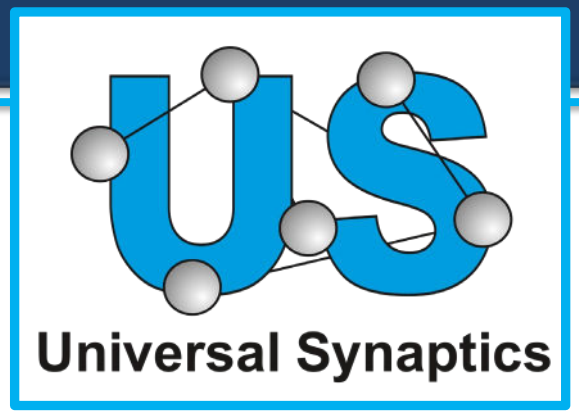

Intermittent Fault Detection

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BLUF

Universal Synaptics Corporation (USC) has partnered with Lockheed Martin (LM) to assist the DoD to solve their intermittent failure problem

- **Capability:** USC / LM has only Automatic Test System (ATS) proven to meet MIL-PRF-32516 (Intermittent Fault Detection – IFD)
- **Readiness Enabler:** across DoD platforms “More Readiness at Less Cost” – TRL9
- **F-35 JPO Authority to Operate (ATO):** Portable Intermittent Fault Detector™ (PIFD™)
- **National Stock Number:** Assigned
- **ILS-S:** Available for Order
- **Boeing AMM:** Approved

IFD CAPABILITY ENABLES READINESS AND REDUCES SUSTAINMENT COSTS

THE PEACE TIME PROBLEM

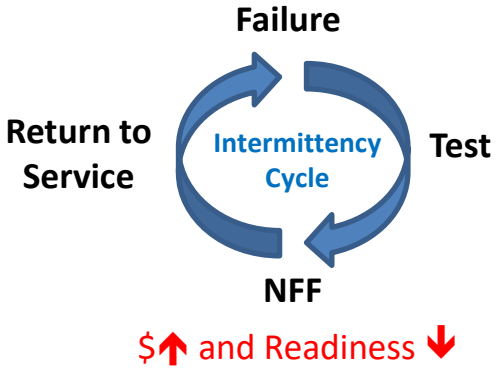
Testing of aircraft electronics results in No Fault Found (NFF) approx. 50% of the time

- LRU malfunctions intermittently during flight → Tests good during subsequent ground testing (NFF)
- Cyclical return to aircraft and back through O, I, and D levels of maintenance

DoD estimates that 75% of weapons systems have undetected, intermittent faults manifesting as operational failure
(Source: OSD Maintenance, CTMA Partners Meeting 2021)

