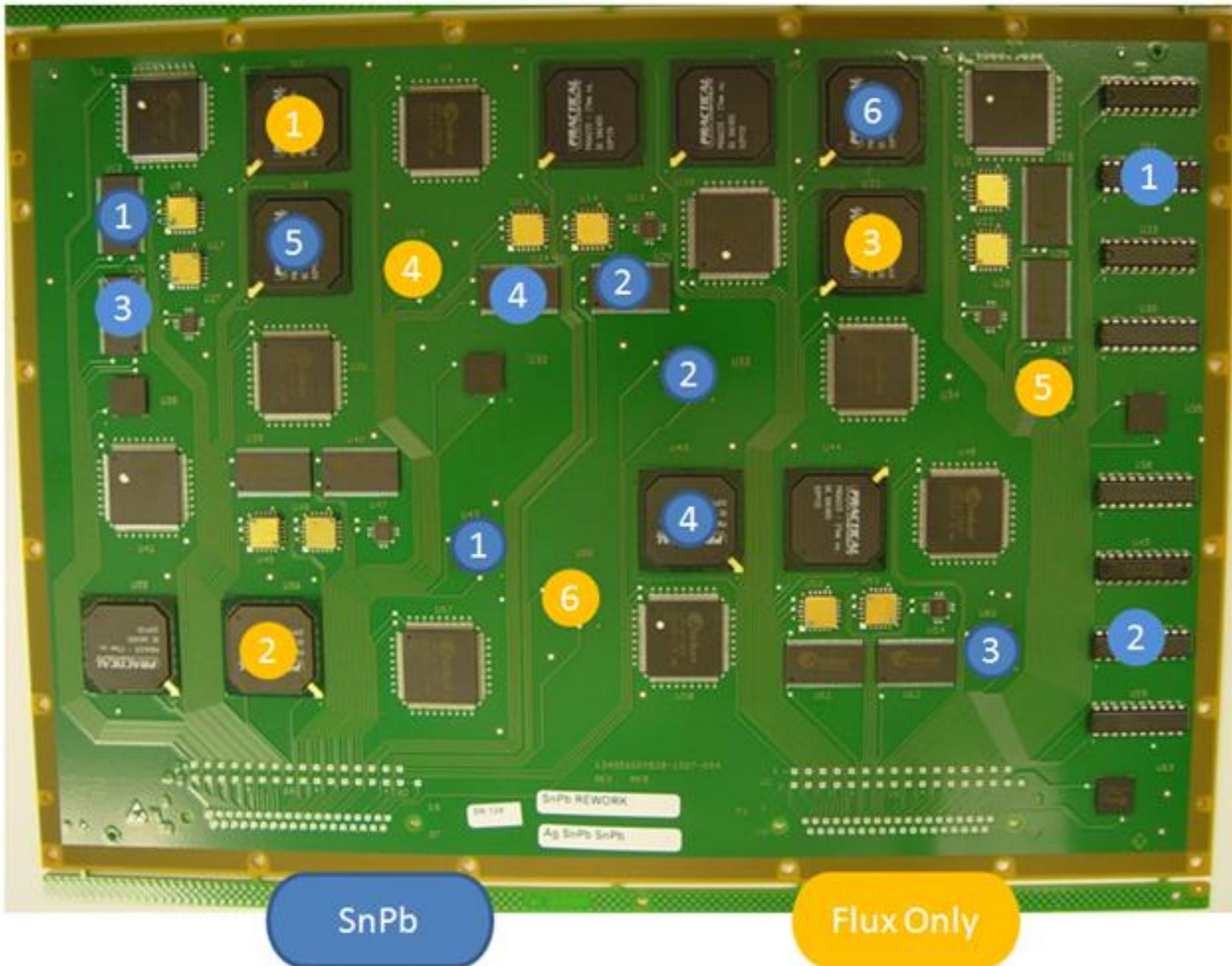
Component Finish/Solder Combinations

SnPb Rework (Batch B)

