Universal Synaptics

TQS

Intermittent Fault Detection & Isolation System (IFDIS)

10 February 2011

Presenter: Ken Anderson

The Problem:

- Maintenance of aircraft electronic Line Replaceable Units (LRUs) and Weapon Replaceable Assemblies (WRAs) pose an ever increasing challenge
- Much of the challenge is related to intermittent faults which occur because of aging wiring and connections
- Intermittent problems manifest themselves as “bad actor” LRUs and WRAs or as repair shop No Fault Found (NFF) test results
- Intermittent faults are a growing problem in electronic equipment

Intermittent Faults:

Variety of intermittent fault causes

- Loose or corroded wire wrap
- Cracked solder joint
- Corroded connector contact
- Loose crimp connection
- Hairline crack in a printed circuit trace
- Broken wire
- Unsoldered joint
- Number of other phenomena, all very common in electronic equipment

These problems are becoming more severe in aging aircraft

Intermittent Faults:

Intermittent fault occurrences

- Consistent discontinuity (hard failure) is not difficult to detect
- Intermittent discontinuity is typically very short in duration, of low amplitude and is difficult to detect and isolate

Intermittence typically manifest itself during stress situations

- High G loading
- Thermal extremes
- Vibration
- Combination of stresses

Intermittent Faults:

- Many times the intermittent open circuit will manifest itself during an initial troubleshooting test
- Equipment item is then transported for maintenance and repair
- Majority of ground testing is done at room temperature on a work bench
- The intermittent circuit is no longer open
- This results in No Fault Found (NFF)

Intermittent Faults:

Intermittence has many names

NFF – No Fault Found
ER – Erroneous Removal
NPF – No Problem Found
NDF – No Defect Found
NTF – No Trouble Found
CND – Can Not Duplicate
RETOK – Retest OK
NEOF – No Evidence of Failure
NTR – Nothing to Report
DCR – Disassemble Clean & Reassemble

Conventional Approach:

- Billions of dollars have been spent industry wide on conventional legacy test equipment
- All designed to detect hard failures, yet 50% of the problems are likely intermittent
- Difficult to detect momentary faults
- Tests or scans one circuit at a time
- Not designed to detect intermittence

Conventional Approach:

- Testing community focuses on digital “accuracy”
- Mathematical processing, scanning, sampling and filtering average intermittent faults right out of the equation
- Counterproductive for finding intermittence
- As a testing community we are placing unrealistic expectations on digital equipment to detect intermittent circuits

Conventional Results:

- April 2010, NAVAIR press release states: “Approximately 72% of total Navy and Marine Corps maintenance actions are avionics related”
- Common rule-of-thumb for older aircraft is that 40% to 60% of all pilot-reported aircraft system malfunctions which occur in the air go undetected during follow-on ground testing
- Ten years ago, Air Transport Association estimated NFF costs at $100,000 per year per aircraft – probably double that cost today

Conventional Results:

- Intermittent problems remain as undetected, unrepaired defects
- Hazards the aircraft and crew
- Repeatedly wastes maintenance and operational resources
- Adversely affects operational sortie capability
- NFF resulting from intermittency is now one of the largest aircraft maintenance cost drivers for the Department of Defense

Conventional Results:

- "The Department of Defense maintained 400 types of test systems and spent $50 Billion to buy and support these systems over a 12 year period" *(Government Accountability Office Study)
- None of these systems are designed to detect intermittent / NFF
- Generally felt throughout the aviation industry that there have been no new technology breakthroughs that will lower intermittent / NFF rates – ***UNTIL NOW!***

Innovative Solution:

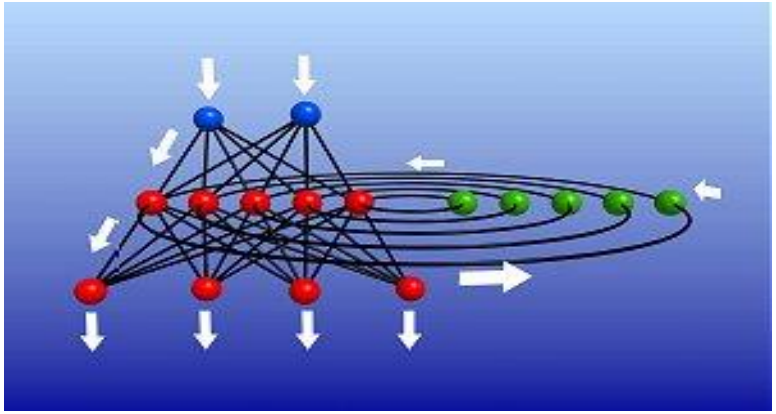
- Build a maintenance tool specifically designed to detect and isolate intermittent faults
- Repairing an intermittent circuit is not difficult
- The challenge is detecting and isolating the intermittence
- **The Intermittent Fault Detection & Isolation System (IFDIS) does just that!**
- Currently configured to test LRU and WRA chassis and aircraft wiring

IFDIS

- Intermittent Fault Detection & Isolation System (IFDIS) contains a patented hardware neural network analog diagnostic system specially designed to detect and isolate intermittent faults in electronic equipment

- Monitors all circuit paths simultaneously and continuously, detecting any intermittent as short as 50 nanoseconds (0.00000005 seconds)

- The IFDIS also detects and isolates any open, short, and incorrect wiring problems that may be present in the Unit Under Test (UUT)



IFDIS

Employs shaker and environmental chamber to simulate aircraft operational environment

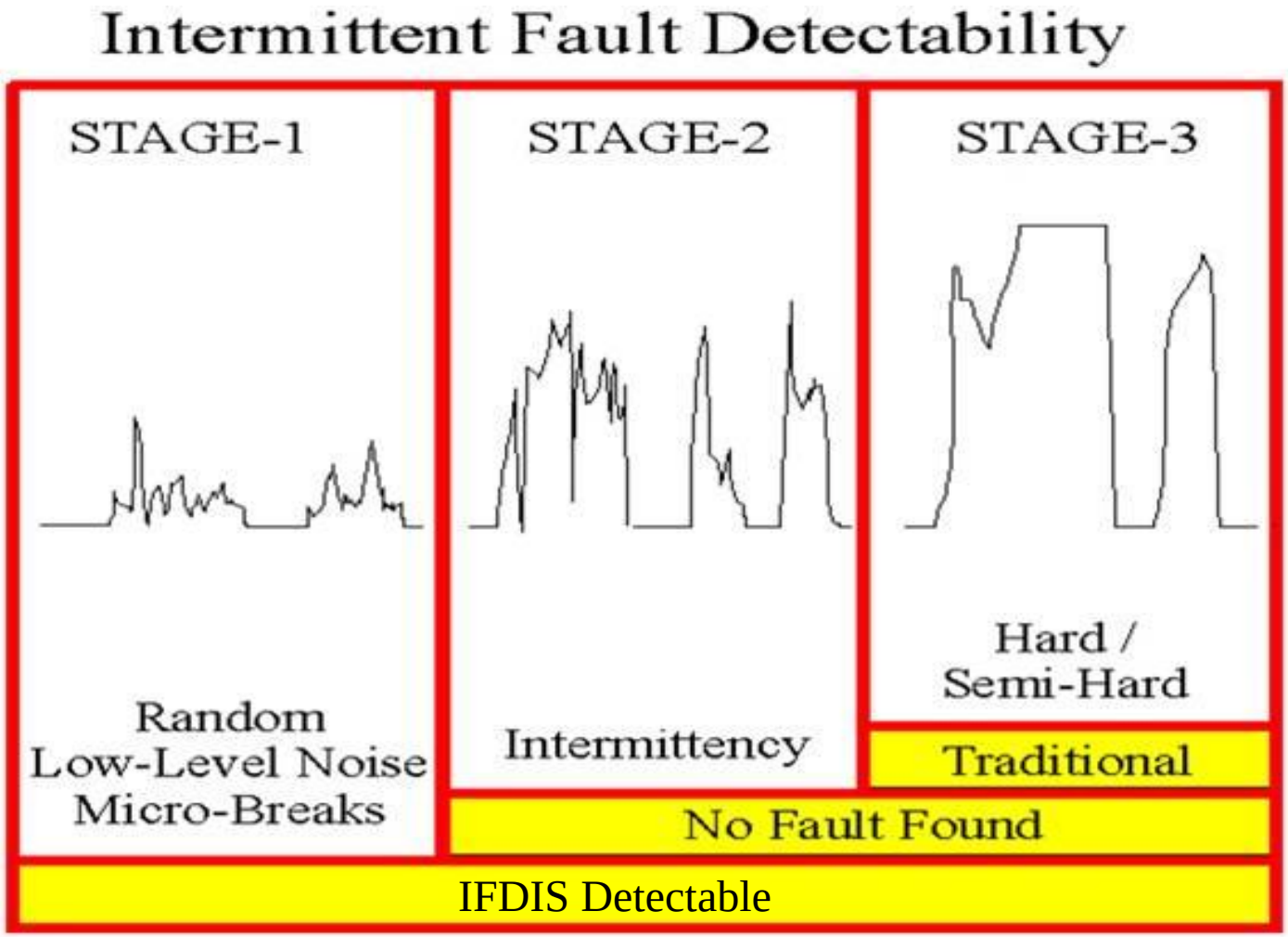
- Temperature
- Vibration
- Forces the intermittent circuit to manifest itself, allowing the IFDIS to detect and isolate the root cause of the fault

Computer controlled

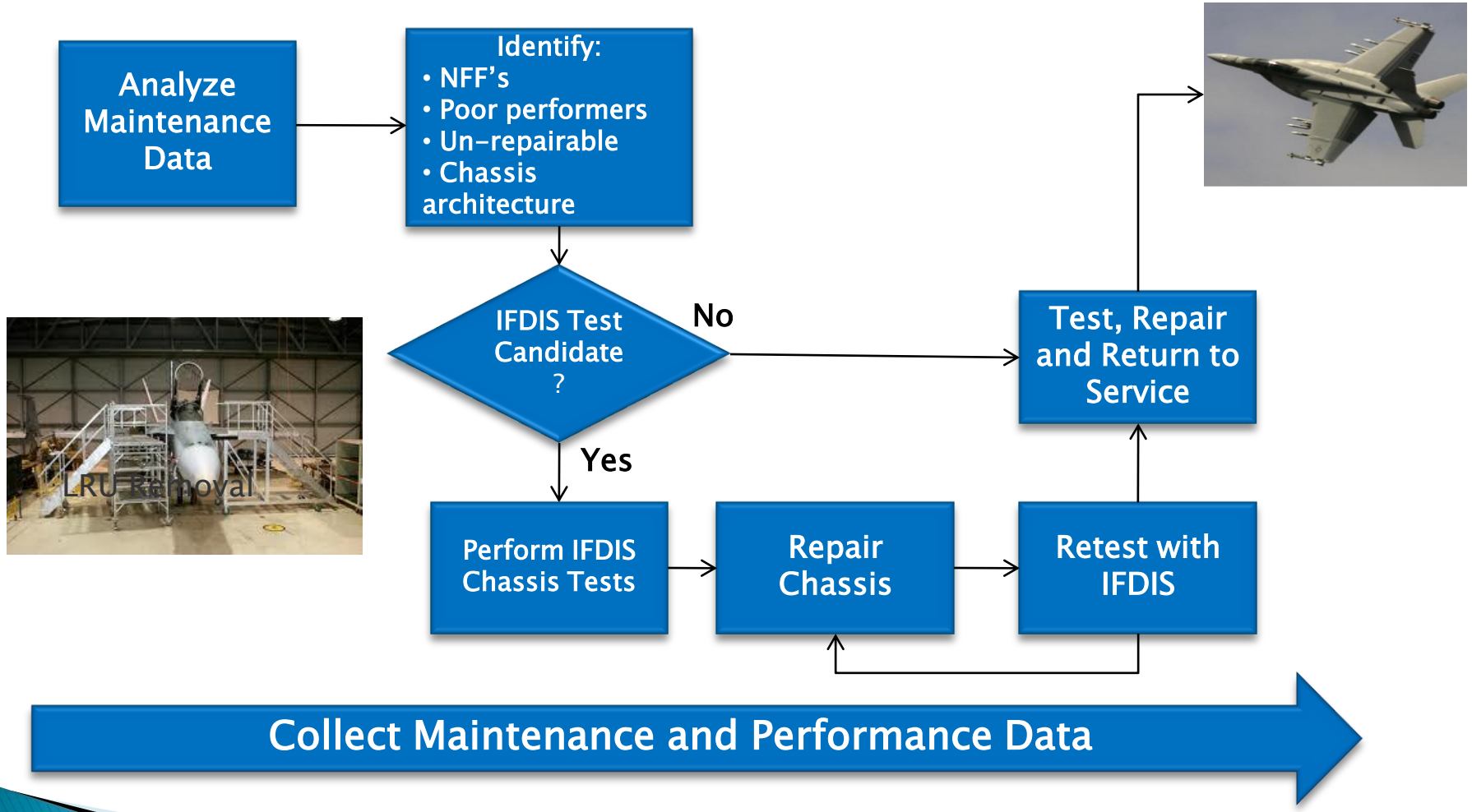
- Easy to use
- Repeatable testing cycles
- Records each detected intermittent fault as short as 50 nano-seconds (0.00000005 seconds)

