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Developing, Fielding, and Sustaining America's Aerospace Force

U.S. AIR FORCE

Effects of Corrosion Inhibiting Lubricants On Electronics Reliability

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Integrity - Service - Excellence

Overview

- History
- Previous Air Force Studies
  - Conclusions -- Ground And Lab
  - Conclusions – Flight
- Current DoD Efforts
- Potential Savings
- Conclusions

History

It is well known in theory and experience that thin, often invisible, insulating films can form on the surfaces of electrical connectors. These films/corrosion can be produced by the reactions of natural environments with the material systems used in commercial and military connectors. Such films may represent a significant source of problems such as False Alarms (FA), Cannot Duplicate (CND) and Retest Ok (RETOK).

History

- **Avionics/Connector Corrosion "Does Not Occur" Per much of the data in Air Force Databases**
  - **Can't be Seen (i.e. It Is Below Levels of Visual Detection)**
  - **Seldom if Ever Reported (i.e. No Data In REMIS by Related Codes)**

- **Connector Corrosion Does Occur In Base Level Environments!!**

AFI 10-602 Definitions

- **False Alarm**

  A system-indicated malfunction that can't be validated because no request for corrective maintenance follows. A CND differs from a false alarm in that it signifies a malfunction that can't be confirmed

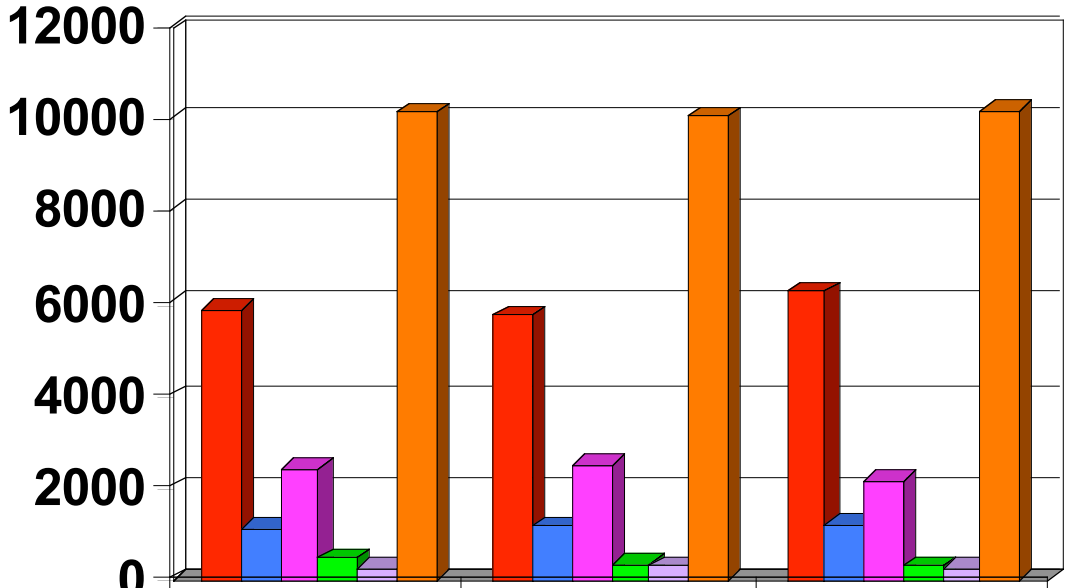
- **Cannot Duplicate**

  A situation that results in an operationally observed or recorded malfunction for a system or subsystem that on-equipment maintenance personnel can't duplicate or confirm.

- **Retest OK**

  A maintenance event involving a part or subsystem malfunction at the on-equipment maintenance level that personnel can't duplicate at the off-equipment maintenance level. As a result of this event, personnel may return the item to service without taking corrective action.

DRs FY03 – FY 05



	FY 03	FY04	FY05
PQDR	5878	5781	6270
MDR	1107	1151	1224
WDR	2445	2505	2150
SWDR	476	367	308
OTHER	263	294	259
TOTAL	10170	10098	10217

Previous Studies

- **Corrosion Preventive Compounds (CPC) Inhibit Corrosion To A Degree Which Makes Their Use Worthwhile**

- **Previous Studies Demonstrated that Connector Corrosion can be Prevented with CPC Lubricants**
  - **Inexpensive**
  - **No Risk**
  - **No Impact On Normal Ops**