RefDes	Component	Original Component Finish	Reflow Solder	Wave Solder	New Component Finish	Rework Solder
U18	BGA-225	SnPb	SnPb		SAC405	SnPb
U43	BGA-225	SnPb	SnPb		SAC405	SnPb
U06	BGA-225	SnPb	SnPb		SAC405	SnPb
U02	BGA-225	SnPb	SnPb		SnPb	Flux Only
U21	BGA-225	SnPb	SnPb		SnPb	Flux Only
U56	BGA-225	SnPb	SnPb		SnPb	Flux Only
U33	CSP-100	SnPb	SnPb		SAC105	SnPb
U50	CSP-100	SnPb	SnPb		SnPb	Flux Only
U19	CSP-100	SnPb	SnPb		SnPb	Flux Only
U37	CSP-100	SnPb	SnPb		SnPb	Flux Only
U42	CSP-100	SnPb	SnPb		SAC105	SnPb
U60	CSP-100	SnPb	SnPb		SAC105	SnPb
U11	PDIP-20	SnPb		SnPb	Sn	SnPb
U51	PDIP-20	SnPb		SnPb	Sn	SnPb
U12	TSOP-50	SnPb	SnPb		SnPb	SnPb
U25	TSOP-50	SnPb	SnPb		SnPb	SnPb
U24	TSOP-50	SnPb	SnPb		Sn	SnPb
U26	TSOP-50	SnPb	SnPb		Sn	SnPb

Rework Procedures per IPC-7711

Rework Procedure – SnPb Rework



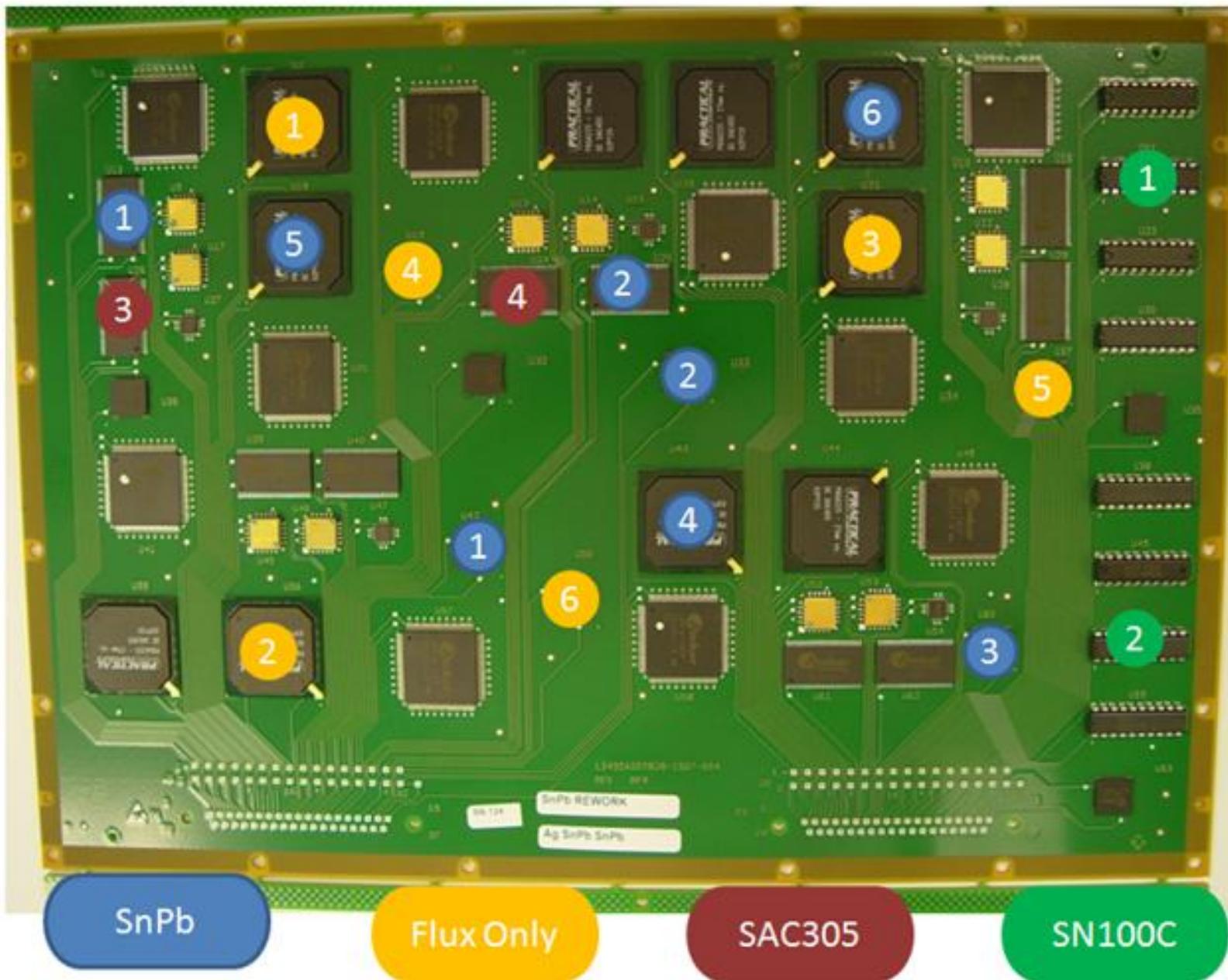
Component Finish/Solder Combinations

Lead-Free Rework (Batch A)

