



Contamination Survey of Deployed Aircraft Avionics

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Background

- Previous laboratory study has identified a significant consequence of dust intrusion and contamination of avionics boards when exposed to elevated temperatures and relative humidity;
- That study did demonstrate a high risk of failure of avionics boards when exposed to SWA dust;
- It did not address the probability of the boards being contaminated as a result of being deployed in SWA



Objectives

- Locate aircraft recently returning from SWA;
- Inspect aircraft and identify any LRU's that demonstrated dust intrusion or a susceptibility to dust intrusion;
- Perform surface chemical analyses of the avionics boards on-site (when possible) to determine levels of ionic contamination;
- Report on the occurrence of dust contamination within LRU's and the presence of ions and their respective concentration levels



- Collaborative team established for surveys:
 - UDRI (Materials Degradation Group);
 - AFRL (RXSA) Electronic Failures Analysis Group;
 - Foresite, Inc (printed circuit board testing and surface analysis)



Sites Visited

- Selfridge Air National Guard Base
 - 127th Wing, Michigan ANG
- Moody AFB
 - 23rd Wing, Valdosta, GA
- Robins AFB
 - WR-ALC, Warner Robins, GA
- McEntire Air National Guard Base
 - 169th Fighter Wing, South Carolina ANG
- Temple OLR Re-set Facility, Temple, TX
- Fort Hood Army Air Field, Aviation Services, Killeen, TX
- Hill AFB, Ogden Air Logistics Center, Ogden, UT



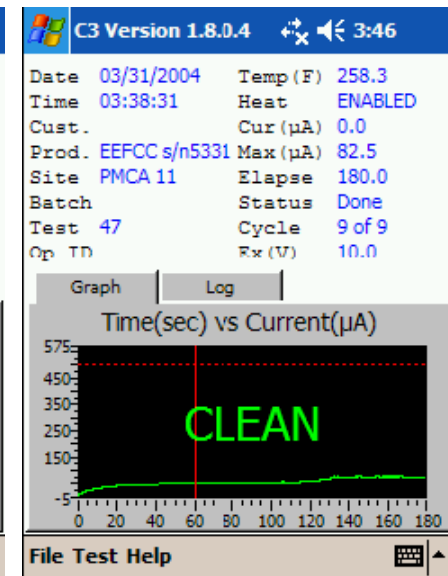
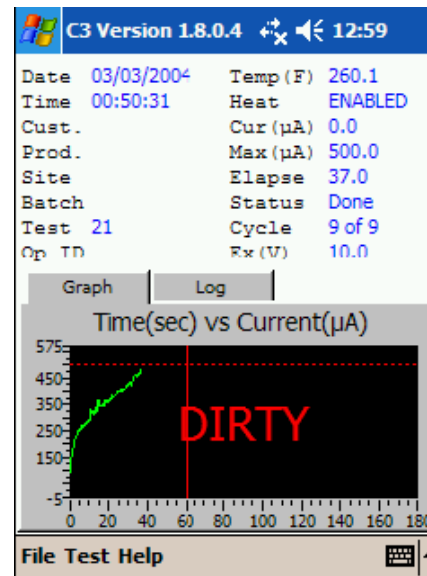
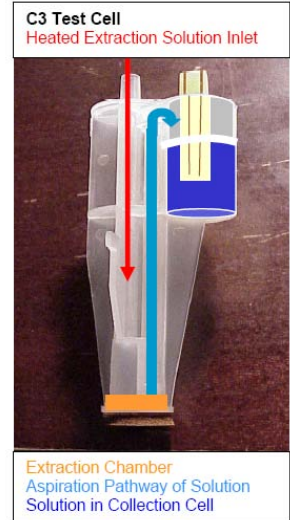
Methodology

- At each site, a briefing was given to the senior maintenance personnel describing the ongoing effort and the results of the previous laboratory study;
- On-site surface analysis
 - C3 Localized Cleanliness Tester system
 - Non-destructively collects and detects presence of ionic and conductive species on printed circuit board (PCB) assemblies;
- Off-site chemical analysis
 - C3 test cell solution analyzed using ion chromatography (Foresite, Inc.)
 - Dust samples and surface swab of PCB's and test equipment deployed in SWA (UDRI)



C3 Tester System

- Deionized steam delivered to sample site (0.1 in²);
- Extraction of soluble ions;
- Aspiration of solution into collection cell;
- Cycle repeated 9 times;
 - Total time: 3 minutes
- Y-pattern electrode used to measure leakage current in cell solution (10 V bias);
- Current threshold of 500 μ A set ;
 - Based on SIR and chromatography data
 - Time limit of 60 seconds for threshold limit
 - Total time: 3 minutes
- Cell solution analyzed off site using ion chromatography





Chromatography

- Analysis performed on C3 Cell solution and solubilized ions from cotton swabs of surfaces;
- These surfaces include:
 - PCB's
 - Test stand equipment
 - Aircraft surfaces
- Look for 4 ions*:
 - Chloride (Cl^-)
 - Sulfate (SO_4^{-2})
 - Nitrate (NO_3^-)
 - Bromine (Br^-)