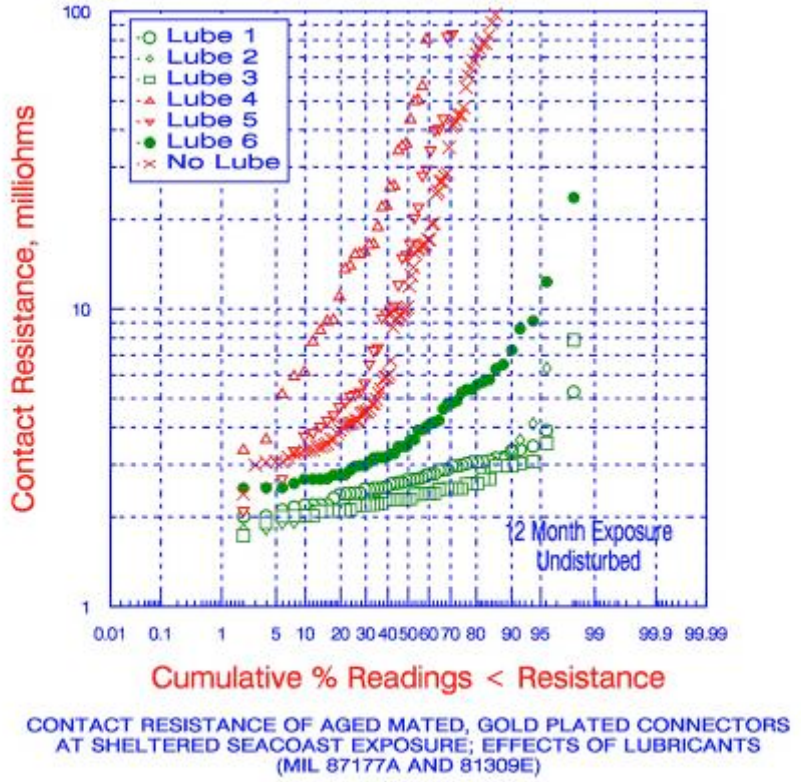
- **Potential Cost Savings Throughout DOD May Be Large Due To <u>Exchange Cost Avoidance</u>**

Previous Air Force Studies

- **USAF Work Accomplished by Battelle Labs Contract Support**
- **Phase I -- Ground Based, Field/Lab Study (2 Years, 1996)**
  - **MIL-C-81309E (Navy) or MIL-L-87177A (Air Force)**
- **Phase II -- Flight Tests (2+ Years, 1997- 1999)**
  - **Select 2 Lubricants; Specific LRUs; Lube I/O Connectors**
  - **F-16: about 150 Aircraft at 10 Locations**
- **Phase III Funded by PRAM (Feb 2001 – Jul 2003) - flight tests**
  - **How are the jets we treated several years ago doing?**
  - **F-15 , HH-60, HH-65, C-141, WR Avionics Complex**
  - **Minimum of 45 LRUs in flight testing**
  - **2 Lubricants (81309E and 87177A), 1 Type Per Base**

"Phase I – Ground and Lab Studies"
Typical Field Exposure Results On Test Connectors

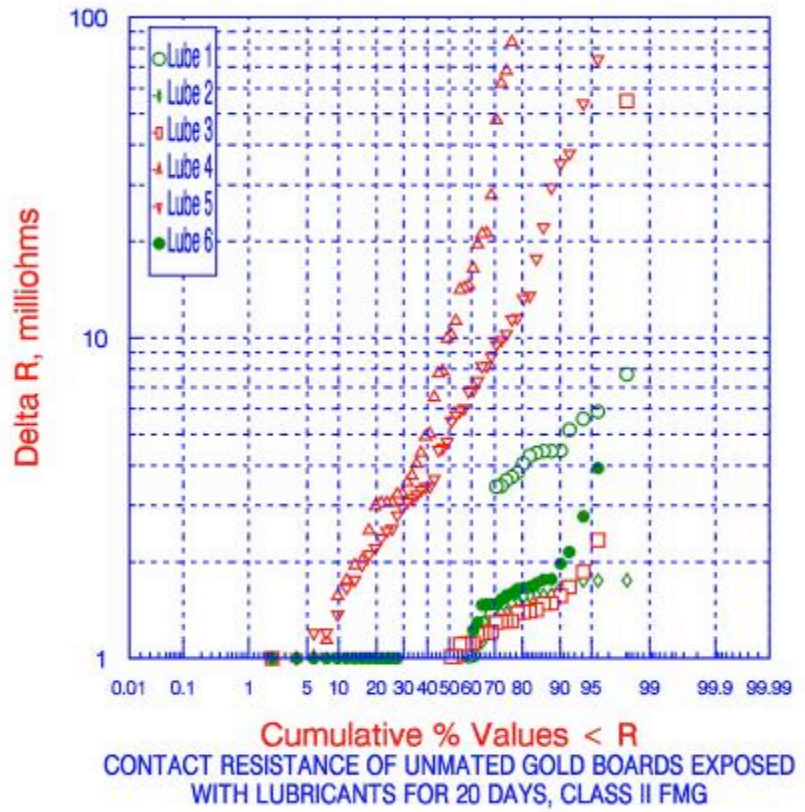
- Contact Resistance Change Distributions
  - 12 COTS CPCs Studied
  - Objective Is Smallest Change Possible (<10 milliohms)
- With No CPC, Failure Is Rapid
- Large Differences Among MIL Spec Lubes
- Few May Promote Corrosion
- Some Give Marginal Benefits
- The Best (2-3) Offer Excellent Corrosion Inhibition
- Objectives For Flight Tests Were
  - Corrosion Inhibition
  - Known Risk



CONTACT RESISTANCE OF AGED MATED, GOLD PLATED CONNECTORS AT SHELTERED SEACOAST EXPOSURE; EFFECTS OF LUBRICANTS (MIL 87177A AND 81309E)