RefDes	Component	Original Component Finish	Reflow Solder	Wave Solder	New Component Finish	Rework Solder
U18	BGA-225	SAC405	SAC305		SAC405	SnPb
U43	BGA-225	SAC405	SAC305		SAC405	SnPb
U06	BGA-225	SAC405	SAC305		SAC405	SnPb
U02	BGA-225	SAC405	SAC305		SAC405	Flux Only
U21	BGA-225	SAC405	SAC305		SAC405	Flux Only
U56	BGA-225	SAC405	SAC305		SAC405	Flux Only
U33	CSP-100	SAC105	SAC305		SAC105	SnPb
U50	CSP-100	SAC105	SAC305		SAC105	Flux Only
U19	CSP-100	SAC105	SAC305		SAC105	Flux Only
U37	CSP-100	SAC105	SAC305		SAC105	Flux Only
U42	CSP-100	SAC105	SAC305		SAC105	SnPb
U60	CSP-100	SAC105	SAC305		SAC105	SnPb
U11	PDIP-20	Sn		SN100C	Sn	SN100C
U51	PDIP-20	Sn		SN100C	Sn	SN100C
U12	TSOP-50	Sn	SAC305		Sn	SnPb
U25	TSOP-50	Sn	SAC305		Sn	SnPb
U24	TSOP-50	SnBi	SAC305		SnBi	SAC305
U26	TSOP-50	SnBi	SAC305		SnBi	SAC305

Rework Procedures per IPC-7711

Rework Procedure – Lead-Free Rework



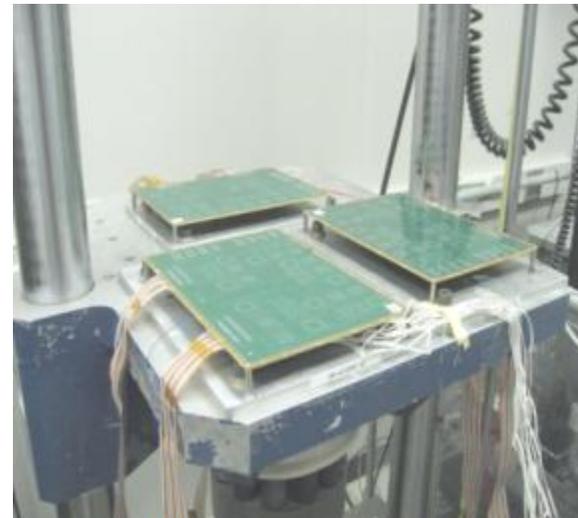
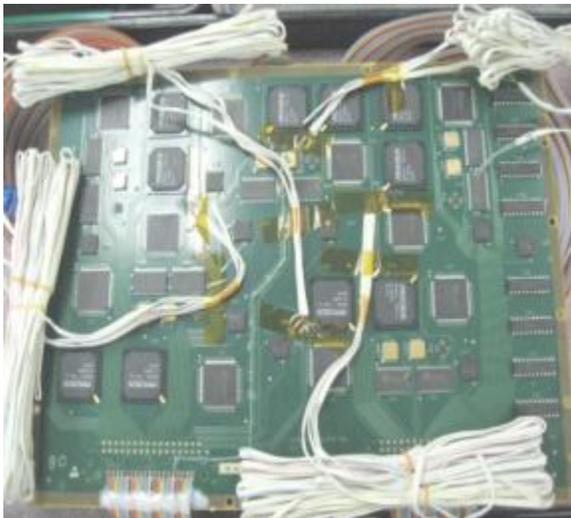
NAVSEA Crane Rework Effort

Built 30 test vehicles (sub-set of the 193 assembled)