IFDIS: Configuration

IFDIS


Intermittent Fault Detectability
STAGE-1
STAGE-2
STAGE-3
Random
Low-Level Noise
Micro-Breaks
Intermittency
Hard /
Semi-Hard
Traditional
No Fault Found
IFDIS Detectable

Identifying IFDIS Test Candidates



Case Study: MLPRF

- **F-16 AN/APG-68 Radar System Modular Low Power Radio Frequency (MLPRF) unit**
- One of the poorest performing LRUs on the F-16
- Cracked ribbon cable solder joints
- Massive re-soldering program
- Shotgun approach to maintenance
- Had no means to detect intermittent circuits

IFDIS: MLPRF Example Serial # 10435

Date	Depot Level LRU Repairs
31-Jul-98	No Fault Found
22-Mar-00	Reseat Circuit Card Assemblies (CCAs)
30-Aug-00	No Fault Found
5-Dec-01	Replace Frequency Synthesizer
	Replace Low Noise Assembly
5-Apr-02	No Fault Found
13-Aug-02	Resolder Ribbon Cable
19-Mar-03	Replace Low Noise Assembly
7-Oct-05	Replace Low Noise Assembly and Micro-Switch
15-Aug-06	Replace Frequency Synthesizer
1-Feb-07	Replace Sample Data Assembly
11-Apr-07	Reseat Reference Oscillator Assembly
27-Aug-09	**IFDIS Tested - 1 Open & 11 Intermittent Circuits**

No Fault Found (NFF)
Quasi NFF Repair Activity

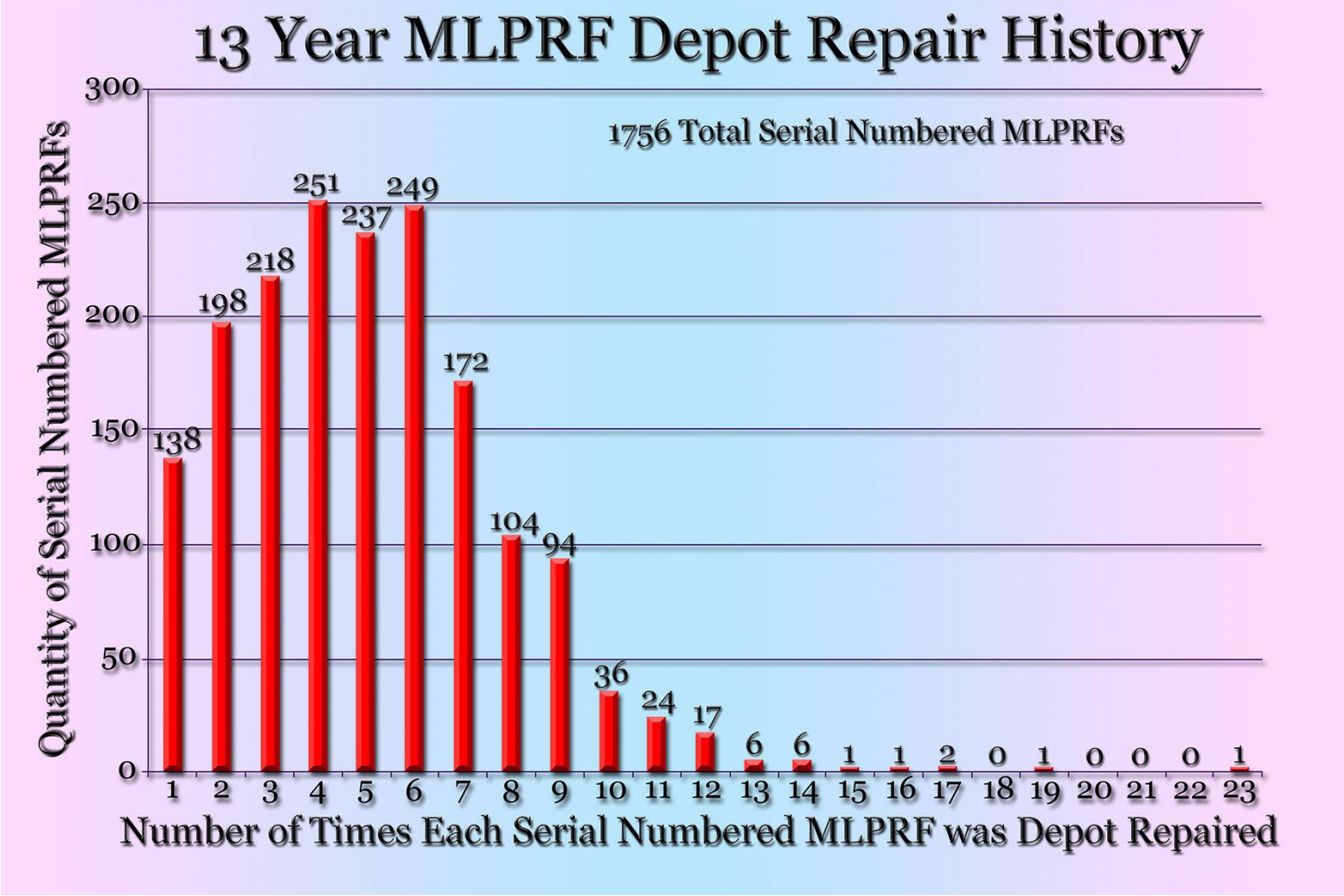
IFDIS: MLPRF Example Serial # 10435

Date	Depot Level LRU Repairs	Depot Level SRU Repairs
31-Jul-98	No Fault Found	None
22-Mar-00	Reseat Circuit Card Assemblies (CCAs)	None
30-Aug-00	No Fault Found	None
5-Dec-01	Replace Frequency Synthesizer	Replace Guide Pin
	Replace Low Noise Assembly	Replace IF Assembly
5-Apr-02	No Fault Found	None
13-Aug-02	Resolder Ribbon Cable	None
19-Mar-03	Replace Low Noise Assembly	Replace Receiver Protector and FET Amp
7-Oct-05	Replace Low Noise Assembly and Micro-Switch	Replace Receiver Protector and FET Amp
15-Aug-06	Replace Frequency Synthesizer	RTOK
1-Feb-07	Replace Sample Data Assembly	Adjust R57 & R7 (Expected 90 +/-3, Measured 93.46)
11-Apr-07	Reseat Reference Oscillator Assembly	None
27-Aug-09	**IFDIS Tested - 1 Open & 11 Intermittent Circuits**	

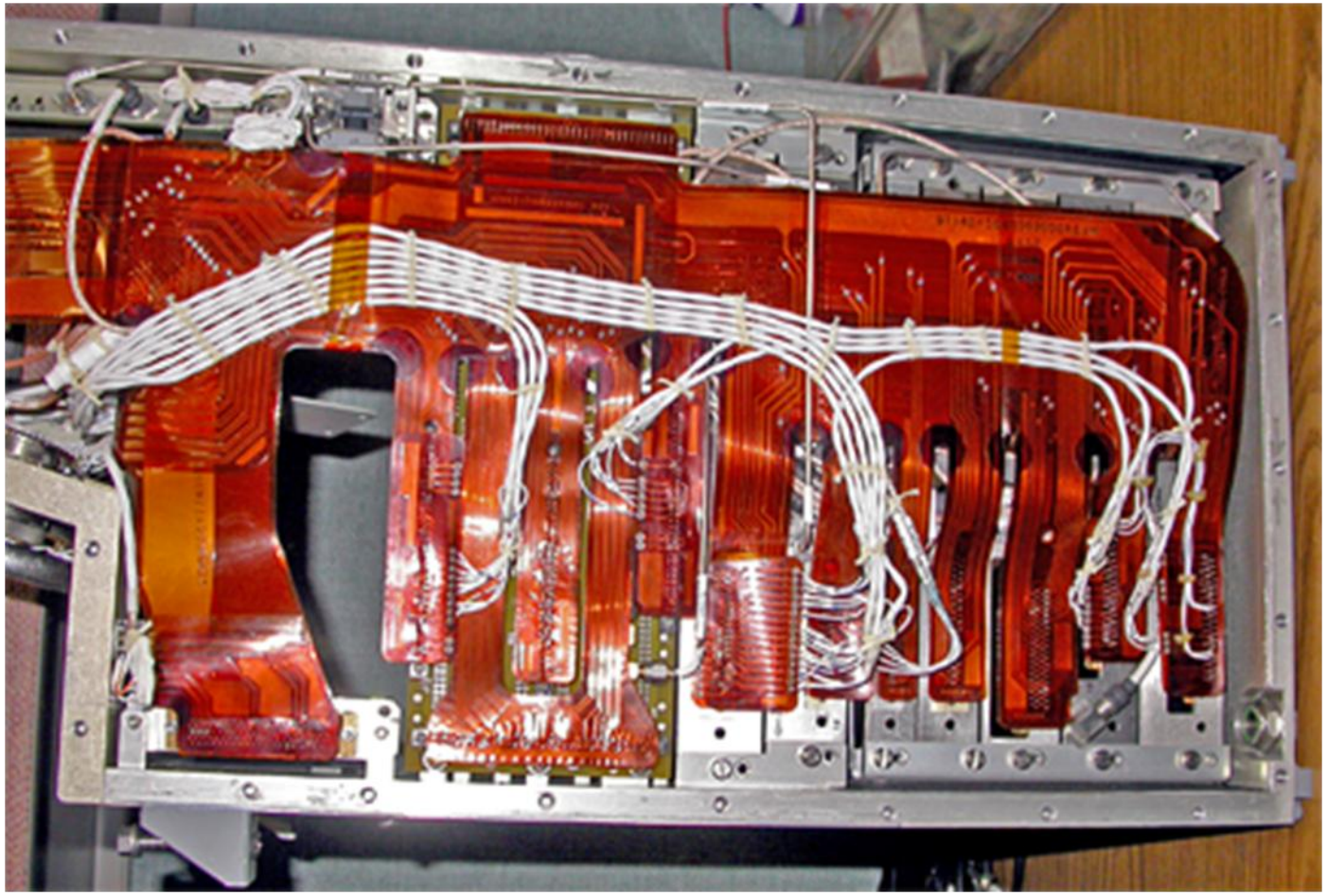
Ref Des	Repair Activity	Intermittent Circuits
A14	Low Noise Assembly - Replaced 3 Times	A14-28 to A13-114
A2	Frequency Synthesizer - Replaced 2 Times	A2A2-3 to Ground
A8	Sample Data Card - Replaced 1 Time	A8-97 to A6-57
A3	Reference Oscillator Assembly - Reseated 1 Time	A3-9 to A13-50 & A3-12 to A13-139