"Phase I – Ground and Lab Studies" Laboratory Validation/Risk Evaluation

- Thermal Aging To Study Long Term Stability (80 C, 1000 Hrs)
- Corrosive Gas Exposure Of Unmated Connectors As Extreme Condition
- Combined Effects Shown
- Lab Results Parallel Field
- 2-3 COTS CPCs Will Survive Comprehensive Evaluation
- Best 2 Materials Selected For Flight Tests



CONTACT RESISTANCE OF UNMATED GOLD BOARDS EXPOSED WITH LUBRICANTS FOR 20 DAYS, CLASS II FMG

ELECTRICAL CONNECTOR CPC
WPAFB CPC VALIDATION STUDY

1.	**D5026NS**	**ZIP CHEM**	**81309 II**	**EXCEL**
2.	**So-Sure**	**LHB Industries**	**81309 III**	**V GOOD**
3.	Spray 706	* Sprayon Products	81309 II	Not Recom
4.	ACF 50	** Lear Chem Resrch	81309 II	Not Recom
5.	CRC 3-6	** CRC Industries	81309E III	Not Recom
6.	**Super Corr B**	**Lektro Tech, Inc**	**87177A I,B**	**EXCEL**
7.	Stabilant 22 **	D.W. Electrochemicals	**NONE**	Not Recom
8.	NOX Rust 212	Daubert Chemical	81309 II	Good
9.	Omega 2775 *	Fine Organics	81309D	Not Recom
10.	Rust Preventive	Battenfield-American	81309 II	Good
11.	Octoil 5068	Octagon Process	81309 II	Good
12.	Alox 2028C	Alox Corp	81309 II	Not Recom

"Phase I" Conclusions -- Ground And Lab Study

- **Large Difference Among Lubricants In Performance**

- **Only Very Few Lubricants Will Survive Comprehensive Evaluation**

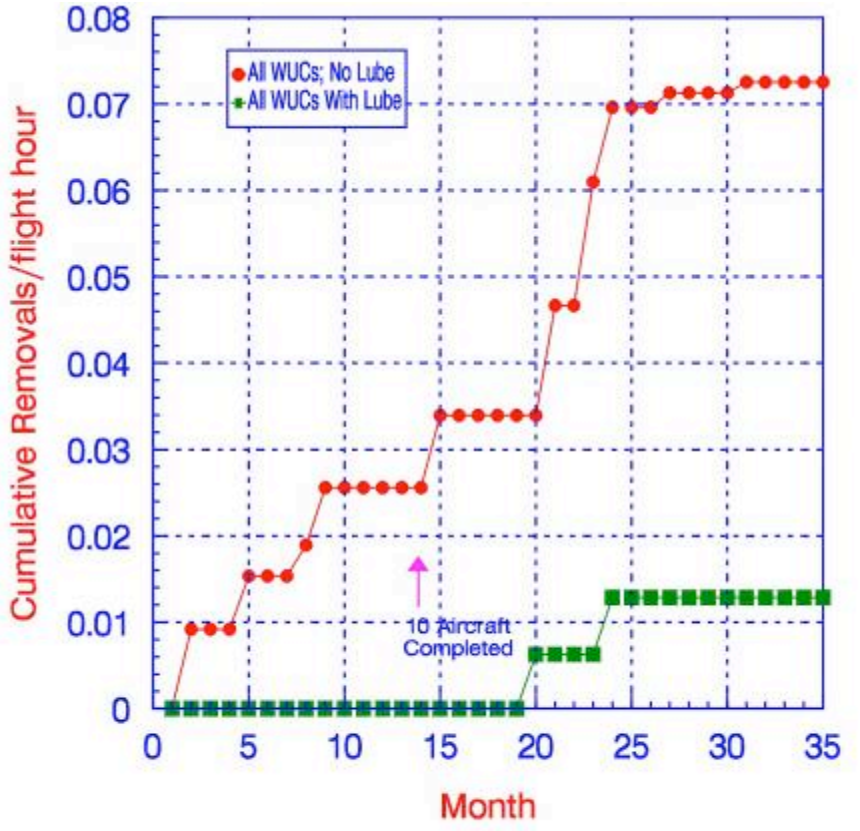
- **Present Qualification Specs Are Inadequate**

- **Best (2) Lubricants: MIL-C-81309E (Zip Chem D5026NS) and MIL-L-87177A (Lektro-Tech Super Corr B)**

  - **Totally Suitable For Flight/Avionics (Tri-Service Manual) "Avionics Cleaning and Corrosion Prevention/Control"**
    - **NAVAIR 16-1-540 (Navy)**
    - **TO 1-1-689 (AF)**
    - **TM-1-1500-343-23 (Army)**
  - **Total Corrosion Inhibition**
  - **No Known Engineering Risk**

"Phase II - F-16 Flight Tests; Treated LRUs"