Results: Moody AFB

(Surface Chemical Analysis of LRU components and surfaces of H-60 Aircraft)

Foresite ID#	Sample Description	Ion Chromatography				C3 Tester	
		Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
	Moody AFB						
1981-03-01	Boost pump control-front side of panel	2.88	0.01	0.25	2.59	Dirty	40
1981-03-02	AN/ALE47 control panel	0.27	0.00	0.06	0.75	Clean	180
1981-03-03	Back of boost pump front panel	0.26	0.00	0.95	0.48	Dirty	52
1981-03-04	Body panel-forward floor collective cowling	11.45	0.20	0.37	4.04	Dirty	0.2
1981-03-05	Reference of sample 4-no sand or dust	0.94	0.00	0.76	1.47	Dirty	29
1981-03-06	Shroud cover	0.37	0.01	0.34	0.44	Clean	149
1981-03-07	Inside forward compartment, shelf on inner wall	4.14	0.01	0.11	0.22	Dirty	28
1981-03-08	Under co-pilot foot controls	15.96	0.02	0.22	2.68	Dirty	0.4

Indicates exceeds recommended limit



Results: Moody AFB

(Sampling surfaces of H-60 Aircraft)





Results: Raytheon F-15 Avionics Engineering Facility (WR-ALC)



Foresite ID#	Sample Description	Ion Chromatography				C3 Tester	
		Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
	Warner Robbins AFB/Raytheon Shop						
1981-03-09	3173-081-170 C Radar board	1.60	0.00	0.05	0.00	Clean	180
1981-03-10	Bare area of 3173-081-170 C Radar board	1.33	0.00	0.05	0.00	Clean	180
1981-03-11	Steam thru plenum of PCB out of F-15E - right side	0.03	0.00	0.02	2.61	No data	
1981-03-12	Steam thru plenum of PCB out of F-15E - center	0.02	0.00	0.02	2.14	No data	
1981-03-13	Steam thru plenum of PCB of F-15E - left side	0.07	0.00	0.05	3.66	No data	
1981-03-14	Steam thru plenum of PCB out of F-15E 038 model returned from SWA less than 3 months - right side	0.03	0.00	0.11	1.09	No data	
1981-03-15	Steam thru plenum of PCB out of F-15E 038 model returned from SWA less than 3 months - center	0.02	0.00	0.09	1.06	No data	
1981-03-16	Steam thru plenum of PCB out of F-15E 038 model returned from SWA less than 3 months - left side	0.05	0.00	0.14	1.71	No data	

Ion chromatography analysis of anions cleanliness measurements on components and surfaces of various avionic printed circuit boards from the Raytheon F-15 Avionics Engineering Facility by Foresite, Inc. Values for ions are in parts per million (PPM);

Indicates exceeds recommended limit





Results: McEntire ANG Base (F-16 Block 52 Aircraft)

Foresite ID#	Sample Description	Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
	McIntyre National Guard Base						
1981-03-17	Card out of 184 ECM pod, returned from SWA in 2003.	0.22	0.00	0.02	0.00	Clean	180
1981-03-18	Sand/dust from test stand	5.46	0.01	0.23	8.59	Dirty	0.7
1981-03-19	Radar LRU module	0.14	0.00	0.19	0.00	Clean	168
UDRI ID#							
5	Sand/dust from test stand tool cabinet	6.38	0.84	2.49	9.21	NA	NA

Ion chromatography analysis of anions and cleanliness measurements on an ECM pod avionics card, a test stand and a radar LRU module at McEntire ANG Base by Foresite Inc. and UDRI. Values for ions are in parts per million (PPM).

Indicates exceeds recommended limit





Results: Temple OLR Re-set Facility (H-60 and AH-64 Aircraft)

- Subject of visit 10-14 December 2007;
- Allowed access to H-60 and AH-64 aircraft recently returned from SWA
 - H-60 aircraft returned previous day to our arrival and had not been touched yet;
 - Deployed to Camp Taji (~20 km north of Baghdad)
 - Surveyed and sampled for dust contamination on various aircraft surfaces
 - AH-64 aircraft had already begun maintenance process;
 - Visual survey only of aircraft
- Allowed access to avionics shop, where LRU's were disassembled after removal from H-60 aircraft;
 - Able to make C3 surface cleanliness measurements on LRU component PCB's;
 - Able to collect surface swabs on various H-60 LRU component PCB's