No Fault Found (NFF)
Quasi NFF Repair Activity

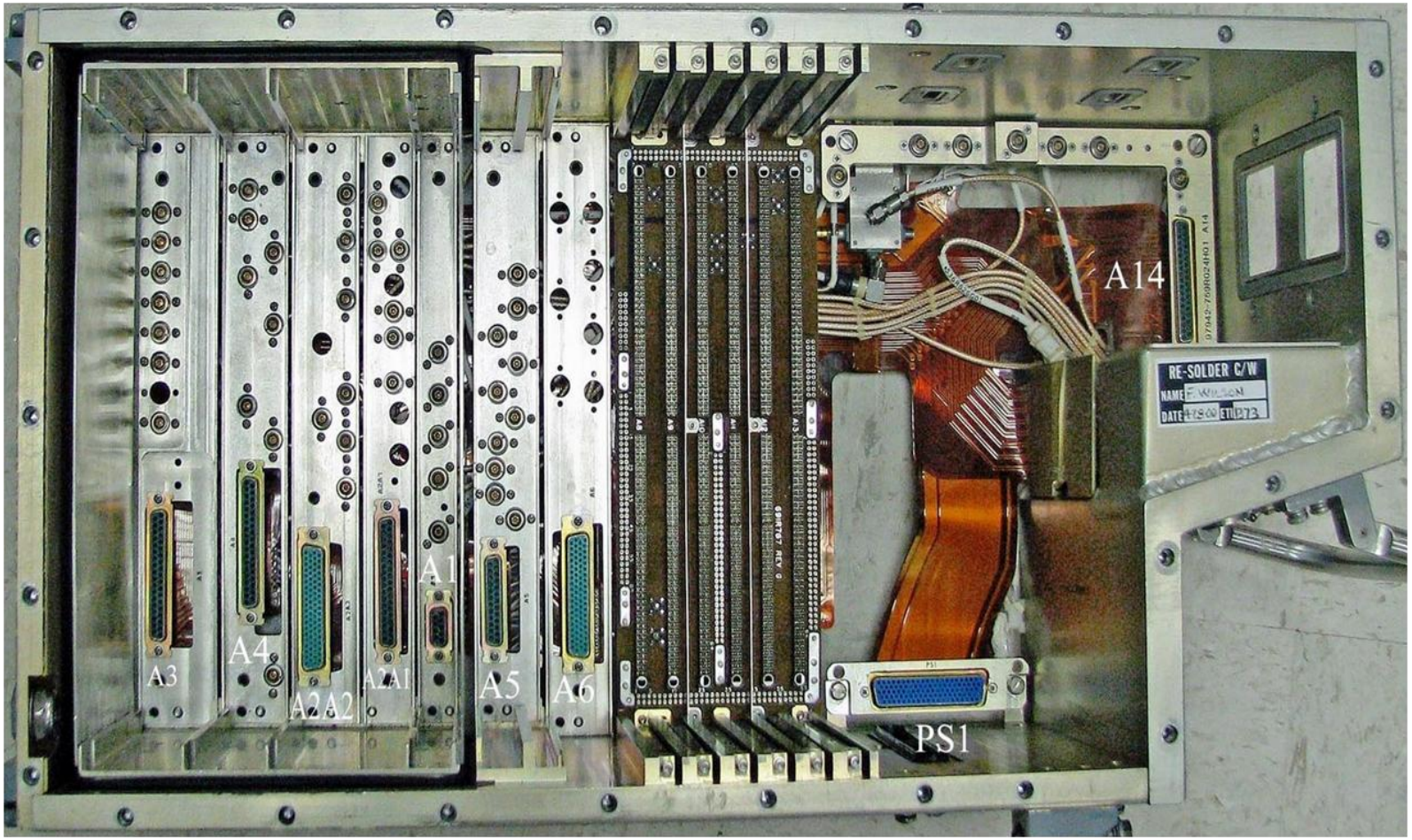
MLPRF: 13 Year History



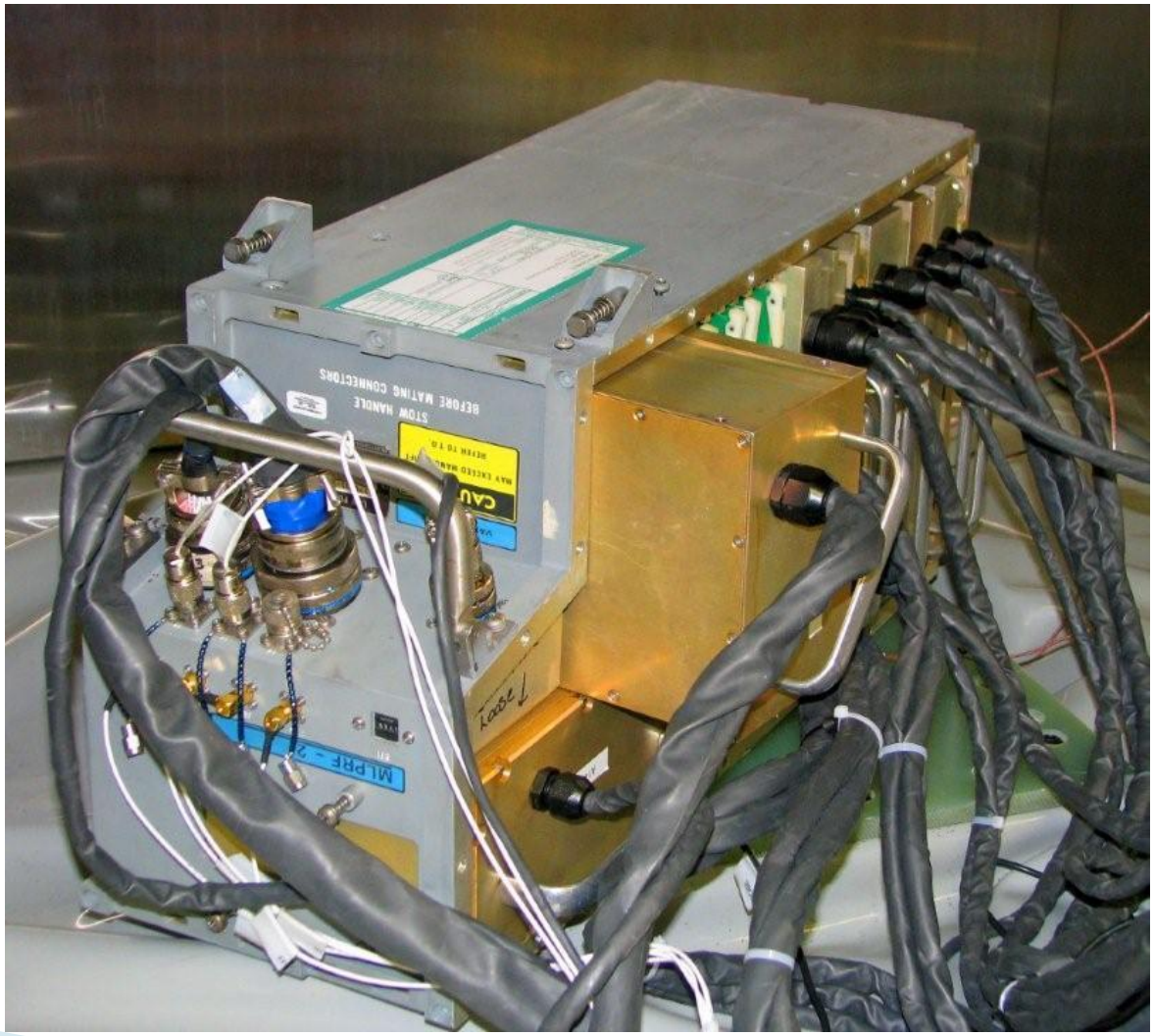
MLPRF: Chassis Wiring



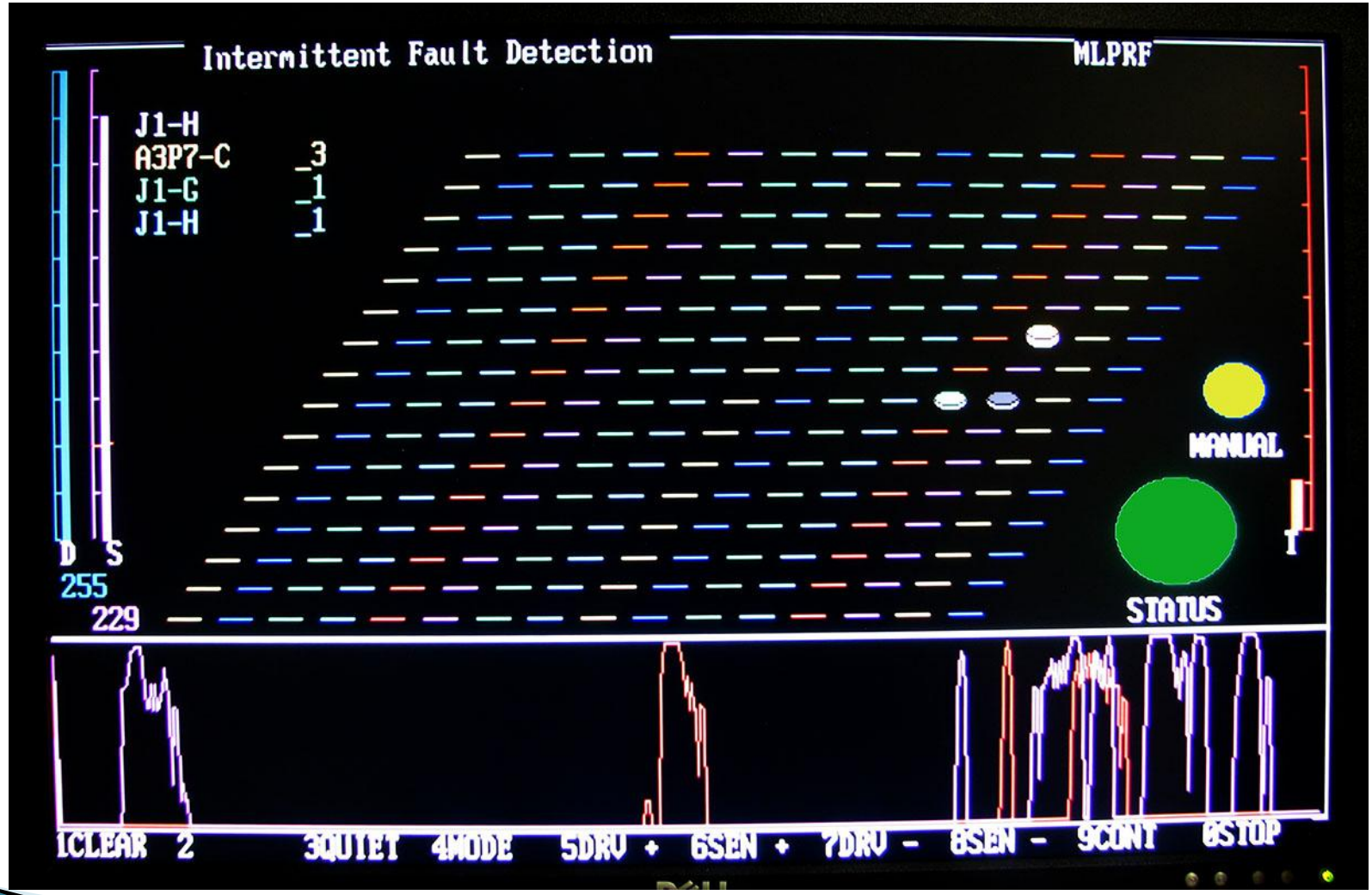
MLPRF: Chassis Connections



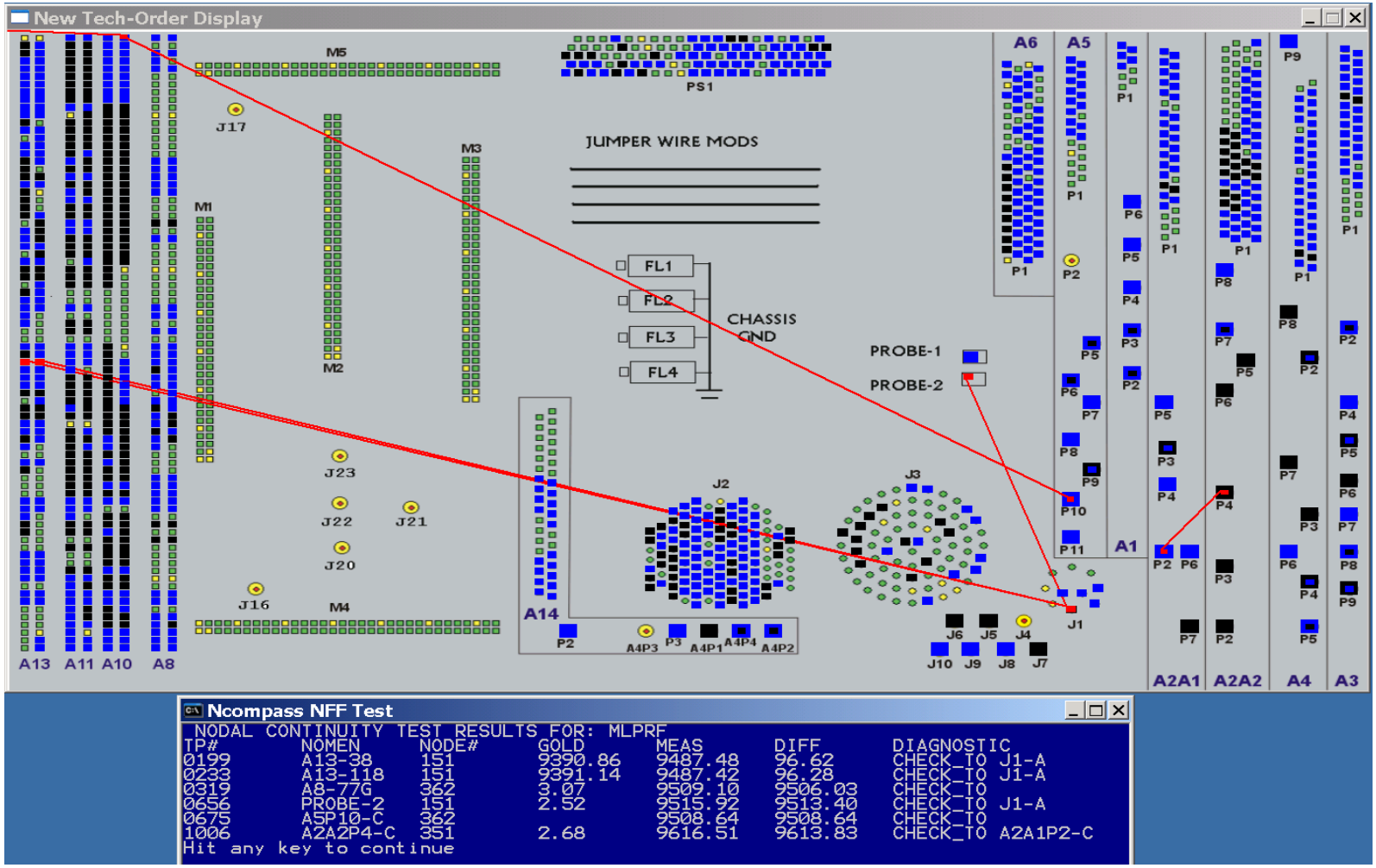
MLPRF: Interface Test Adaptor



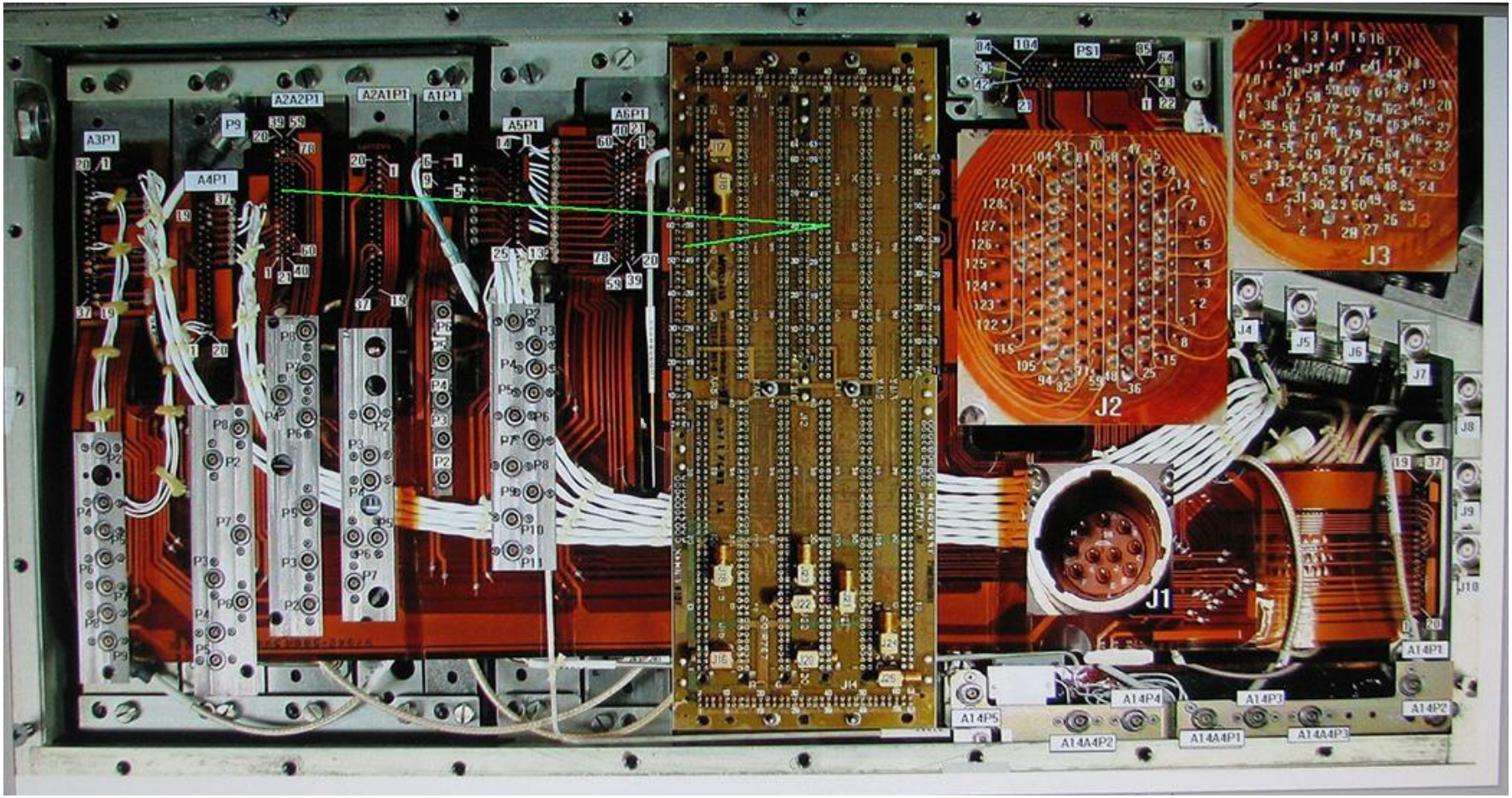
MLPRF: Fault Display



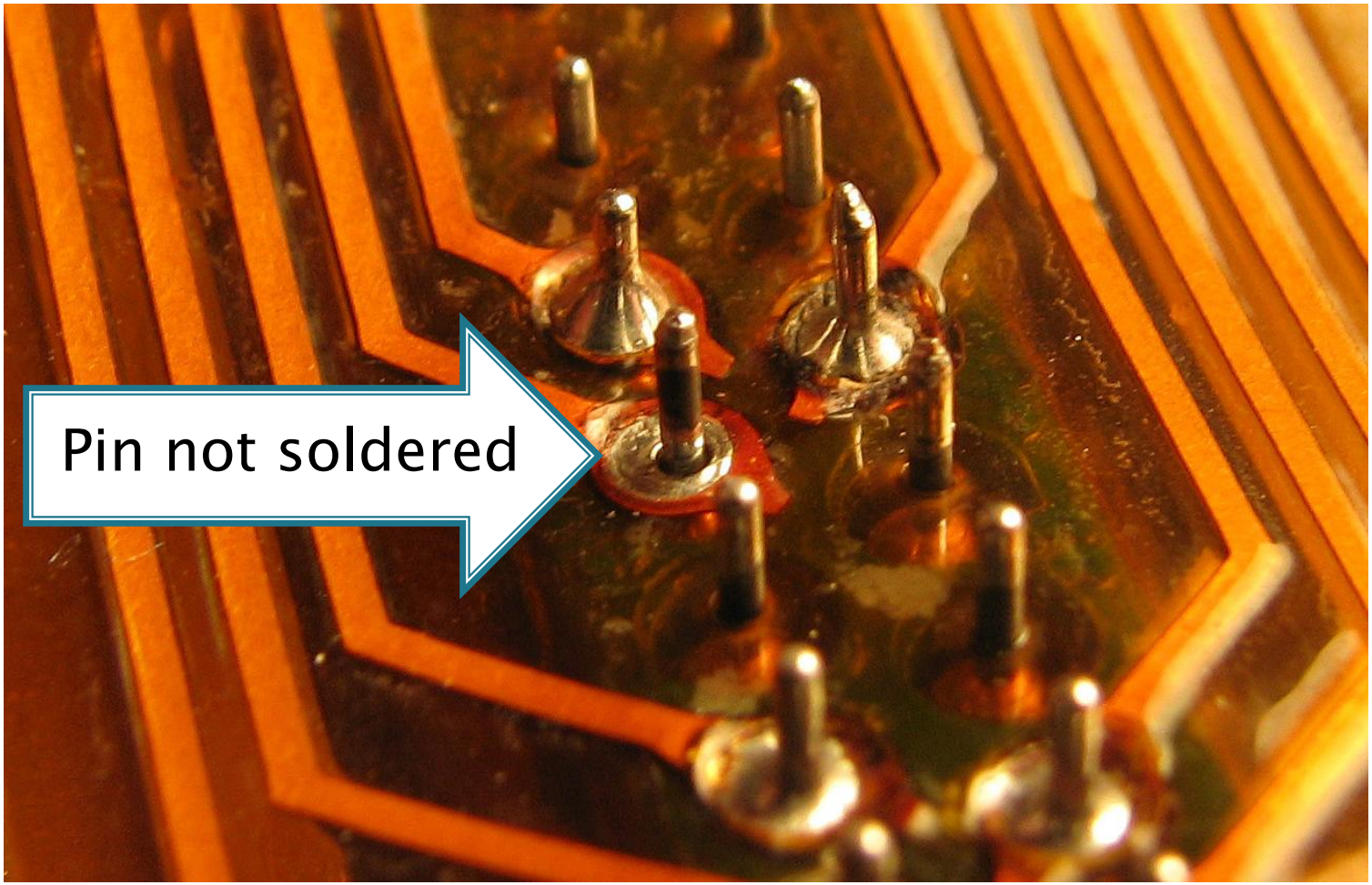
MLPRF: Fault Isolation Graphic



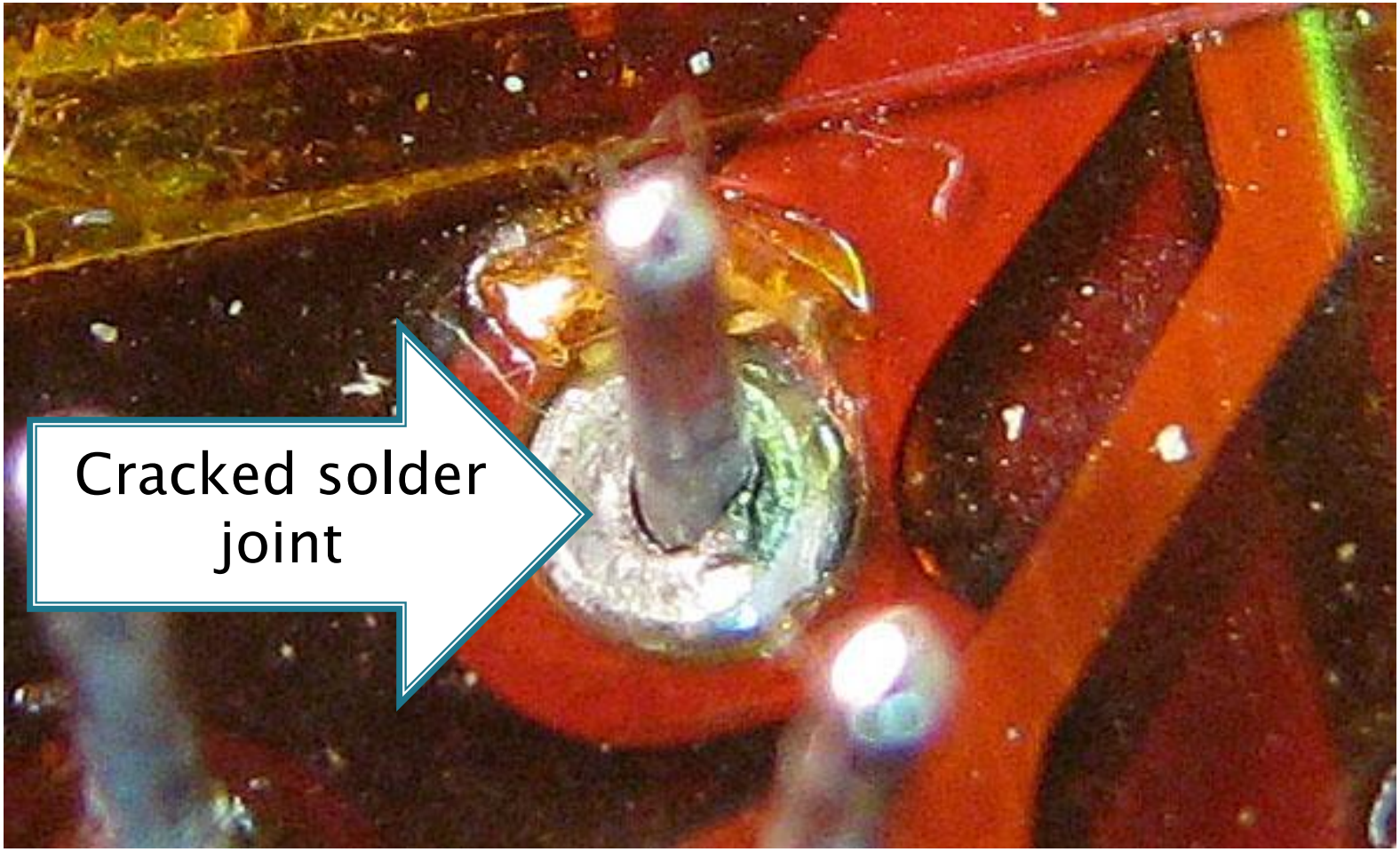
MLPRF: Fault Identification Graphic



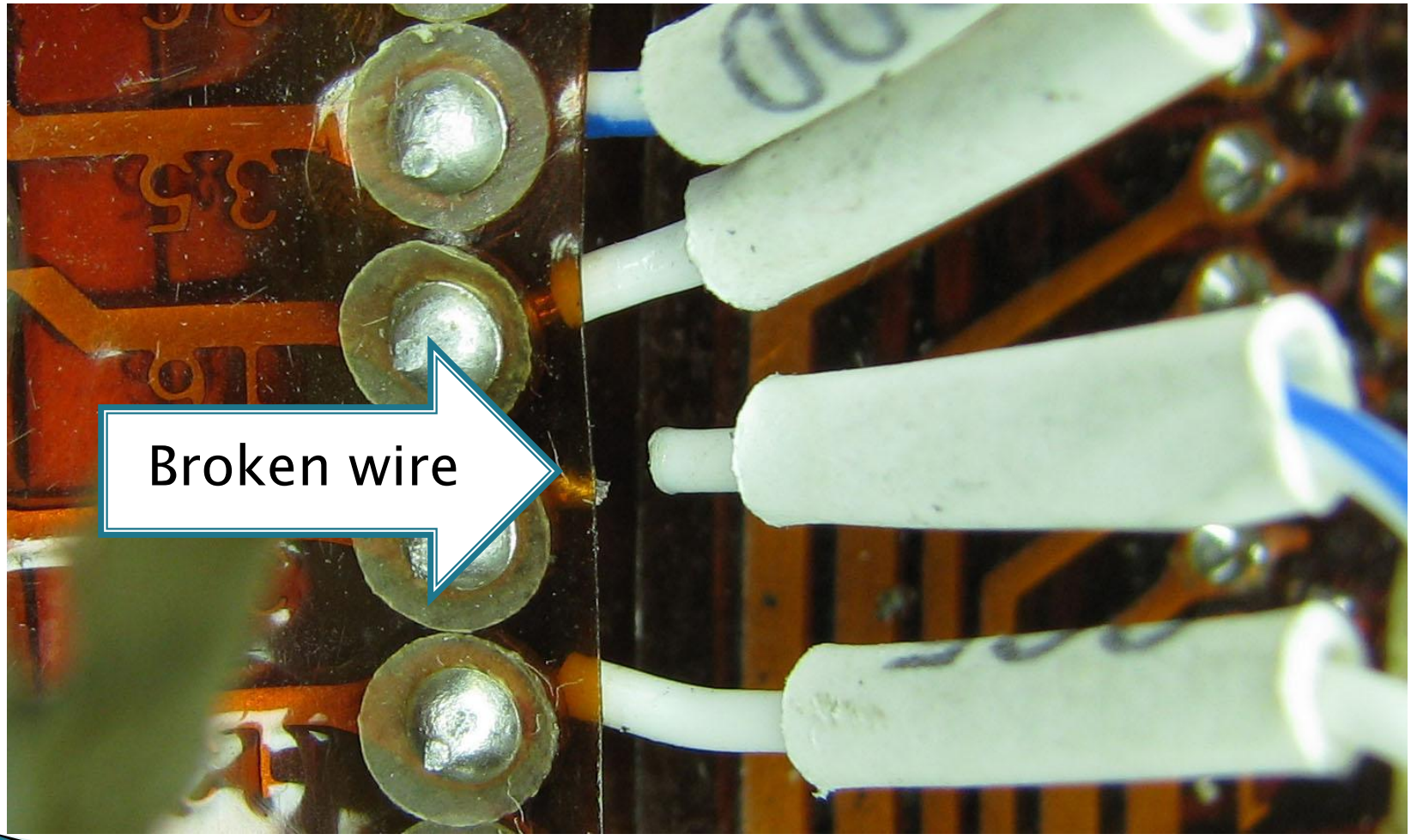
MLPRF: Intermittent Faults



MLPRF: Intermittent Faults



MLPRF: Intermittent Faults



MLPRF: Results