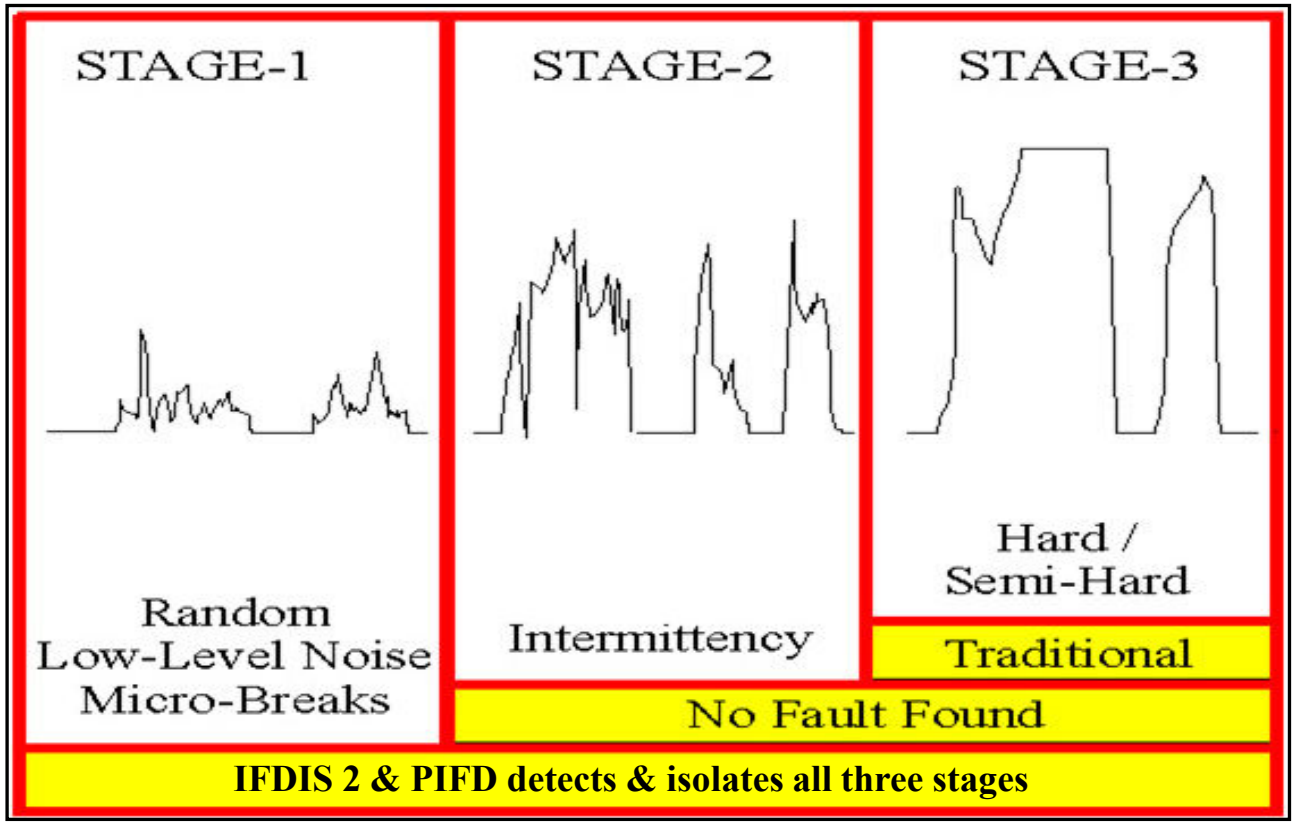
NFF is an **annual $5.5B non-value-added expense** to DoD
(Source: OSD Maintenance, DASD (MR) Memo 2019, GAO-20-116 Report 2020, DoD Report to Congress 2021, OSD Mx Memo 2022)

- 383,000 non-available days of end-item sub-components due to intermittent / NFF
- DoD estimates 50% readiness improvement with IFD implementation



INTERMITTENT FAULTS

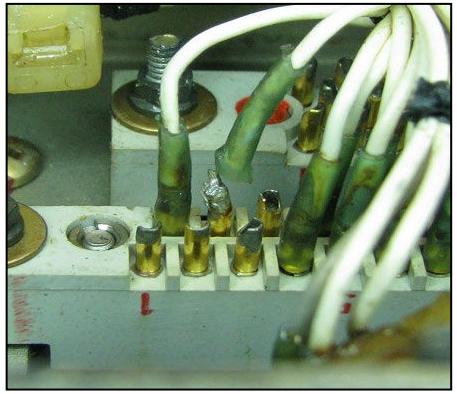
Three Stages to an intermittent fault:

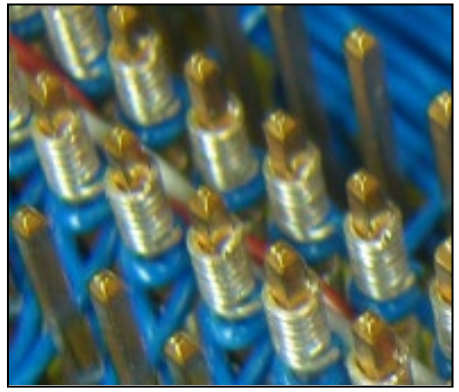


- **Stage 1** – random low-level nanosecond micro-breaks, likely not operationally evident yet. However, these faults are on the early curve of degradation and will become exacerbated over time based on Op Tempo and environmental conditions and will graduate to Stage 2.
- **Stage 2** – fails intermittently in operation yet passes ground tests and labeled A-799 (CND or NFF). These in-flight failures are evident to the pilot and reported to the ground crew as “the radar lost lock”, “Heads up Display (HUD) blanked or blinked out”, “Gun Controls didn’t work”, etc. and will eventually become Stage 3.
- **Stage 3** – semi-hard or hard failures, currently fielded Automatic Test Systems (ATE) are designed to detect hard faults (open circuits or shorted circuits). According to the GAO, the DoD currently maintains $50B worth of ATE all designed to detect hard failures, “conventional” ATE was not designed to detect and is incapable of detecting momentary faults causing A-799.