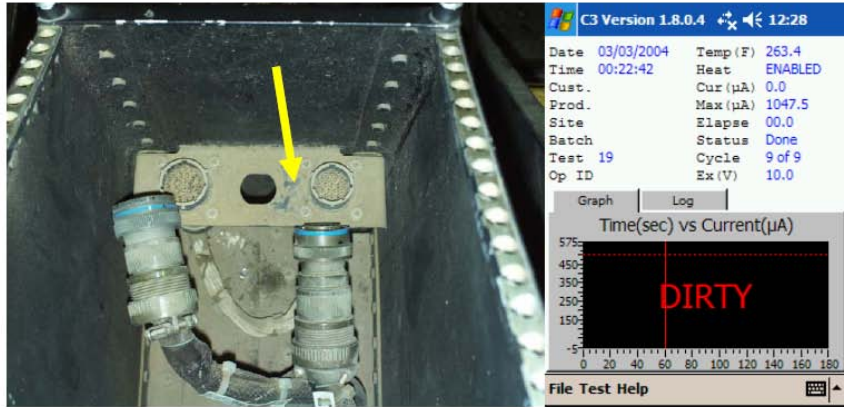


Results: Temple OLR Re-set Facility (H-60 Aircraft)

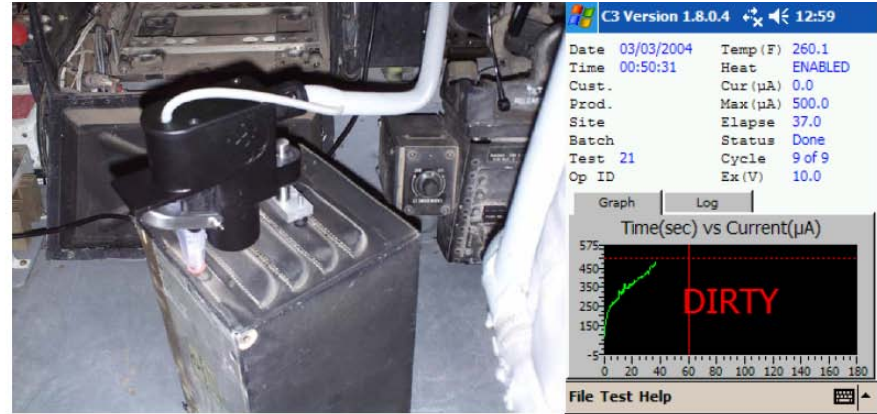




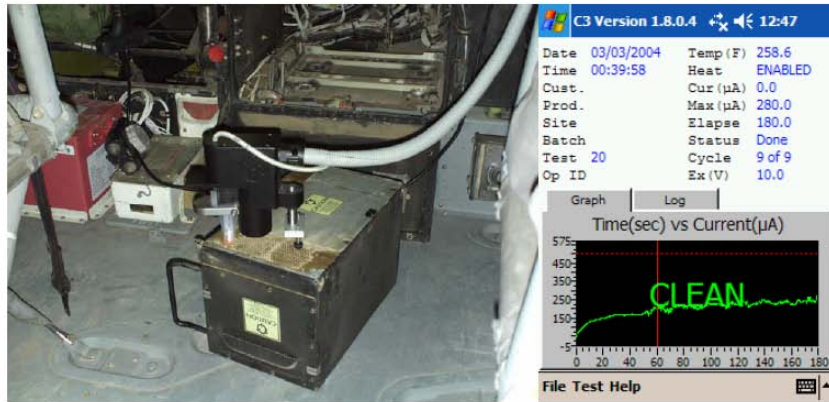
Results: Temple OLR Re-set Facility (H-60 Aircraft)



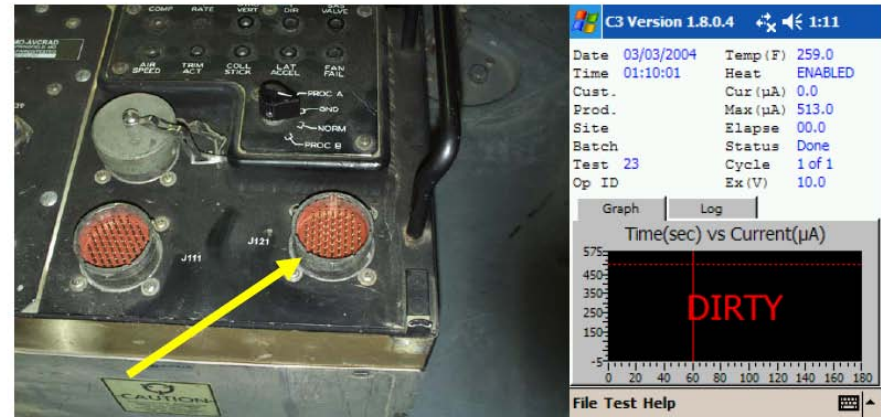
Sample #1 H-60 UHF/VHF Radio Re-Trans Unit Area



Sample #3 H-60 FTS Computer Cooling Out-Vent



Sample #2 H-60 FTS Computer Cooling In-Vent



Sample #4 H-60 FTS Computer inside J121 Connector



Results: Temple OLR Re-set Facility (H-60 Aircraft)