F-16 AN/APG-68 Radar System Modular Low Power Radio Frequency (MLPRF) unit

- **171** MLPRF chassis IFDIS tested to date
- **131** were considered “un-repairable” - completely out of service
- **33** had been in the shop for over one year
- **9** had been in the shop for over three years
- **116** had one or more intermittent circuits (**68%**)
- **33** had "opens", **9** had "shorts", and **4** were wired incorrectly
- Average cost of a replacement MLPRF chassis **$307,000.00 each**

MLPRF: Results

- Over $26 million dollars worth of flight assets recovered thus far and counting
- Enables technicians to repair LRUs that had previously been considered unrepairable
- Mean Time Between Depot Repair (MTBDR) increase from 315 hours to 731hours and growing – additional depot cost savings of $1.3 million annually

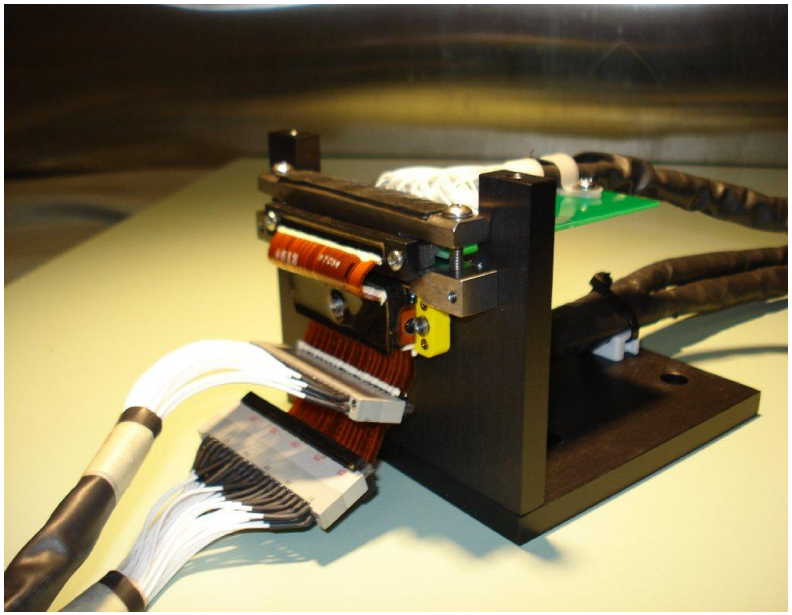
MLPRF: Results

- Over $27 million dollar return on investment (ROI) on 1 LRU chassis on 1 aircraft platform
- $2.2 million dollar government investment
- Over 12 times return on the IFDIS investment has already been realized!
- By incorporating IFDIS into the lean initiatives and Continuous Process Improvement (CPI) program, the 523rd Avionics Maintenance Squadron received the only "Outstanding Rating" at Ogden Air Logistics Center during the Headquarters Air Force Material Command (HQ AFMC) Logistics Compliance Assessment Program (LCAP) June 2010 inspection.