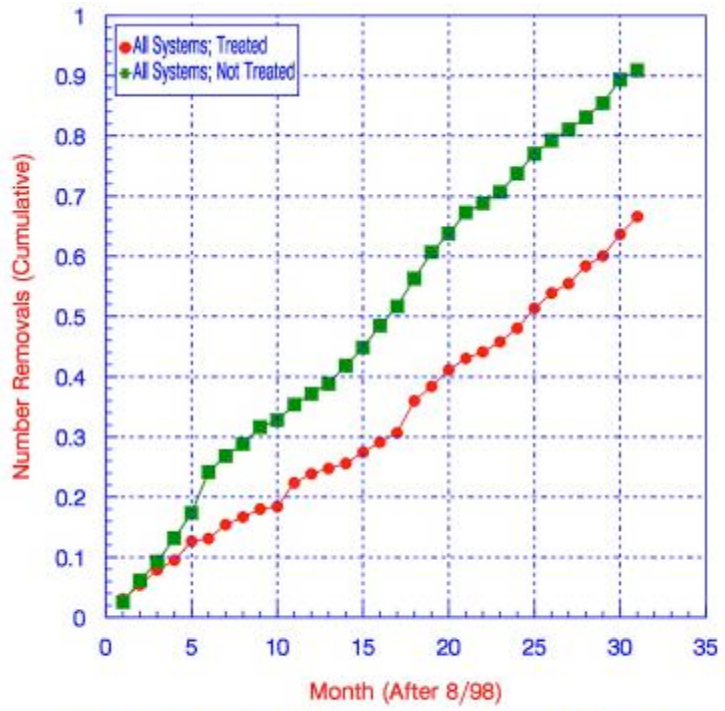
- Weapons System LRUs
  - Treated vs. Untreated
  - Flight Line Applications
  - Removals/Flight Hr.
- Positive Results
- Positive Base Feedback
- No Implementation Problems
- Minimal Labor



PPS (On Equipment) Data For Removals/Flight Hour; All Weapons System (WUC 75); Base A; With And Without Lube

"Phase II - F-16 Flight Tests; All Systems"

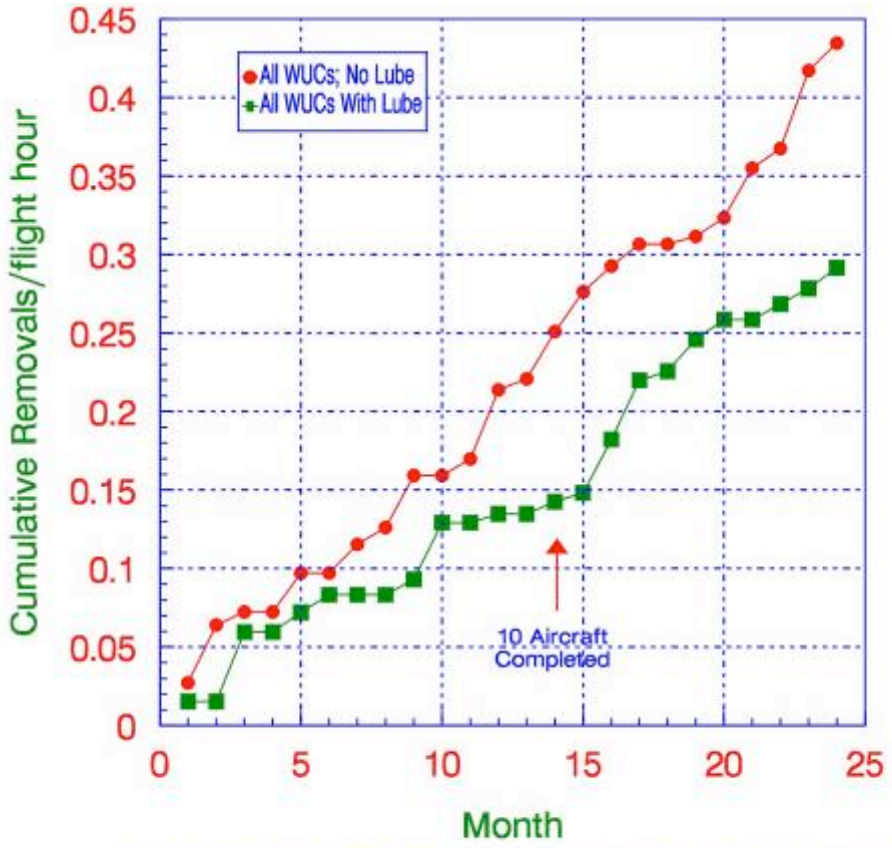
- All System LRUs (Avionics (Weapons), (Flight Control
  - Treated vs. Untreated
  - Flight Line Applications
  - Removals/Flight Hr.
- Positive Results
- Positive Base Feedback
- No Implementation Problems
- Minimal Labor
- Large Potential Cost Savin From Reduced Removals And Exchange Cost Avoidance



F-16 Aircraft PPS (On Equipment) Removals/Flight Hour
Base B With And Without Lube

Phase II - Example Of Potential Savings – Single Base

- 10 Aircraft Completed
- Single Lubricant
- Weapons and Avionics
- Positive Feedback
- Positive Results
- 482 FW Report Savings of $ 3.1M; 6 months with 10 of 18 A/C Done
- Calculated = $ 2.2M @ $25K Average DLR XCh Cost