Foresite		Ion Chromatography				C3 Tester	
ID#	Sample Description	Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
1981-06-01	H-60 UHF/VHF Radio Retrans Unit	27.92	0.05	4.52	123.08	Dirty	0.0
1981-06-02	H-60 FTS Computer Housing In-Vent	0.22	0.00	0.2	0.07	Clean	180.0
1981-06-03	H-60 FTS Computer Housing Out-Vent	1.04	0.00	0.82	7.11	Dirty	37.0
1981-06-04	H-60 FTS Computer J121 Connector	4.73	0.03	1.42	14.14	Dirty	0.0
1981-06-05	H-60 Rate Gyro Assy Floor under Nose Cover	15.49	0.00	2.08	35.55	Dirty	13.7

Ion chromatography analysis of anions and cleanliness measurements on various surfaces of avionics components on board H-60 aircraft at Temple Re-set facility by Foresite, Inc. Values for ions are in parts per million (PPM).

Indicates exceeds recommended limit



Results: Temple OLR Re-set Facility (Avionics Shop, H-60 Aircraft)

Foresite		Ion Chromatography				C3 Tester	
ID#	Sample Description	Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
1981-06-06	H-60 Inverter Unit Near Diodes	0.30	0.00	0.27	0.97	Clean	180.0
1981-06-07	H-60 FTS Card 7697131-1A Top Side	28.11	0.03	9.66	64.13	Dirty	0.0
1981-06-08	H-60 FTS Card 7697131-1A Bottom	0.23	0.00	0.31	0.99	Clean	71.2
1981-06-09	H-60 FTS Card 769707-1A Top Side	1.19	0.00	0.60	3.72	Dirty	36.9
1981-06-10	H-60 FTS Card 769707-1A Bottom Side	1.70	0.00	1.16	6.90	Clean	64.0
1981-06-11	H-60 MO-AVCRAD 769704-2 85120926	18.07	0.04	8.36	51.22	Dirty	0.0
1981-06-12	H-60 New FTS Card "Cleaned"	0.12	0.00	0.04	0.29	Clean	180.0
1981-06-13	H-60 FTS Card Top side S/N 2-361	4.46	0.00	1.30	11.12	Dirty	3.7
1981-06-14	H-60 FTS Card Bottom S/N 2-361	0.00	0.00	0.05	0.04	Clean	180.0

Ion chromatography analysis of anions and cleanliness measurements on various surfaces inside LRU's and their component circuit cards from a H-60 aircraft at Temple Re-set facility by Foresite, Inc. Values for ions are in parts per million (PPM).

Indicates exceeds recommended limit





Results: Temple OLR Re-set Facility (AH-64 Aircraft)





Results: Temple OLR Re-set Facility (Avionics Shop, AH-64 Aircraft)

Foresite		Ion Chromatography				C3 Tester	
ID#	Sample Description	Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
1981-06-15	AH-64 TADS Card A3 Top side S/N 503	0.40	0.00	0.43	0.66	Clean	74.0
1981-06-16	AH-64 TADS Card A3 Bottom S/N 503	0.30	0.00	0.19	0.45	Clean	99.5
1981-06-17	AH-64 TADS Card A5 Top side S/N 305314A	0.71	0.00	0.87	2.95	Clean	68.6
1981-06-18	AH-64 TADS Card A5 Bottom S/N 305314A	0.15	0.00	0.00	0.00	Clean	180.0
UDRI ID#							
Temple 10	Inside cover of Target Acquisition & Designation System (TADS) LRU	4.82	0.46	3.21	14.60	NA	NA

Ion chromatography analysis of anions and cleanliness measurements on various surfaces inside LRU's and their component circuit cards from a AH-64 aircraft at Temple Re-set facility by Foresite, Inc. Values for ions are in parts per million (PPM).

Indicates exceeds recommended limit





Results: Ft. Hood Army Airfield Facility (H-60 Aircraft)



Foresite		Ion Chromatography				C3 Tester	
ID#	Sample Description	Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
1981-06-19	ARC220 Radio Control Set Board	4.08	0.00	0.35	6.90	Dirty	0.6
UDRI ID#							
Hood 11	ARC220 Radio Control Set Circuit Board	3.53	0.00	1.17	8.39	NA	NA
Hood 12	Interior wall of ARC220 Radio Control Set LRU	2.95	0.00	1.00	10.16	NA	NA