INTERMITTENT FAULT ROOT CAUSES

- Cracked solder joint
- Broken wire
- Loose crimp connection
- Loose or corroded wire wrap
- Corroded connector contact
- Sprung connector receptacle
- Deteriorated wire insulation
- Hairline crack in printed circuit trace
- Unsoldered connection





Physical Manifestations, Not Electronic Component Failures

OPERATIONAL IMPACT

- **DoD Budget**
  - $5.5B Annual Loss (nearly 50% of Electronics Mx Budget); 383,000 days of lost combat capability annually
- **High MICAP rates**
  - Missions canceled and postponed
  - Readiness is negatively impacted
- **High NFF / RTOK / CND rates**
  - Wasted maintenance resources and supply man-hours
  - Wasted time on supply documentation, transportation, and troubleshooting
- **Supply chain becomes more expensive and less responsive**
  - Each LRU sent to the depot for a non-fix, unnecessarily wastes Combat and Support Commands millions of dollars each year
  - High availability (even a 100% production fill rate) does not equal high reliability or weapon system readiness

Change is required to reduce NFF & improve operational availability

MX & SUPPLY IMPACT

- **Tools provided to maintainers are not sufficient:**
  - Just because an LRU or wiring system passes BIT or ATE tests multiple times in a row, does NOT mean intermittent problems do not exist in the system
  - BIT / ATE testing does not check all circuits simultaneously or functional paths in an LRU or connection paths to circuit card assemblies
  - Conventional ATE does not test in an operationally relevant environment
  - Conventional ATE is incapable of detecting short-duration intermittent faults that cause NFF

- **Flight Line "Blacklisting" of LRUs and wiring systems makes an expensive supply problem worse**
  - Creates availability issues and drives unnecessary spares acquisition
  - Masks the real problem and drives "swaptronics"
  - Recirculates "bad actors" to other operational units, thus perpetuating the problem

An Innovative Solution is Needed to Solve This Problem

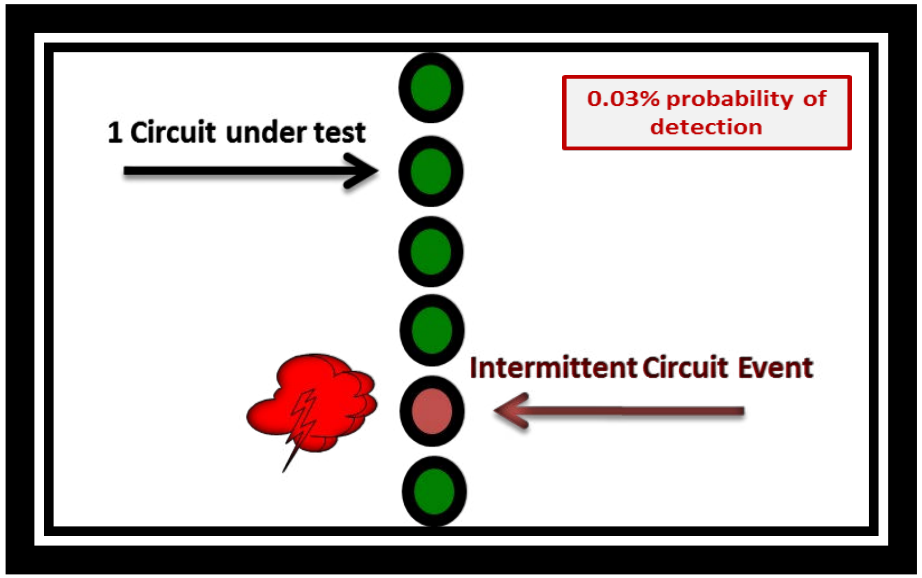
CONVENTIONAL APPROACH

- **Functional ATE and Continuity testers cannot detect and isolate intermittent faults causing NFF**
  - Test only one function at a time
  - Test only one circuit at a time, even when connected to multiple circuits
  - Digital averaging, scanning, and sampling masks / misses the intermittent faults – a testing "blind spot" / "testing void" exists
  - LRUs are not typically tested in an operational environment which is where the failures occur, EWIS is also tested in a static environment
  - Only designed to find functional failures, failed components, and "hard" failures (open circuits / short circuits)
  - Intermittent faults causing NFF test results on the ground do not follow specific failure patterns