- Test vehicles were built with **Lead-Free solder and Lead-Free component finishes only** = similar to Manufactured test vehicles for Mechanical Shock, Vibration and Drop Testing
- Lead-Free alloys, SAC305 and SN100C
- Rework was done using **only SnPb solder**
- Performed multiple pass rework 1 to 2 times on random Pb-free DIP, TQFP-144, TSOP-50, LCC and QFN components
- Testing
 - ❑ Thermal Cycling -55°C to +125°C – Tested with the NASA-DoD test vehicles {Rockwell Collins}
 - ❑ Vibration Testing {Celestica}
 - ❑ Drop Testing {Celestica}

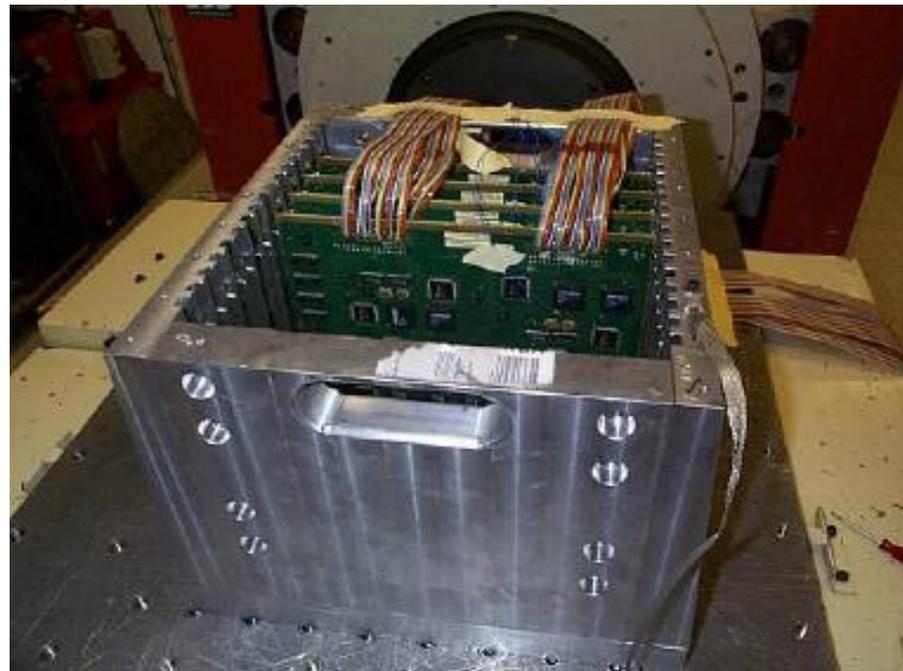
Drop Testing - NSWC Crane Test Vehicles

- Shock parameters: 500 G, 2.0 ms duration (340 G for cards 80, 82, 87 for first 10 drops)
- Number of drops: 20
- 9 cards in total / 3 cards tested per drop
- Each card monitored for shock response
- Each card monitored for resistance
- Cards 80, 83, 86 monitored for strain



Vibration Testing

- Subject the test vehicles to $8.0 g_{\text{rms}}$ for one hour.
- Then increase the Z-axis vibration level in $2.0 g_{\text{rms}}$ increments, shaking for one hour per step until the $20.0 g_{\text{rms}}$ level is completed.
- Then subject the test vehicles to a final one hour of vibration at $28.0 g_{\text{rms}}$.



Testing Activities - NASA-DoD Test Vehicles

- Thermal Cycle Testing (-20/+80°C) - Boeing
- Combine Environments Testing - Raytheon
- Drop Testing - Celestica
- Thermal Cycle Testing (-55/+125°C) - Rockwell Collins
- Vibration Testing - Boeing
- Mechanical Shock Testing - Boeing
- Interconnect Stress Test - PWB Interconnect Solutions
- Copper Dissolution - Celestica & Rockwell Collins

Specific testing details can be found in the Joint Test Protocol

http://www.teerm.nasa.gov/projects/NASA_DODLeadFreeElectronics_Proj2.html

Thermal Cycle Testing (-20/+80°C)

- 5 to 10°C/minute ramp
- 30 minute dwell at 80°C
- 10 minute dwell at -20°C
- Completed about 7,000 cycles



Combine Environments Testing

- -55°C to +125°C
- 20°C/minute ramp
- 15 minute dwell at -55°C and +125°C
- Vibration for the duration of the thermal cycle
- 10 g_{rms} pseudo-random vibration initially
- Increase vibration level 5 g_{rms} after every 50 cycles
- 55 g_{rms} maximum