PPS (ON) DATA FOR REMOVALS/FLIGHT HOUR; ALL WUCS FOR KYJL WITH AND WITHOUT LUBE; MONTH 1 = JANUARY 1997

"PHASE II"
F-16 FLIGHT TESTS, LRU TREATMENT

- **REMOVAL & LABOR SAVINGS FOR CPC TREATED ACFT COMPARED TO NON-TEST ACFT**

		xMTBF
• LANDING GEAR SYS REMOVALS:	54% FEWER	2.17
• LANDING GEAR SYS MMH:	59% LOWER	
• FLIGHT CONTROL SYS REMOVALS:	55% FEWER	2.22
• FLIGHT CONTROL SYS MMH:	41% LOWER	
• FIRE CONTROL SYS REMOVALS	38% FEWER	1.61
• FIRE CONTROL SYS MMH	38% LOWER	
• WEAPONS DELIVERY SYS REMOVALS	64% FEWER	2.78
• WEAPONS DELIVERY SYS MMH	48% LOWER	

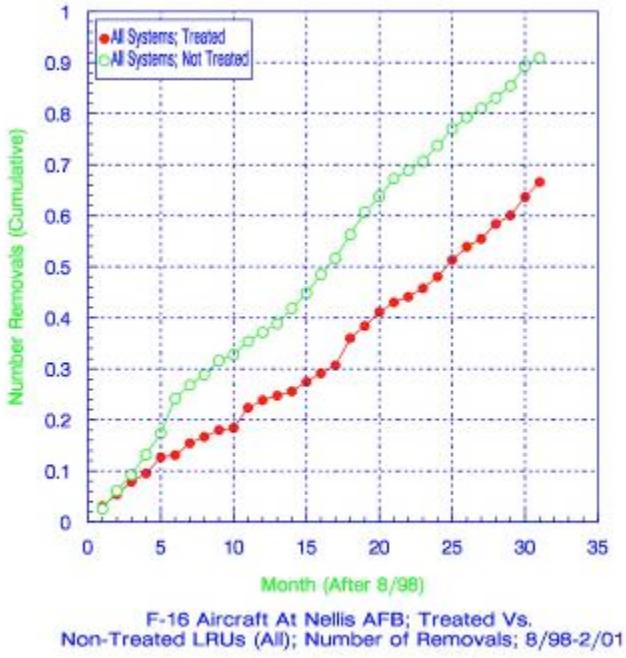
INDEPENDENT STUDY
SANDIA LABS TESTS OF MIL-L-87177

- **Dept. of Energy tasked Sandia National Laboratories to test MIL-l-87177's ability to protect electrical connectors against corrosion. The Sandia Report was titled:**
  - "MIL-L-87177 LUBRICANT BULLETPROOFS CONNECTORS AGAINST CHEMICAL AND FRETTING CORROSION"

- **GAO Report – GAO-03-753**
  - **"For several decades the AF has conducted extensive studies on the corrosion of avionics connectors and what should be done about it. In the 1990s several studies recommended the use of specific CILPs that have the potential of ELIMINATING avionics connector corrosion on F-16 aircraft with an annual savings of $500M/year"**

"Phase III" - Update on Previous Work

- **August 2001, Battelle Monthly Report**
  - -- **F-16, Several Years after Lubricant Application, Continue Beneficial Effect**



All Systems Combined

“Phase III” - F-15 LRU’s in Study

NOMENCLATURE	WORK UNIT CODE
Radar Analog Processor (039)	74FS0
Radar Low Voltage Power Supply (610)	74FH0
Radar Data Processor (081)	74FQ0
Programmable Digital Processor (42)	74FY0
Radar Transmitter (011)	74FA0
Radar Receiver (022)	74FC0
Radar Frequency Oscillator (001)	74FJ0