AZ/EL: Results

F-16 AN/APG-68 Radar System Antenna Azimuth Elevation (AZ/EL) Shop Replaceable Unit (SRU) Ribbon Cable

- Grounding F-16s
- Current testing equipment unable to identify intermittent ribbon cables
- IFDIS testing quickly identifies which ribbon cables are intermittent
- 95 AZ/EL ribbon cables IFDIS tested
- 24% have tested good
- IFDIS testing is preventing functional hardware from being discarded



Helicopter LRU: Results

- 45% NFF at I-Level
- 57% of backplanes tested failed on intermittence test
- Most faults repairable
- 75% of the failed items had previously passed LRU-level conventional ATE Depot testing

Courtesy: CTL / MOD

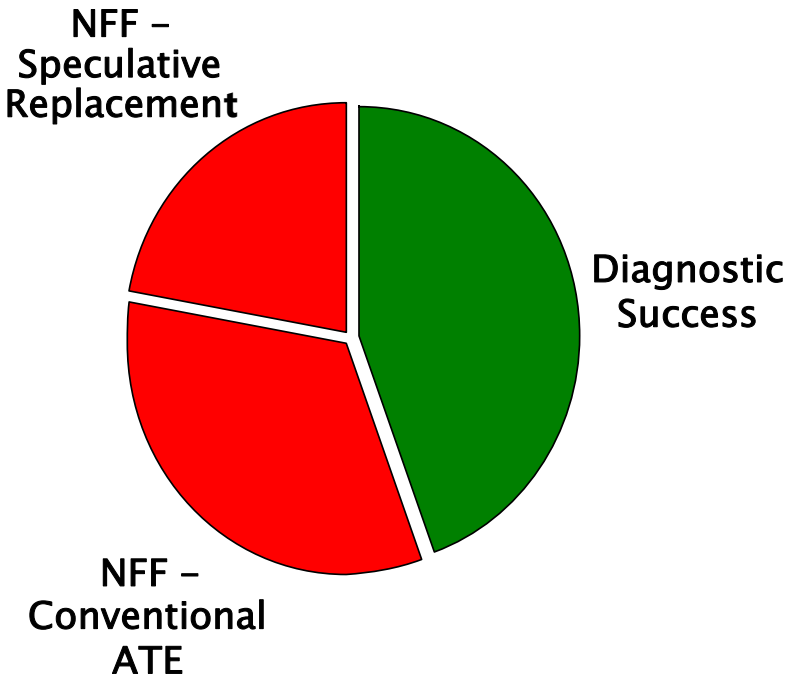
Surveillance Aircraft LRU: Results

The Problem:

- The customer operates an airborne system which provides high value operational intelligence
- The prime mission system suffers numerous intermittent faults

The Result:

- Analysis identified high NFF
- Testing identified intermittent faults
- It also identified additional components requiring intermittent fault testing

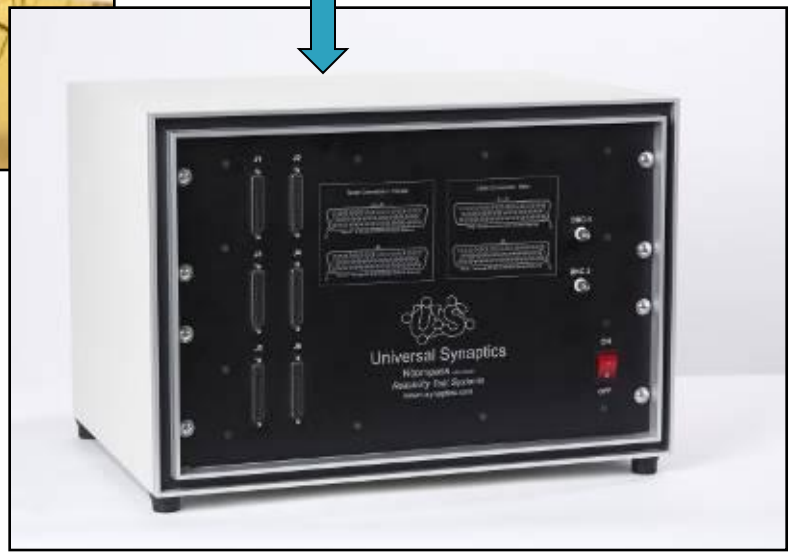


Courtesy: CTL / MOD

IFDIS: Expandability

Intermittent Fault Detection & Isolation System (IFDIS)

IFDIS expandability is virtually unlimited, installed in 256 test point modules – with no loss of speed or sensitivity



Department of Defense Maintenance Symposium "Great Ideas" Winner 2010

IFDIS: Utility

- The IFDIS approach is ***simple***, ***highly cost effective*** and ***extremely successful*** in fixing the intermittent / NFF testing void

- The IFDIS approach is wholly generic and can be used to test a wide variety of Line Replaceable Units (LRUs) and wiring systems in the DoD inventory

IFDIS: Advantage

- Quickly detect, isolate and repair intermittent circuit paths, shorts, opens and incorrect wiring problems in complex LRUs
- Root cause fault identification
- Advanced prognostic and diagnostic capability
- Increase mission readiness, availability and reliability
- Remediate bad actor LRUs and WRAs
- Reduce ownership cost through quick and correct intermittent fault detection, isolation and repair

IFDIS: Depot MX Perspective

Mr. Rick Buhl
Director
309th Electronics Maintenance Group
Ogden Air Logistics Center
Air Force Material Command

IFDIS: Depot MX Perspective

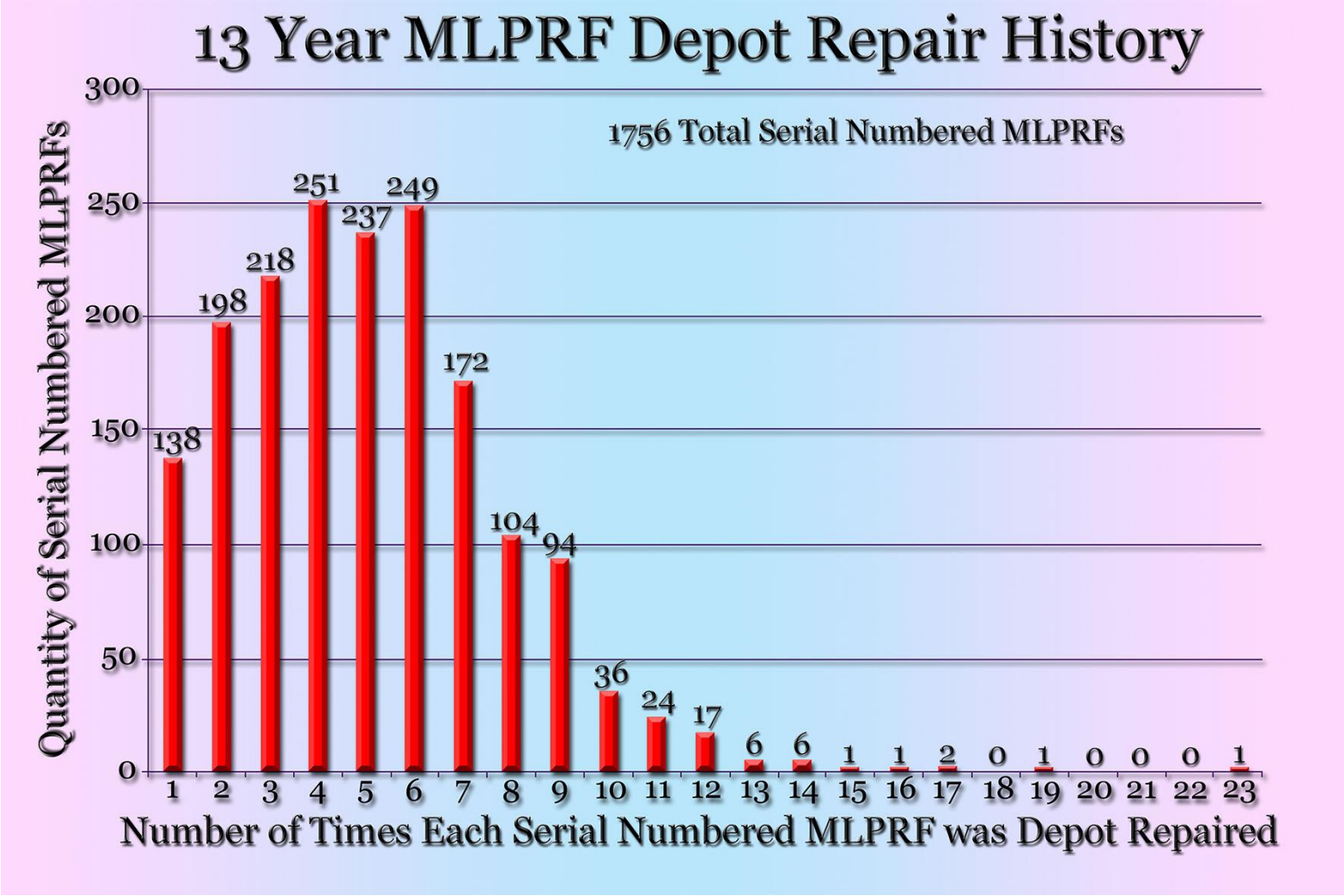
- IFDIS is supporting our product lifecycle management objectives:
  - Increasing Reliability
  - Reducing sustainment costs
  - Reducing field maintenance burden
  - Improving mission effectiveness
- IFDIS is recovering previously unrepairable assets
  - Prevents carcass constraint issues
- Currently have a large base of conventional ATE that is not resolving the intermittency issue