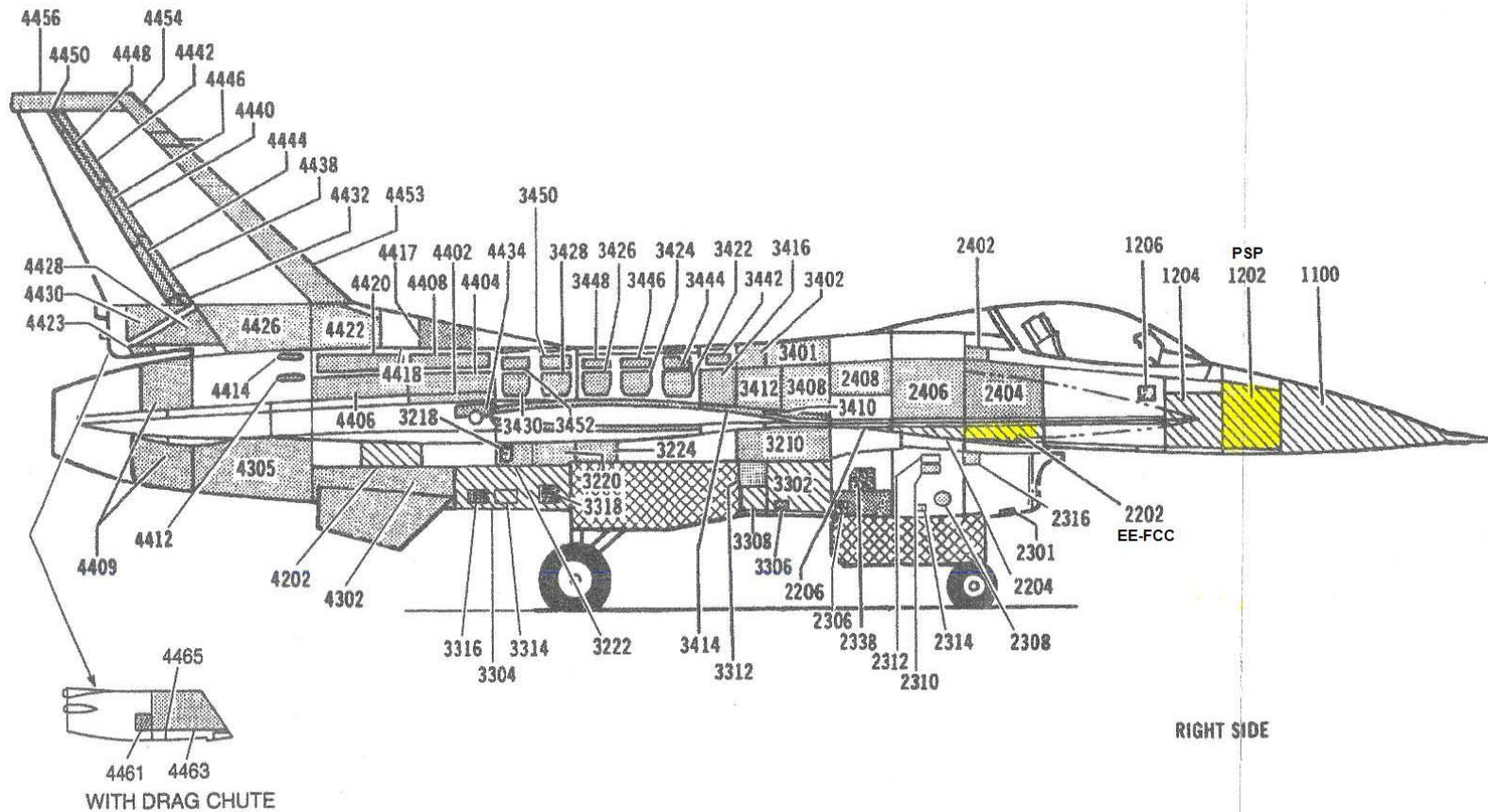
Ion chromatography analysis of anions and cleanliness measurements on surfaces of avionics components of H-60 aircraft at Ft. Hood Army Airfield Aviation facility by Foresite, Inc and UDRI. Values for ions are in parts per million (PPM).

Indicates exceeds recommended limit





F-16 LRU Locations

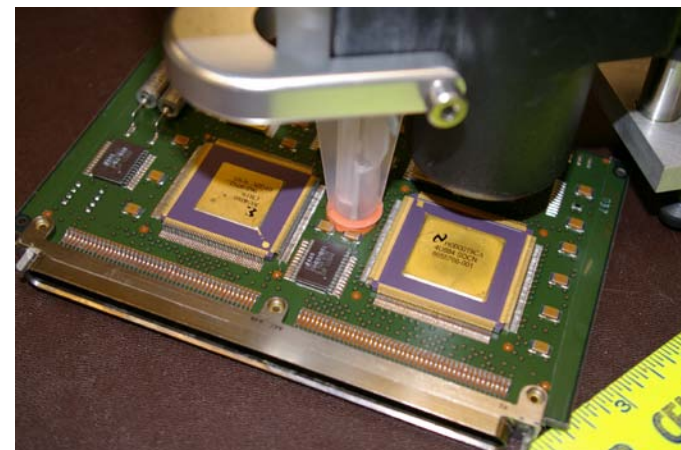




EE-FCC LRU from SWA



PMC A11 Card





Results: Hill AFB, Ogden ALC (F-16 LRU's)