Phase III – F-15s – 2002 -Kadena

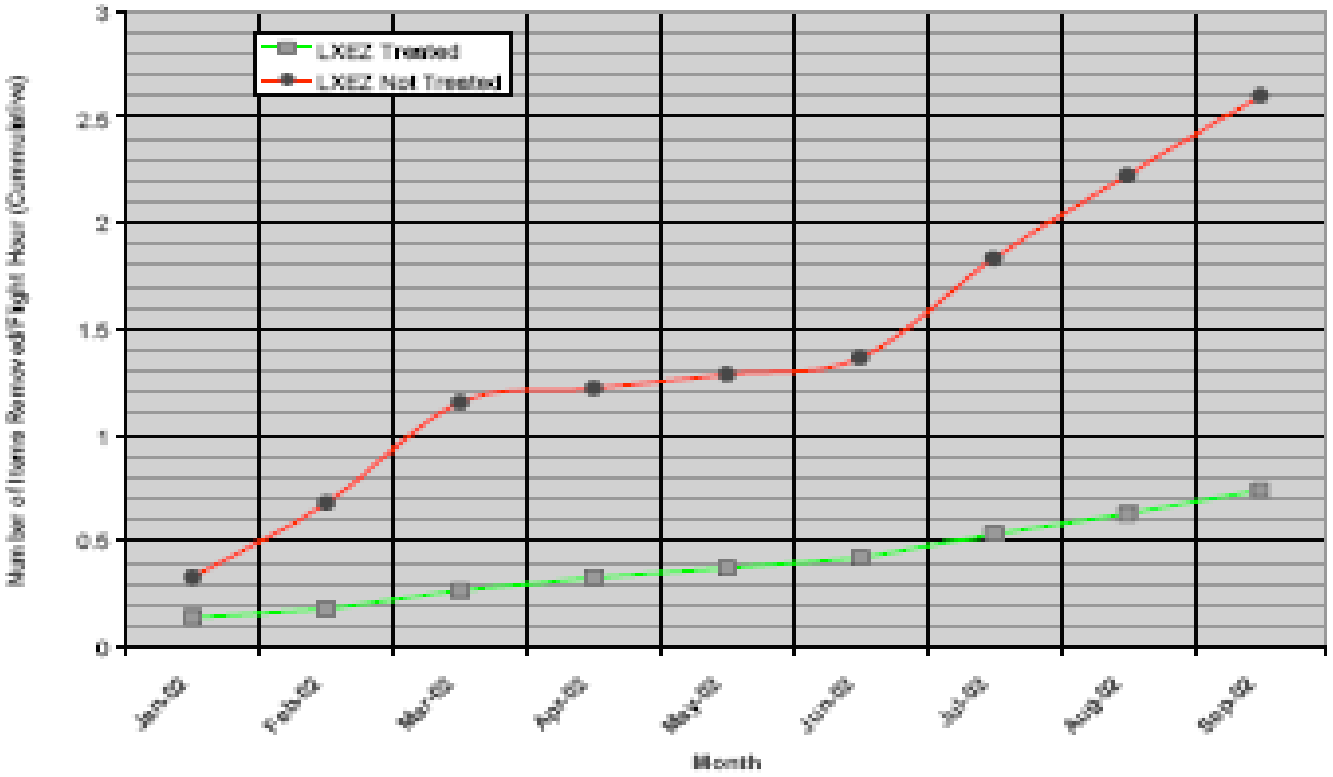


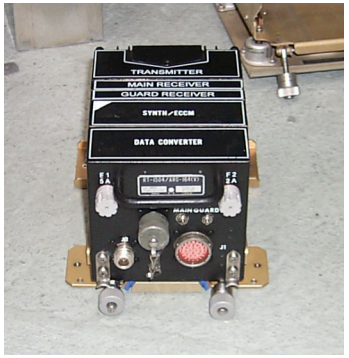
Figure 4. Number of items a Removed for All Systems F15 Aircraft, Kadena

"Phase III - Depot Level LRU's in Study

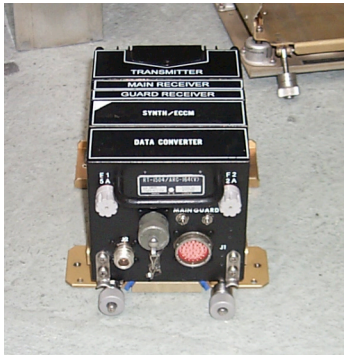
NSN #	Nomenclature	System	Work Unit Code (WUC)
5998-01-303-4375EW		ALQ155	
5998-01-461-8083EW		ALQ155	
6625-01-302-4960KV	Part No: 8948667, master unit	A-10 turbine engine monitoring system	
6625-01-221-3841KV	Part No: 091000-632, slave unit	A-10 turbine engine monitoring system	
5945-01-008-0708BY		E3	
5985-01-297-2613AY		B52	
5826-00-917-8679		AWACS	
6130-01-056-[illegible]65CW		AWACS	
5865-01-408-[illegible]78	Su[illegible]meterodyne Co[illegible]ll[illegible]SH	[illegible]-56M	76LE0
5865-01-381-[illegible]74	Di[illegible]ion [illegible]di[illegible]Ver[illegible]FR)	ALR-56M	76LH0, 76LJ0, 76LK0, 76LL0
5865-01-463-[illegible]47 (-005 config[illegible]ion	Analysis Processor (AP)	ALR-56M	76LF0
5865-01-463-[illegible]950EW (-006 configuration)	Analysis Processor (AP)	ALR-56M	76LF0
5865-01-364-8983EW (-003 configuration)	Analysis Processor (AP)	ALR-56M	76LF0
1270-01-236-8438FX	Converter Programmer	F-15 EW	
1270-01-236-3657FX	Converter Programmer	F-15 EW	

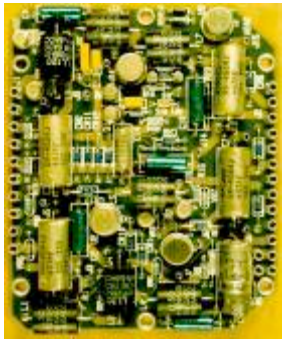
Inconclusive

Current Efforts - Implementation Concepts



System/Platform ➡ **LRU**





Depot ➡ **LRU** ➡ **SRU**

Field Level <u>and</u> Depot Level Implementation for LRU and SRU

Application to Virtually <u>ANY</u> Electronics Would Gain a Benefit

Current Efforts - F-15 Involvement

- Engineering reviewed prior inhibitor studies
- Saw opportunity to reduce costly false component removals, ease maintainer burden
- Presented prior study results/opportunity to ACC and maintainers - feedback positive
- Incorporated inhibitor as part of an increased F-15 PDM Wiring Integrity Effort/Strategy
- Approved internally and presented to MRRB as low cost, low risk approach to improve mission readiness
- Supported WR-ALC/LYE with F-15 field evaluation on feasibility for use at flight line level
- Field level implementation strategy under way