IFDIS: Depot MX Perspective

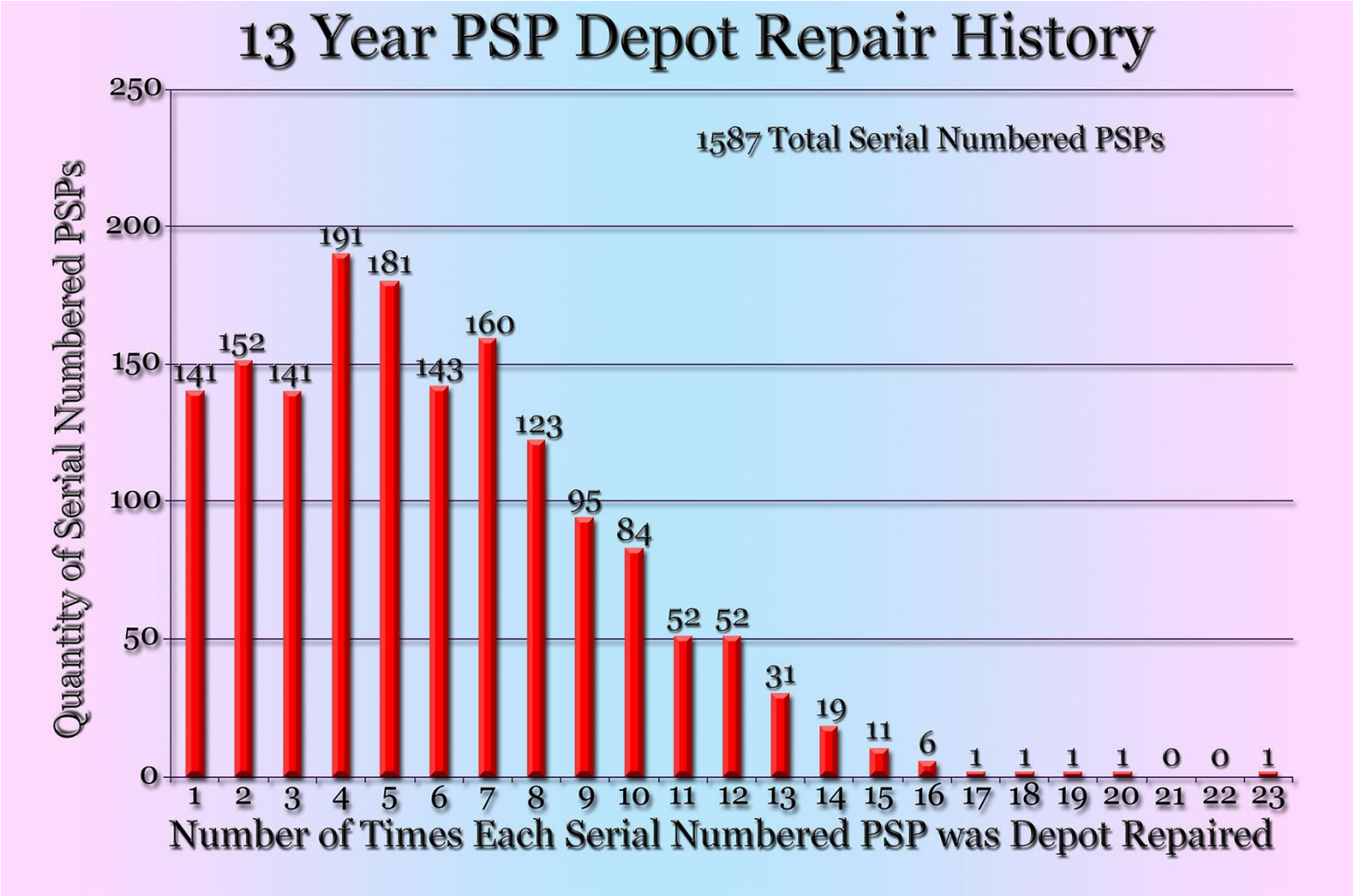
- **Already discussed the F-16 APG-68 Radar System MLPRF**
- Finding and repairing the problems in previously unrepairable units
- Finding and repairing intermittent faults, doubling the MLPRF reliability

- **That same Radar System has another problem box, the Programmable Signal Processor (PSP)**
- Have more unrepairable units than the MLPRF
- Convinced the PSP intermittent fault problem is worse

MLPRF: 13 Year History



PSP: 13 Year History



PSP Example Serial # 20362

Date	LRU Repair Activity	SRU Repair Activity
22-Nov-04	Did not fail any tests - disassemble, clean, reassemble, load and verify OFP	None
1-Apr-05	RTOK	None
21-Oct-05	RTOK. Intermittent FCR MFLs reported.	None
8-Jan-06	Load & verify OFP	None
20-Feb-06	Load & verify OFP, touch-up paint, R/R Jackscrew	None
2-May-06	RTOK. Technician requested to track item.	None
6-Nov-06	RTOK	None
1-Feb-07	Load & verify OFP	None
16-Mar-07	Load & verify OFP	None
24-Apr-07	R/R Symbol Input/Memory Module (A16)	Resolder lifted leads
	R/R SPC IO/Test OV (A21)	RTOK
	Load & verify OFP, touch-up paint	None
3-Jun-07	RTOK - Load & Verify OFP	None
29-Jun-07	RTOK	None
30-Jul-07	R/R Synchro/Digital CCA (A1)	No Data
	Disassemble, clean, reassemble	None

No Fault Found (NFF)
Quasi NFF Repair Activity

PSP Example Serial # 20362 Continued…

Date	LRU Repair Activity	SRU Repair Activity
6-Sep-07	RTOK	None
24-Sep-07	Failed test #7 and #8 Intermittently	None
	R/R Video Interface CCA (A39)	RTOK
20-Nov-07	Load & verify OFP	None
4-Dec-07	RTOK	None
6-Feb-08	RTOK	None
20-Mar-08	R/R Signal Gen/Sync (A38)	R/R capacitor-resistor network
	Load & verify OFP, touch-up paint	None
23-Dec-08	Load & verify OFP	None
26-Mar-09	RTOK	None
24-Jul-09	RTOK	None
4-Oct-09	RTOK. Load & verify OFP, epoxy side air vent panel, reseat all CCAs, touch-up paint	None
26-Oct-09	RTOK	None
12-Mar-10	Ran for 4 days in the advanced lab before detecting any failures	None
	Recommend replacing ETI meter, A2, A5, and A37	Not yet inducted

No Fault Found (NFF)
Quasi NFF Repair Activity

IFDIS: Depot Immediate Need

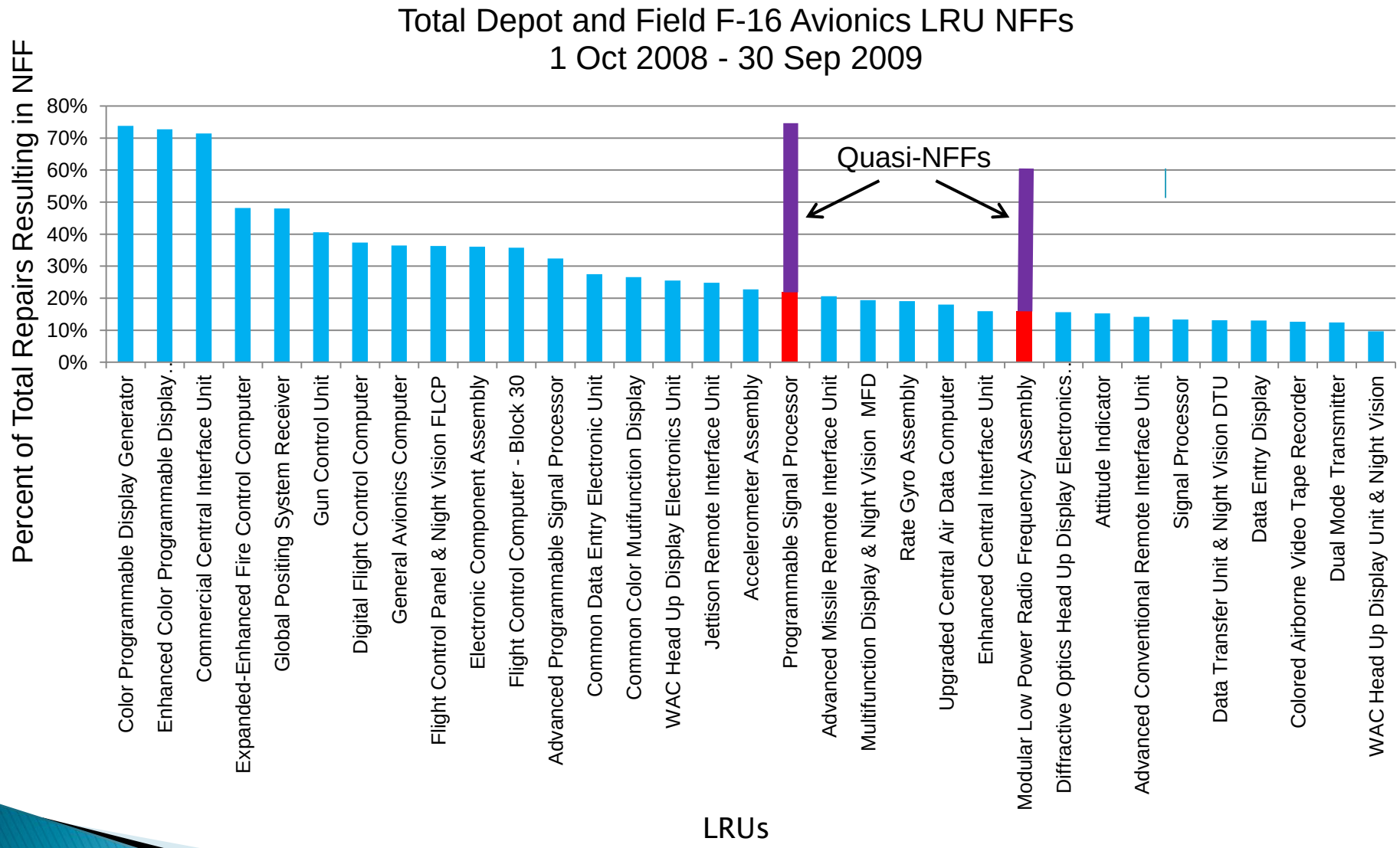
- **51% of the MLPRFs that come into depot do not have a bad part**
- Field NFF rate is 31%
- Driven in for some reason other than a bad part
- Most likely by intermittent faults

- **59% of the PSPs that come into depot do not have a bad part**
- Field NFF rate is 54%
- Worse intermittent problem than the MLPRF
- Whereas 68% of the MLPRFs have intermittent faults, we anticipate the PSP intermittent fault rate will be even higher

IFDIS: Why Fund This Program?

- MLPRF required a 1024 channel IFDIS to test all circuits all the time
- PSP will require an 8448 channel IFDIS
- PSP appears to be the most demanding circuit point requirement LRU at OO-ALC
- An 8448 channel IFDIS will be capable of testing any LRU under 8448 circuits
- If a larger requirement exists, the IFDIS can be easily expanded in 256 channel module increments

Broad F-16 Potential Application



IFDIS: Broad Application

- **USAF:**
- Aerospace Maintenance and Regeneration Group (AMARG) pulled 13,000 parts in FY10 ($545M)
- Caused by supply / repair shortfalls
- Not an option for some platforms

- **DoD:**
- The basic physics of this issue apply

IFDIS: Conclusion

- Convinced intermittents are a systemic issue
- Multiple tours of the IFDIS capability have all garnered strong interest
- Clearly a cost effective approach to lowering maintenance and sustainment costs

- **309th EMXG is the beach head:**
- Cultural Competency
- Technical Competency
- Mature Partnership
- Strategic Geography
- Already Pursuing DoD Depot MX Partnerships

It's Time to Stop Admiring the Problem

Questions?

For additional IFDIS information please contact:

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Bryan Steadman – Total Quality Systems
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Back up slides

Conventional ATE vs. IFDIS

- The fastest scanning continuity testers, test only one line at a time at a speed of 17milliseconds (.017 seconds)
- IFDIS is monitoring all lines all the time waiting for intermittent faults as short as 50 nanoseconds (0.00000005 seconds)
- .017 divided by .00000005 = 340,000. IFDIS is 340,000 times more probable to detect intermittent / NFF on a single line
- This single circuit testing advantage applied to testing 3000 simultaneous circuits for intermittence (APG-73 RR), increases IFDIS detection probability at 3 trillion 60 billion times more probable to detect intermittent / NFF than scanning continuity testing
- Applied again to 10,000 circuits, the IFDIS detection probability increases to 34 trillion times more probable to detect intermittent / NFF than scanning continuity testing

Conventional ATE vs. IFDIS

Without IFDIS technology applied to resolve the intermittent / NFF problem, you have better odds of getting into orbit with a hang glider!