Conventional Approach = Conventional Results

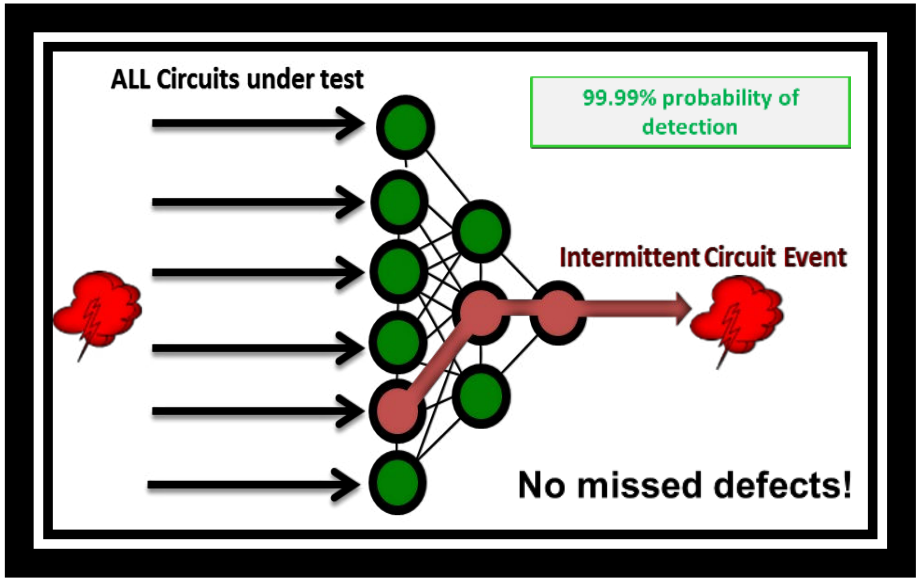
CONVENTIONAL or IFDIS 2.0 / PIFD

Conventional ATE



- Parametric testing (scanning one circuit or one function at a time)
- Makes assumptions based on set parameters (sampling or averaging test data and results)
- Tests component in static environment (does not simulate operational environment)

IFDIS 2.0 / PIFD



- Deterministic testing (all circuits under test monitored at the same time)
- Makes no assumptions, if a fault is present, it is detected and isolated in real-time
- Similar to having an oscilloscope on every circuit under test
- Tests components in a simulated operational environment (3G, -20C to +70C temp range)

PROVEN NFF SOLUTIONS

Portable Intermittent Fault Detector (PIFD)

- MIL-PRF 32516 Compliant
- Detects: intermittent faults, open circuits, shorted circuits, mis-wiring
- AutoMap™ (No TPS development)
- 256 & 512 test point variants
- TRL 9
- F-35 ATO
- NSN assigned
- Available in ILS-S
- Boeing AMM approved, all type / model / series

DoD Mx Symposium “Great Ideas” Competition Finalist 2014

PROVEN NFF SOLUTIONS

Intermittent Fault Detection & Isolation System 2.0 (IFDIS 2.0)

IFDIS 2.0

- MIL-PRF 32516 Compliant
- Detects: intermittent faults, open circuit, shorted circuits and mis-wiring
- AutoMap™ (No TPS development)
- Easily expandable
- TRL 9

DoD Mx Symposium “Great Ideas” Competition Winner 2010 & 2012

DOD NFF SOLUTION

OSD Establishes Joint Intermittent Testing IPT

- 2012 – Joint Service effort to address the intermittent fault testing void
- 2015 – DoD issues MIL-PRF-32516 *"Electronic Test Equipment, Intermittent Fault Detection & Isolation"*
- 2016 – JIT Industry Week held at NAES Lakehurst
- 2017 – MADW data analysis to determine "Top 10" IFDIS & PIFD candidates for each service
- 2018 – MC 80 Directive issued / JIT Implementation Plan drafted to support
- 2019 – JIT Implementation released
- 2019 – Second JIT Industry Week held at NAES Lakehurst
- 2020 – Intermittent failure mode added to DoD Wiring MIL-HDBK-525 Chg-1
- 2021 – F-35 ATO issued for the PIFD
- 2021 – DoD submits report to Congress on Intermittent Failure Problem and solution

DoD estimates a Mx savings of $2 to $10B annually with a 50% readiness improvement with DoD wide implementation of IFDIS 2.0 and portable IFD

(source: GAO-20-116)

IDENTIFYING TEST CANDIDATES

Analyze Maintenance Data

Identify:
- NFF's
- Poor performers
- Un-repairable
- System architecture
- Feasibility Study

Test Candidate?