F-15 has established program requiring use of CILs on electrical connectors during flightline depot maintenance by simply mandating the recommended use as stated in the Joint Service avionics tech manual…

Production Time & Costs Considerations for CPCs @ Depot

SRU Calculations

Action	*Time/min*	*$*
Remove SRU from LRU	3	5.00
Prep SRU for Treatment	2	3.34
Treat SRU with Compound	0.1	0.17
Dry SRU	5	8.33
Replace SRU in LRU	3	5.00
Input Serial # Data to Track	1	1.67
Total Additional Time & $s	**14.10 m**	**$23.51**

Assumptions: Avg LS Repair Shop RCC Rate of $100 /per hour

LRU Calculations

Action	*Time/min*	*$*
Treat 10 SRUs from LRU each	141.0	$235.10
Prep LRU Connectors	2	3.34
Treat LRU Connectors	0.1	0.17
Dry LRU Connectors	5	8.33
Input Serial # Data to Track	1	1.67
Total Additional Time & $s	**148.20 m**	**$248.61**

Assumptions: Avg LS Repair Shop RCC Rate of $100 /per hour
Avg 10 SRU's per LRU

Corrosion Control *One Year* Production Costs Estimates for all LS Managed Items

Total LS Avionics Items Repaired Last Year: 40,000 SRU's + 20,000 LRU's = 60,000 Total Items

$ to Add Corrosion Preventative to all LS Assets:

(40,000 × $23.51/SRU) + (20,000 × $248.61/LRU) = **$5,912,600**

Money Management

1st year Effort: funded via one 206 from LS to MAI and work will be incorporated as Temporary Job Order

FY06 and beyond: Build requirement into Work Control Document and adjust repair rate accordingly

Human Factors Costs Considerations for CPCs @ Depot

•The Primary Human Factor to be addressed is Fume Control. The original study was not performed in a enclosed shop atmosphere. Control of the fumes is essential to ensure success.

•The most cost efficient method is to purchase portable, flexible vapor filtration units to be used at Avionics repair benches. Portable units are cheaper, moveable with LEAN initiatives, don't require permanent installation, and are rapidly procureable and usable.

•Costs:

•Vapor Filtration Unit: $2,195.00

- Filters – Prefilter: $100.00
- HEPA: $195.00
- Carbon: $195.00

•Number of Units needed:

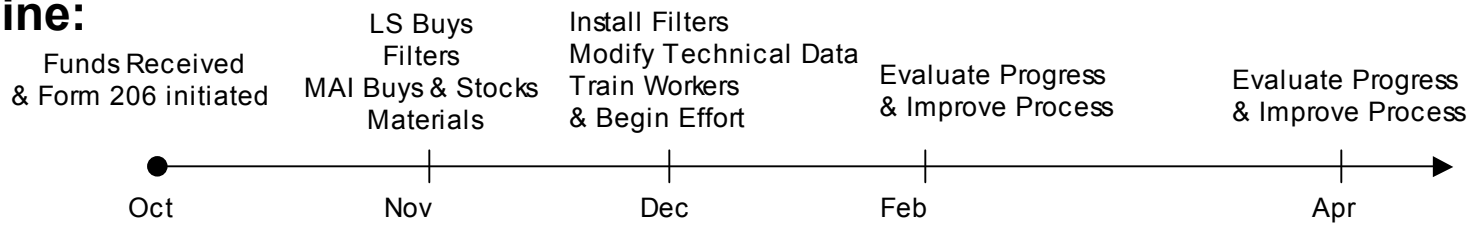
•(4 ea/repair line × 75 repair lines) = 300 units

- $2,195/Vapor Filtration Unit x 300 units = $658,500
- 2 prefilters/year x $100/prefilter x 300 units = $60,000
- 2 HEPA filters/year x $195/HEPA filter x 300 units = $117,000
- 2 Carbon filters/year x $195/Carbon filter x 300 units = $117,000
- **Human Factors 1st Year Costs = $952,500**

Note: The filter company has agreed to test any compounds we use to certify the effectiveness of the system before we buy.

Timeline and Risk Considerations for CPCs @ Depot

Timeline:



Risk Analysis — Overall Risk Minimum to Moderate

Health Risk – Safety (Minimum) The items have already been approved for use in WR-ALC/MAI shops by the BioEnv Flight, Environmental Mgmt, & Ground Safety.

Product Risk – (Moderate) The compounds will be used on a much wider range of materials and avionics components that have not been previously tried. Materials Compatibility issues will have to be monitored very closely.

Results Risk – (Moderate) The results will be hard to quantify. Baseline reliability figures have not been established on most end items, therefore improvements will be hard to statistically show. No system is currently in place to track treated items.