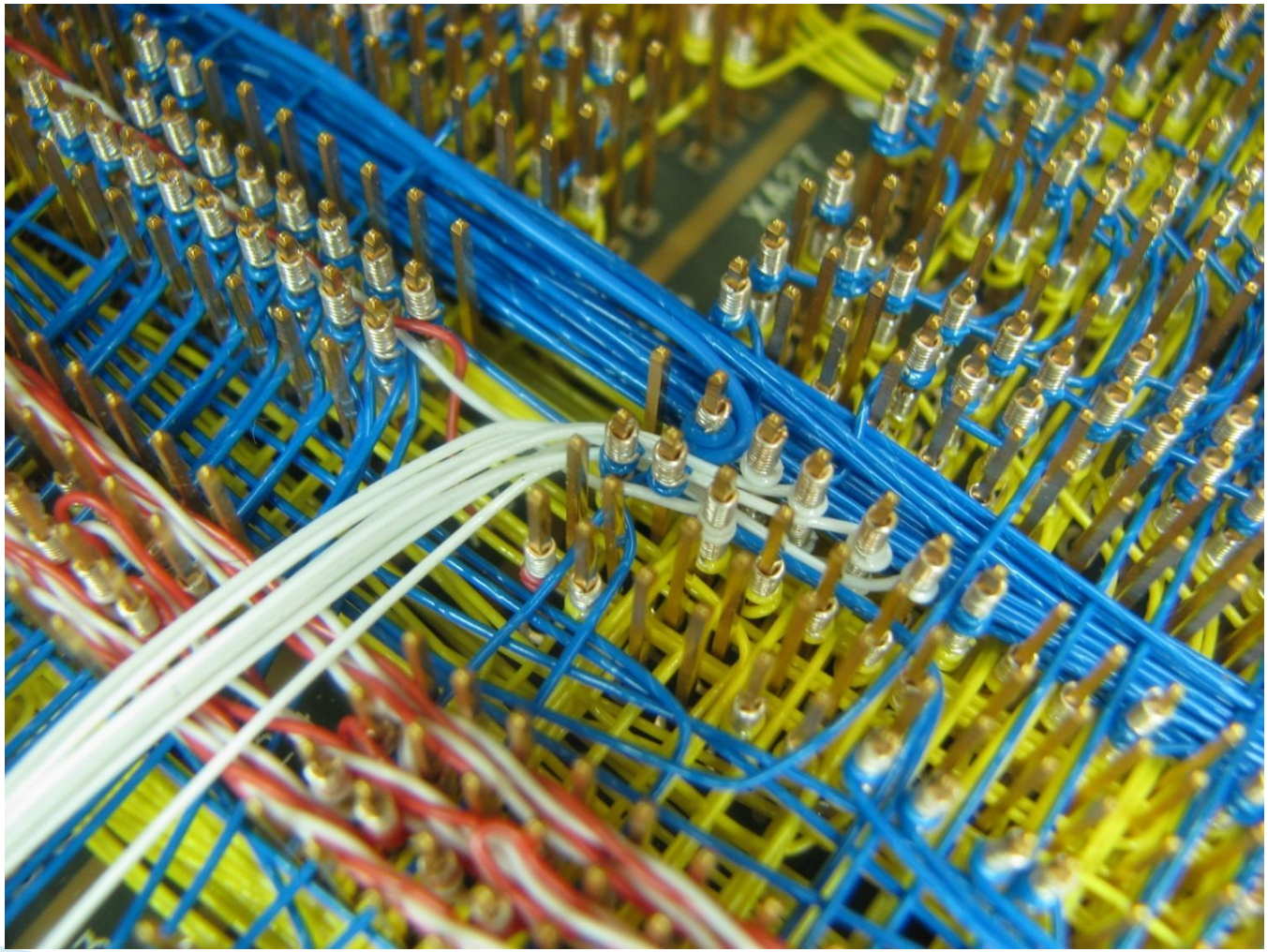
Conventional ATE vs. IFDIS

- TDR / SWR tests one line at a time and will tell you distance to fault if you're on the correct line, will not detect momentary faults
- Digital Ohm Meter tests one line at a time, averages out momentary faults and hence hides intermittence
- IFDIS with it's all of the lines, all of the time, simultaneous and continuous circuit monitoring, is the only applicable solution to the extensive intermittent / NFF problem

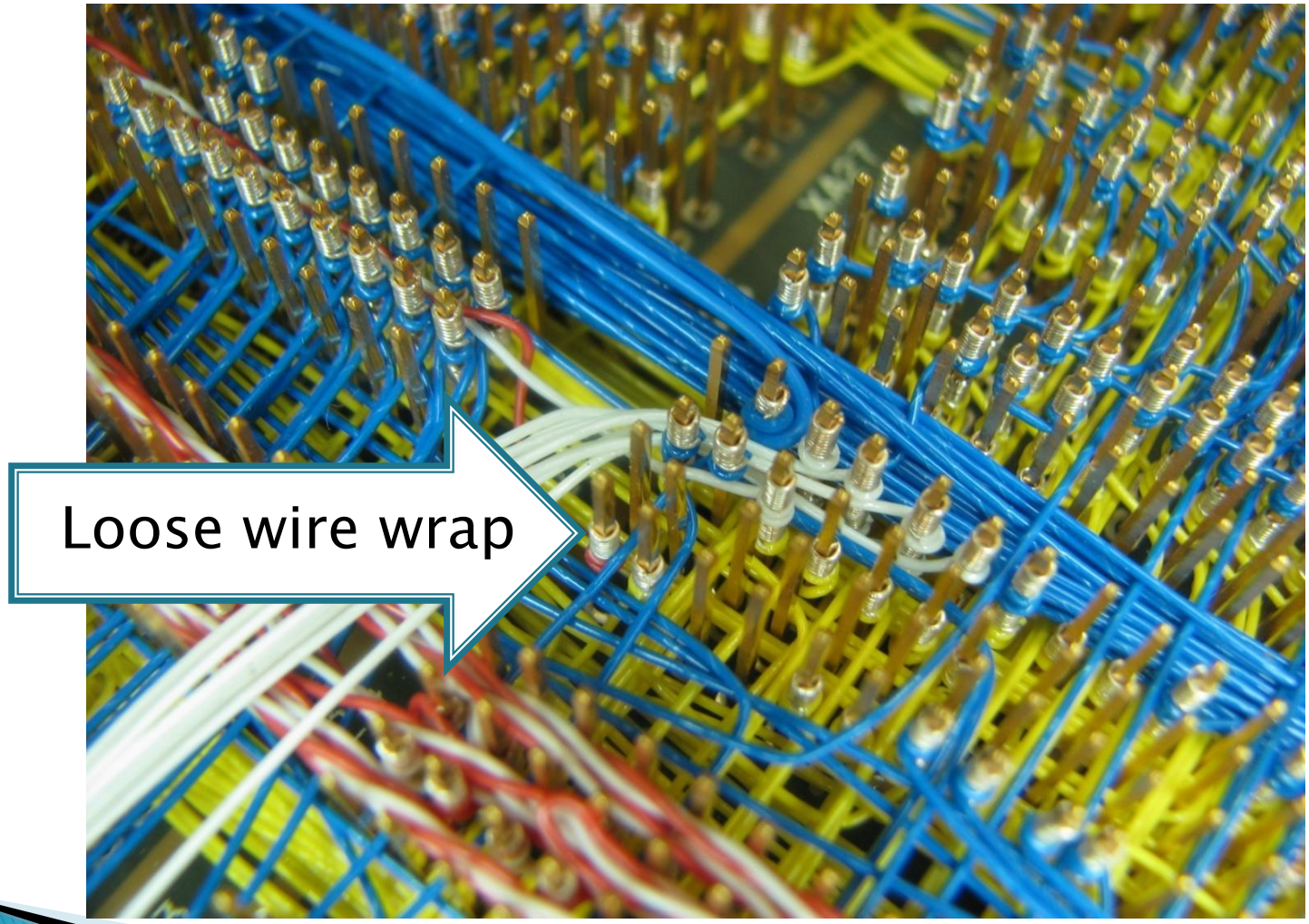
Intermittent Faults:

- A typical avionics system has thousands of internal and external circuit paths moving electrons through thousands more physical interconnection points which are all aging to some degree and will likely fail intermittently long before they fail permanently
- Intermittence occurs randomly in time, place, amplitude and duration
- Electromechanical devices go into a long and frustrating period of low-level intermittency as their mechanical tolerances change

Intermittent Faults:

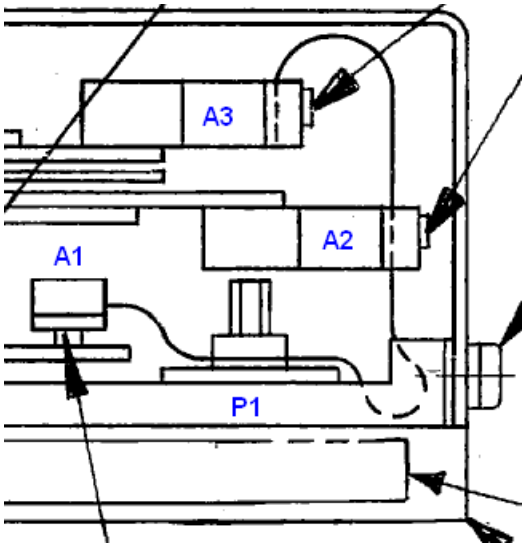


Intermittent Faults:

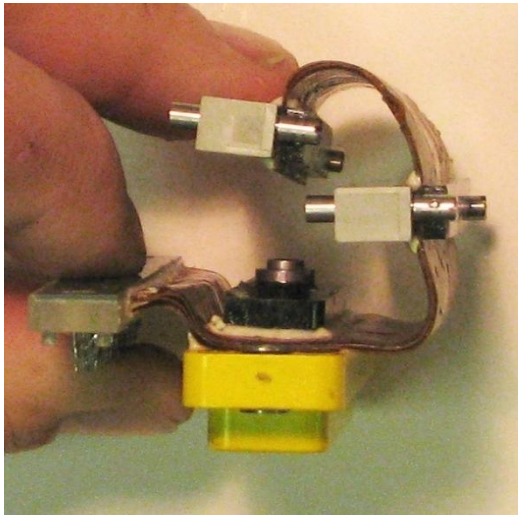


AZ/EL: IFDIS Findings

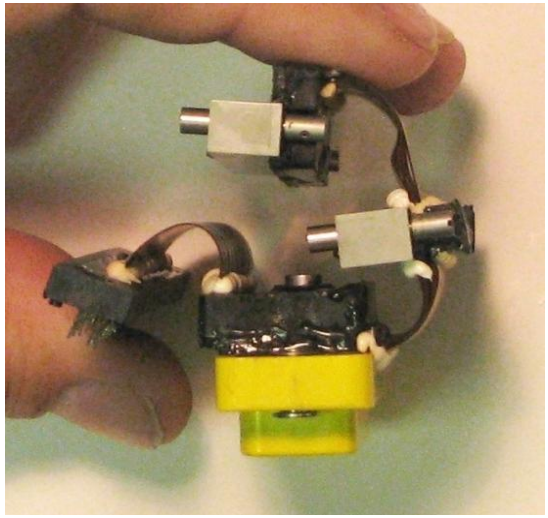
F-16 AN/APG-68 Radar System Antenna Azimuth Elevation (AZ/EL)



SRU Drawing Configuration



Matches SRU Drawing



Configuration Being Used

Current configuration does not match the SRU drawing
(Could be the root cause of the high failure rate)