Foresite	Sample Description	Ion Chromatography				C3 Tester	
		Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
	F-16 COLD PLATE COOLED LRUs						
	Returned for repair						
1981-06b-01	EEFCC S/N 5029 Card PMCA11	0.00	0.00	0.00	0.00	Clean	133.0
1981-06b-02	EEFCC S/N 5029 Internal Housing	0.00	0.00	0.00	0.00	Clean	180.0
1981-06b-03	EEFCC S/N 5029 ADC Card Ref Area	0.00	0.00	0.00	0.00	Clean	180.0
1981-06b-05	EEFCC S/N 5029 ADC Contam Area	0.00	0.00	0.00	0.00	Clean	180.0
	Returned, repaired and cleaned						
1981-06b-06	EEFCC S/N 5331 Card PMCA 11	0.00	0.00	0.00	0.00	Clean	180.0
1981-06b-07	EEFCC S/N 5331 Housing	0.00	0.00	0.00	0.00	Clean	180.0
1981-06b-08	EEFCC S/N 5311 ADC Card Ref Area	0.20	0.00	0.05	0.07	Clean	180.0
1981-06b-09	EEFCC S/N 5311 Through Hole area	0.00	0.00	0.00	0.00	Clean	180.0

Ion chromatography analysis of anions and cleanliness measurements on surfaces of avionics components of F-16 aircraft at Hill Air Force Base repair facility by Foresite, Inc and UDRI. Values for ions are in parts per million (PPM).





Results: Hill AFB, Ogden ALC (F-16 LRU's)

Foresite		Ion Chromatography				C3 Tester	
ID#	Sample Description	Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
	F-16 COLD PLATE COOLED LRUs						
	Returned for repair						
1981-06b-10	PSP 20161 Card A1	0.00	0.01	0.02	0.00	Clean	180.0
1981-06b-11	PSP 20161 Card A38	0.03	0.00	0.01	0.00	Clean	158.0
1981-06b-12	PSP 20161 Card A39 Bottom	0.00	0.01	0.01	0.02	Clean	180.0
1981-06b-13	PSP 20161 Card A39 Top	0.00	0.00	0.00	0.00	Clean	180.0
	Returned, repaired and cleaned						
1981-06b-14	PSP 10164 A1 Bottom	0.11	0.02	0.01	0.00	Clean	180.0
1981-06b-15	PSP 10164 A38	0.06	0.00	0.00	0.00	Clean	163.0

Ion chromatography analysis of anions and cleanliness measurements on surfaces of avionics components of F-16 aircraft at Hill Air Force Base repair facility by Foresite, Inc and UDRI. Values for ions are in parts per million (PPM).





Results: Hill AFB, Ogden ALC (F-16 LRU's)



UDRI		Ion Chromatography				C3 Tester	
ID#	Sample Description	Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
	F-16 COLD PLATE COOLED LRUs						
	Returned for repair						
HAFB1	PMC-A11 Processor memory card	2.47	0.00	0.66	4.13	NA	NA
HAFB2	ADC-A2 Card	3.36	0.00	0.29	5.51	NA	NA
	Returned, repaired and cleaned						
HAFB4	EE-FCC PMC-A11 processor memory card	3.79	0.00	1.16	4.85	NA	NA
HAFB5	EE-FCC ADC-A2 Card	2.55	0.00	0.24	3.82	NA	NA
	Returned for repair						
HAFB6	programmable signal processor (PSP) A1 card cold wall cooling channel	4.63	0.78	0.78	5.48	NA	NA
HAFB7	Exterior of PSP LRU	2.91	0.00	0.47	5.74	NA	NA
	Returned, repaired and cleaned						
HAFB8	programmable signal processor (PSP) A1 card cold wall cooling channel	2.72	0.00	0.32	3.61	NA	NA