Thermal Cycle Testing (-55/+125°C)

- 5 to 10°C/minute ramp
- 30 minute dwell at 125°C
- 10 minute dwell at -55°C
- Completed 4,068 thermal cycles



Vibration Testing

- Subject the test vehicles to $8.0 g_{\text{rms}}$ for one hour.
- Then increase the Z-axis vibration level in $2.0 g_{\text{rms}}$ increments, shaking for one hour per step until the $20.0 g_{\text{rms}}$ level is completed.
- Then subject the test vehicles to a final one hour of vibration at $28.0 g_{\text{rms}}$.

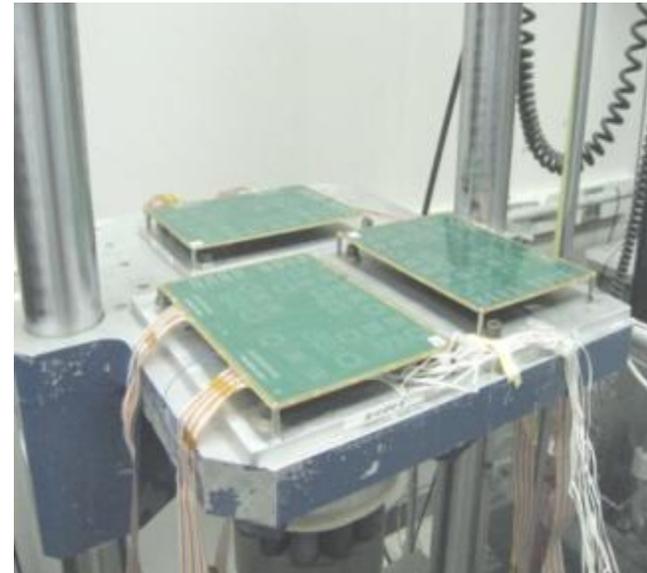
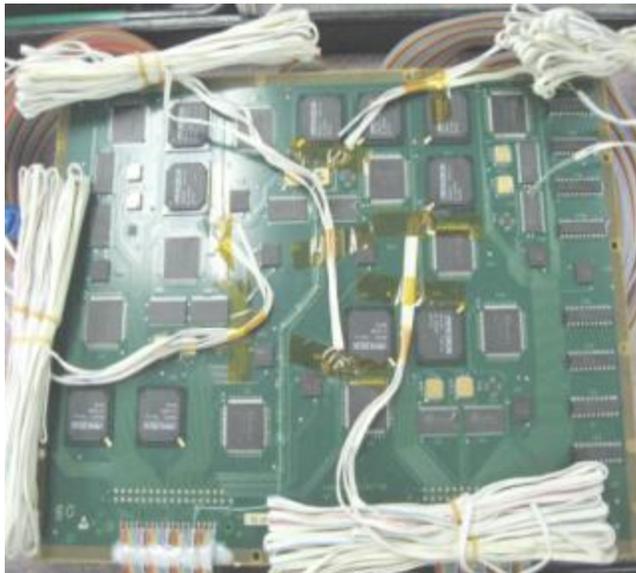


Mechanical Shock Testing

- Level 1: 100 shock pulses using a 20 G SRS
 - ❑ Functional Test for Flight Equipment; MIL-STD-810G, Method 516.6
- Level 2: 100 shock pulses using a 40 G SRS
 - ❑ Functional Test for Ground Equipment; MIL-STD-810G, Method 516.6
- Level 3: 100 shock pulses using a 75 G SRS
 - ❑ Crash Hazard Test for Ground Equipment; MILSTD-810G, Method 516.6
- Level 4: 100 shock pulses using a 100 G SRS
- Level 5: 100 shock pulses using a 200 G SRS
- Level 6: 400 shock pulses using a 300 G SRS

Drop Testing - NASA-DoD Test Vehicles

- Shock testing will be conducted in the Z - axis
- 500Gpk input, 2ms pulse duration
- Test vehicles will be dropped until all monitored components fail or 10 drops have been completed





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NASA-DoD Lead-Free Electronics Project:

http://www.teerm.nasa.gov/projects/NASA_DODLeadFreeElectronics_Proj2.html

JCAA/JGPP Lead-Free Solder Project

http://www.teerm.nasa.gov/projects/LeadFreeSolderTestingForHighReliability_Proj1.html