Scope Risk – (Minimum) If all LS items, including Surge & MICAPs are treated, field support could be impacted with delays due to increased time to repair items.

"Current Snapshot"

- **USAF**
  - **F-16 – not waiting on anybody.**
    - **Funded program (OSD).**
    - **ACC direction - implement at operating bases – non-impact**
    - **Issued interim T.O supplement for 87177A and revisions**
  - **WR-ALC - F-15 PDM line using 87177 Super Corr B**
  - –
  - **WR-ALC C-5, C-17, C-130, U-2 reviewing F-15 and CIL/CPCs**
    - **JSTARS implementing 87177 during programmed maintenance**
  - **752nd CSSS – FY07 MSD Engineering Project for Depot Spiral I**
- **NAVY**
  - **P-3 Test program – Karl Martin's Feb 2005 white paper**
  - **NAVAIR working to get engineering authority to step out with 87177A for avionics**
  - **87177A initiative in DoD Strategic Plan**
- **ARMY**
  - **Partnership with NAVAIR**
  - **87177A testing in work**
- **All Services Should - Leverage off trail that F-16 is blazing**

By C.O.B today – how much savings did we forfeit - because we didn't apply BENEFICIAL CPCs or ANY CPCs in the avionics complex or the PDM lines?

Cross Service Wide Use

F-16 Fleet Estimated Operating and Cost Avoidance by Reducing / Eliminating Turn In of R-TOK's

$ 500 Million +

- **Cross Service Implementation Very Easy**
- **Cross Service Implementation Very Low Cost**
- **Cross Service Implementation Potential is High**

DoD Wide Impact - HUGE !!

Estimated $$ Cost Savings For F-16 Fleet By Exchange Cost Avoidance

Calculated exchange cost savings for LRU connector lubrication

Potential dollars at indicated percentage reductions for F-16 aircraft by exchange cost avoidance

		54 percent	55 percent	38 percent	64 percent	
		Sys WUC				
Command	Flight, hrs/yr	13[a]	14	74	75	Dollar Summary by Command, units
ACC	91800	1.9	40.6	70.6	123.1	236.2
AFE	26460	0.5	9.9	17.9	15.3	42.8
AFR	15700	0.3	7.1	9.9	6.5	23.9
ANG	123000	2.5	52.1	66.2	71.1	191.9
PAF	40015	1.1	20.3	24.3	28.7	74.4
Dollars by Sys WUC; MM[b]		6.3	130.1	188.0	244.7	569.2

Conclusions

- **Selected CPCs Offer Inexpensive Means Of Reducing LRU Removals Due To Connector Related Reliability Effects (FAs, CNDs, RETOKs.)**
- **Only A Few COTS CPCs Will Survive Comprehensive Evaluation**
- **No Impediment To Routine Implementation**
- **No Identified Risk To Aircraft Systems**
- **No identified Human Factors Problems**
- **Performance Results – USAF, NAVY, ARMY - Positive**
- **High Cost Savings Potential**
  - **Reduction In MMH/Flight Hour**
  - **Reduction In Removals and Exchange Costs**

USE THESE CPCs on AVIONICS and ELECTRICAL CONNECTORS! CPCs (87177A and D-5026NS) SUPPORT THE WARFIGHTER!!!

AFMC

- THE RELIABILITY OF EVERY U.S. WEAPON SYSTEM THAT USES ELECTRONIC PARTS MAY BE INCREASED BY USING THIS CORROSION INHIBITING LUBE IN THEIR CONNECTOR SETS
- MANY OTHER USES FOR THIS CPC COULD BE BENEFICIAL
- COST IS SHOWN AS PRIMARY BENEFIT BUT EFFECTIVENESS & SAFETY FOR OUR TROOPS IS EVEN MORE IMPORTANT

Backups

- **MIL 87177A CPC Success Stories**
  - **NAV AIR - P3**
  - **AMTRAK**
  - **IBM - barrier strength over time**
  - **PLEXUS**
  - **Bombardier Aero**
  - **Sandia Labs**
  - **F-16 Hill**
  - **Learjet**
  - **Honeywell**
  - **BIW Connector**
  - **Trident Submarines**
  - **E-3 Phased Array**
  - **GCU - A10**

WR-ALC Program Briefings

-- Joint Service Review Committee (JSRC) - May 2001

-- Joint Program Opportunities Board (JPOB) - July 2001

-- Asst Dep Commandant Marine Aviation (RADM Moffit) – September 2001

-- Army, PEO/PM (MGen Bergantz) Redstone Arsenal, - September 2001

-- Apache Maintenance Officer Conference – December 2001

-- AFMC Engineering Council – January 2002

-- 93 Air Control Wing, Joint STARS – February 2002

-- 2002 Air Force Corrosion Program Conference – March 2002

-- F-16 Cost Reduction IPT (CRIPT) – March 2002

-- 21st Digital Avionics System Conference – Oct 2002

-- Joint Technology Exchange Group – Nov 2002

-- WR-ALC Engineering Advisory Board – Sept and Oct 2005

-- Joint Group on Depot Maintenance – Mar 2003

-- 9th Annual Aging Aircraft Conference – March 2006