No

Other Remediation Option

Test, Repair and Return to Service

Yes

Perform IFD Diagnostics

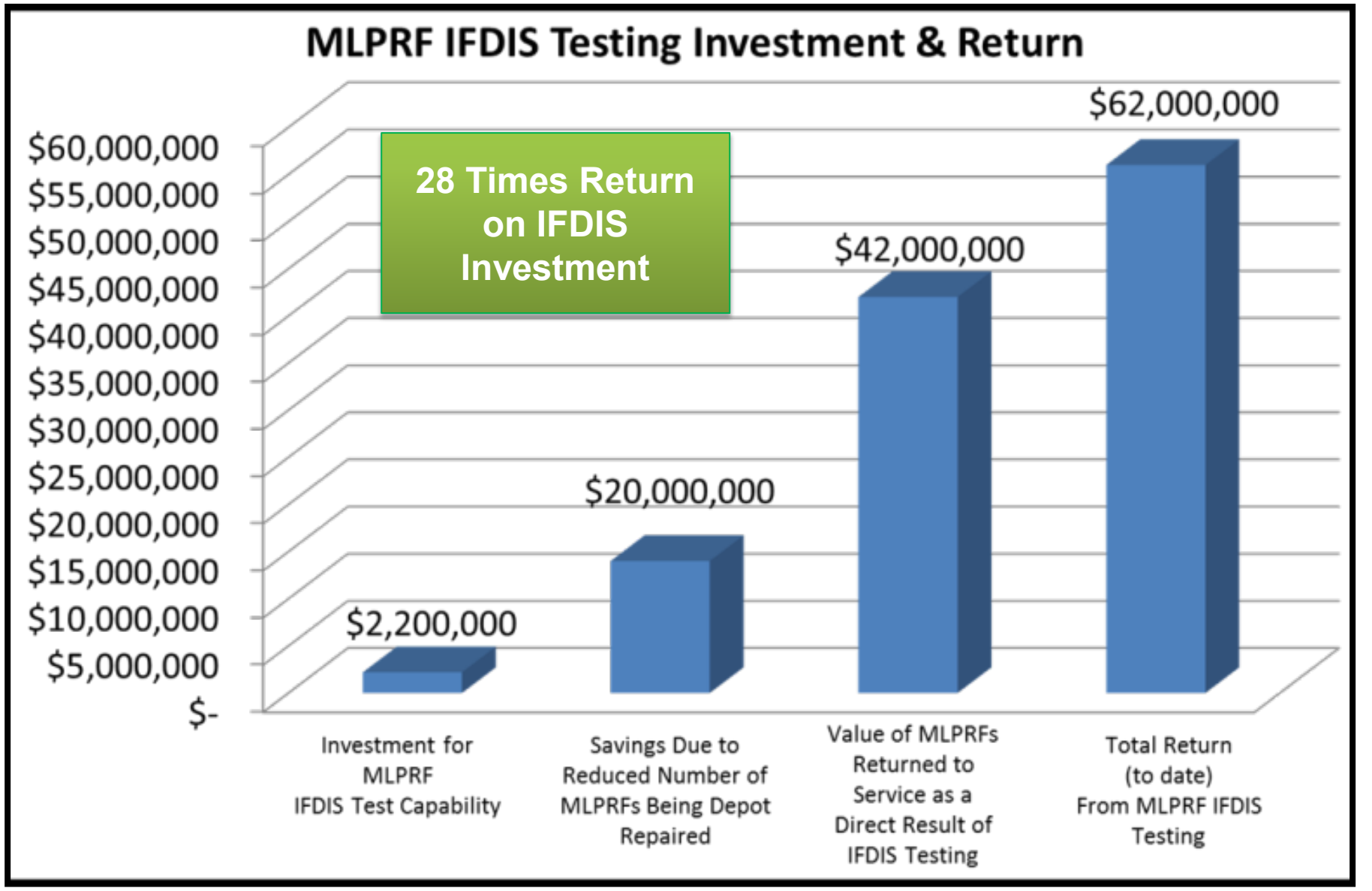
Repair Chassis or wiring harness

Retest with IFD Technology

Collect Maintenance and Performance Data

Universal Synaptics

F-16 MLPRF RESULTS

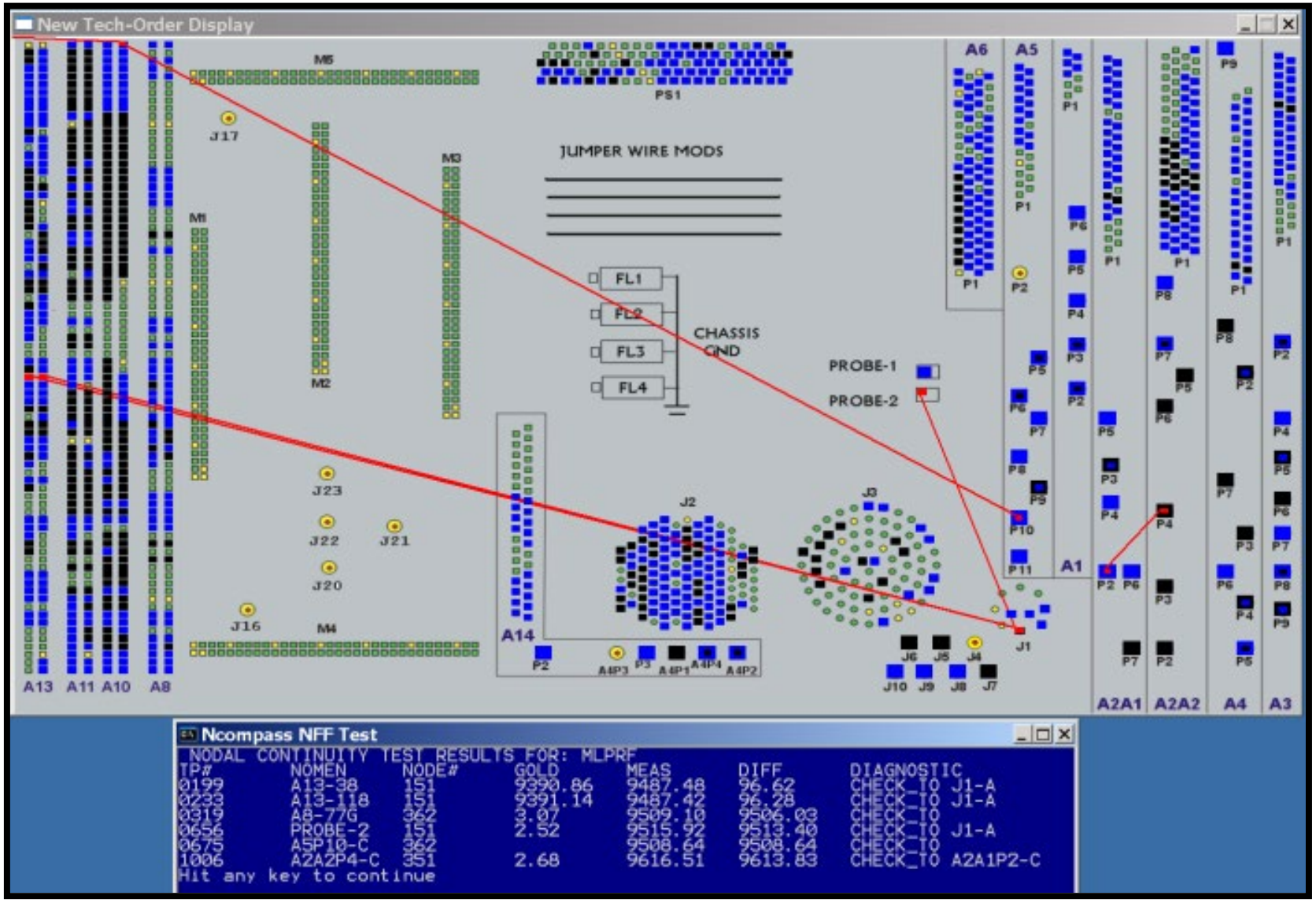


Universal Synaptics

F-16 MLPRF RESULTS

F-16 MLPRF Results	Before IFDIS Testing	After IFDIS Testing	Increase In Average Hours Between Depot Repair	% Increase
Serial Number	Average Hours Between Depot Repair	Average Hours Between Depot Repair		
10074	182	1884	1702	935%
11347	168	1267	1099	654%
10849	59	941	882	1495%
10888	286	1132	846	296%
11877	257	1010	753	293%
10725	79	697	618	782%
11437	72	622	550	764%
11863	463	1008	545	118%
11188	567	1102	535	94%
11525	164	646	482	294%
10386	157	611	454	289%
11792	127	581	454	357%
11732	70	477	407	581%
11296	24	430	406	1692%
11267	317	713	396	125%
11665	183	568	385	210%
10752	707	1086	379	54%
Average	228	869	641	281%