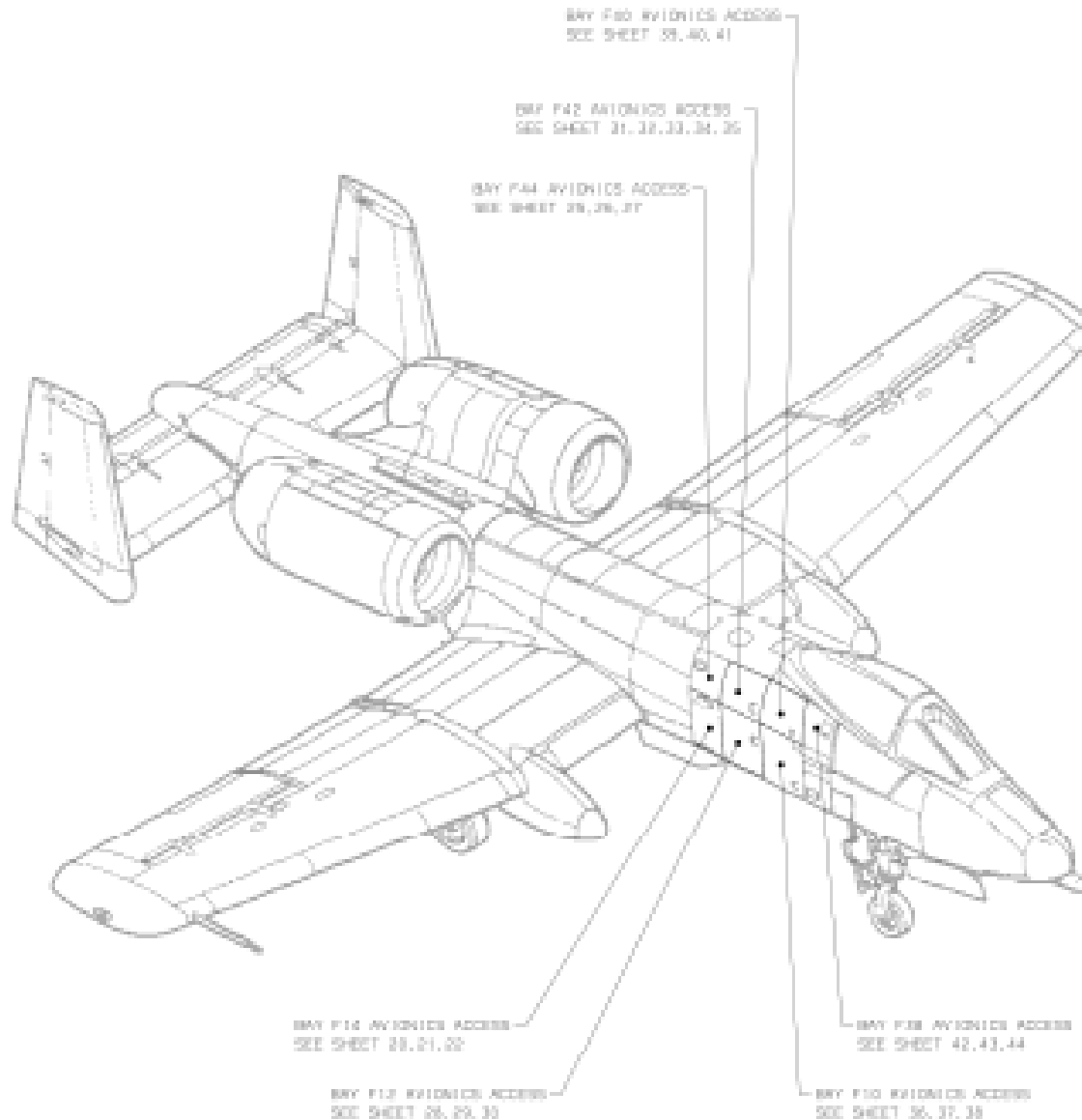
Ion chromatography analysis of anions and cleanliness measurements on surfaces of avionics components of F-16 aircraft at Hill Air Force Base repair facility by Foresite, Inc and UDRI. Values for ions are in parts per million (PPM).

Indicates exceeds recommended limit



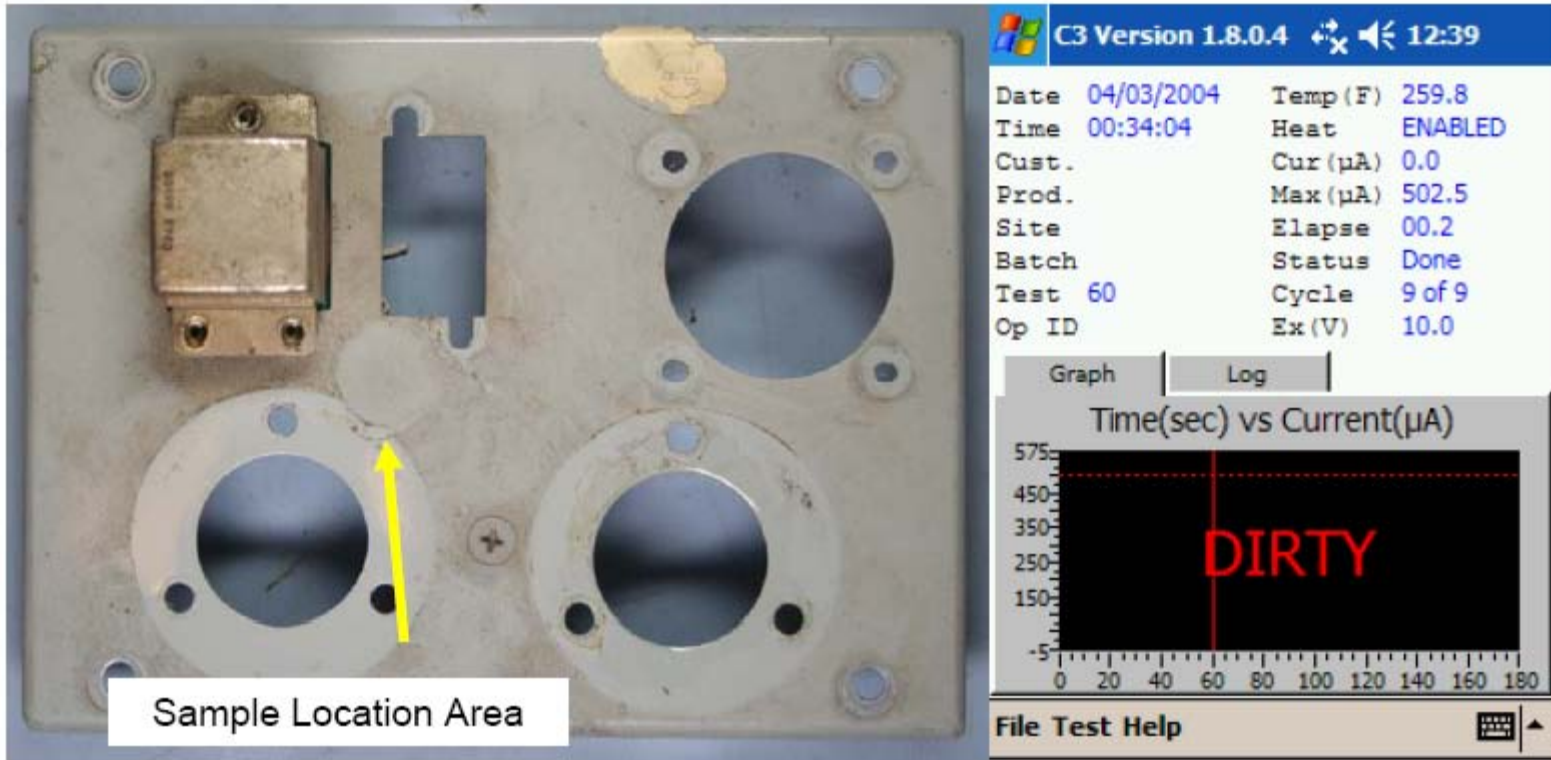


A-10 LRU Locations





Results: Hill AFB, Ogden ALC (A-10 LRU's)



Sample #16 A-10 Power Panel (Note: Dust on Panel Surface)



Results: Hill AFB, Ogden ALC (A-10 LRU's)

Foresite ID#	Sample Description	Ion Chromatography				C3 Tester	
		Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ²⁻	Results	Time(sec)
	A-10 NON-COLD PLATE COOLED Assembly						
1981-06b-16	A-10 Power Panel Exterior (visible dust)	0.83	0.00	3.73	12.25	Dirty	0.0
	UDRI ID#						
HAFBA10-1	Armament Circuit Breaker Panel	7.09	0.19	3.26	20.93	NA	NA
HAFBA10-2	Box Assembly AC Power Relay Cover	4.51	20.8	1.53	4.19	NA	NA
HAFBA10-3	Connector boot, Armament CB Panel	4.24	0.00	31.27	1.80	NA	NA
HAFBA10-4	AC Power Relay Face Panel	14.49	0.00	1.39	6.47	NA	NA

Ion chromatography analysis of anions and cleanliness measurements on surfaces of avionics components of A-10 aircraft at Hill Air Force Base facility by Foresite, Inc and UDRI. Values for ions are in parts per million (PPM).

Indicates exceeds recommended limit





Summary

- Based upon the surveys at seven visitation sites:
 - Highest probability of dust intrusion is on LRU's that rely on open air venting;
 - H-60, A-10 aircraft
 - Lowest probability of dust intrusion for LRU's that are cold-wall cooled or with conditioned and filtered air;
 - C-5, C-17, F-15, F-16 and AH-64 aircraft surveyed



Summary

- Random sampling of circuit card surfaces for cleanliness and chemical analysis resulted in 57% of the surfaces exhibiting elevated levels of anions;
- The elevated levels exceed the recommended levels for 4 aggressive anions*



Summary

LRU Type	# of cards	Anion			
		Cl ⁻	Br ⁻	NO ₃ ⁻	SO ₄ ⁻²
Cold wall cooled or conditioned/filtered air	23	39%	4%	30%	52%
Open Air Vented	18	94%	5%	83%	94%

Occurrence of anion concentration exceeding the recommended threshold levels for circuit boards by LRU type on fixed wing and rotor aircraft surveyed

- Occurrence of dust contamination in cold wall or filtered air cooled LRU's is higher in rotor wing aircraft (AH-64) than fixed wing aircraft (F-16).



Summary

- A number of the cards surveyed *did not* have conformal coating;
 - Apparently removed during repair
- Important to note that while conductivity and corrosion rate increases with increasing %RH, moisture film thickness depends on surface temperature;
- Powered devices and component cards generally experience less water adsorption and lower corrosion rates than expected from %RH of surrounding environment*;



Conclusions

- Overall probability of dust contamination is high for avionic PCB components of LRU's deployed in SWA;
 - Higher probability of dust intrusion and contamination of avionics in open vented LRU's than cold wall cooled or filtered and conditioned air cooled LRU's;
 - Filtered and conditioned air cooled LRU's of rotor wing aircraft have a higher probability of contamination than fixed wing aircraft



Acknowledgments

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