F-16 MLPRF FAULT ISOLATION GRAPHIC



IFD RESULTS – IMPLEMENTED TODAY

Universal Synaptics

USAF Location
- Hill AFB

USAF Results
- **1600%** ROI
- **350%** LRU Operational Readiness Improvement
- **50%** Reduction in Functional ATE test time

Navy Locations
- FRC SW
  - F/A-18 GCU A-D Overhaul and Repair LES NI F-18-010-05 REC C
- NSWC Crane
- NAS Lemoore
- NAS Oceana

Navy Results
- **TBD** ROI
- **500%** WRA Operational Readiness Improvement
- **67%** Reduction in Functional ATE test time

F-35A/B/C
- **Authorized for use Information Technology (IT) Special Equipment (ITSE) Authority to Operate (ATO)**

In Operation Today

F-16 (USAF configuration Hill AFB)
- AN/APG-66 Radar System, Low Power Radio Frequency (LPRF)
- AN/APG-68 Radar System, Modular Low Power Radio Frequency (MLPRF)
- AN/APG-68 Radar System, Programmable Signal Processor (PSP)
- AN/APG-68 Radar System, Antenna Array
- AN/APG-68 Radar System, Digibus Matrix Plate Assembly
- AN/APG-68 Radar System, Azimuth / Elevation (Az/EL) ribbon cable
- Central Air Data Computer (CADC)
- Signal Acquisition Unit (SAU)

EA-18G (NSWC Crane)
- AEA Suite – seven (7) WRAs & EWIS

F/A-18 (FRCSW, Lemoore, & Oceana)
- Generator Converter Unit – G1 (A-D BLK aircraft)
- Generator Converter Unit – G2 (E-F BLK aircraft)
- Generator Converter Unit – G3 (E-F BLK aircraft)
- GCU – Chassis Wire Harness

E8-C JSTARS (WR AFB)
- EWIS

Support and sponsored Test Case Studies

F-35A - FCS Power
F-35B - 1394b RIO & Grd Mx Mode Pump
F-35C - Fuel High-Level Float Value

C-130J – EWIS / NIU / FOIS
C-17 – Power Supply cable harnesses

A-10 – EWIS

AH-64 – Armament Systems Wiring
UH-60 – Main Rotor Blade De-Icing cable wiring

M1-A1 – Turret Slip Rings & wiring harnesses

CH-47
- Automatic Flight Control System (AFCS)
- Switch Panel & Circuit Breakers
- AFCS wiring harnesses
- Radio Transmitter / Receiver

Eurofighter
- Landing Gear Computer (LGC)
- Landing Gear Undercarriage wiring harnesses

Tornado GR4
- Secondary Power System (SPS)
- Nose-Wheel Steering wiring harnesses

Patriot Missile System – Radar system EWIS

CONCLUSION

- Undetected intermittent faults are a systemic issue – a $5.5 billion dollar a year testing void exists – currently deployed test sets are not solving the problem
- Advanced IFD diagnostic solutions are available to detect and isolate intermittent faults that cause NFF in compliance with US DoD MIL-PRF-32516
- Intermittent fault detection and isolation capability has proven to reduce NFF, reduce life cycle costs, reduce repair cycle times, improve Time on Wing (TOW), and improve operational readiness
- IFDIS 2.0™ & PIFD™ are objectively proven solutions making a positive impact today and can be utilized on any platform

It's Time to Stop Admiring the Problem

QUESTIONS?

Back Up

DoD Intermittent Fault Definition

JIT Team Definition of "Environmentally Induced Intermittent Fault"

- A discontinuity that occurs in LRU/WRA chassis and backplane conductive paths as a result of various operational environmental stimuli, including, but not limited to, thermal stress, vibrational stress, gravitational G-force loading, moisture and/or contaminant exposure; as well as changes in the material due to age and use, such as tin whiskers, metal migration and delamination of materials. These faults can occur individually and/or in rapid succession on any chassis or backplane circuit.

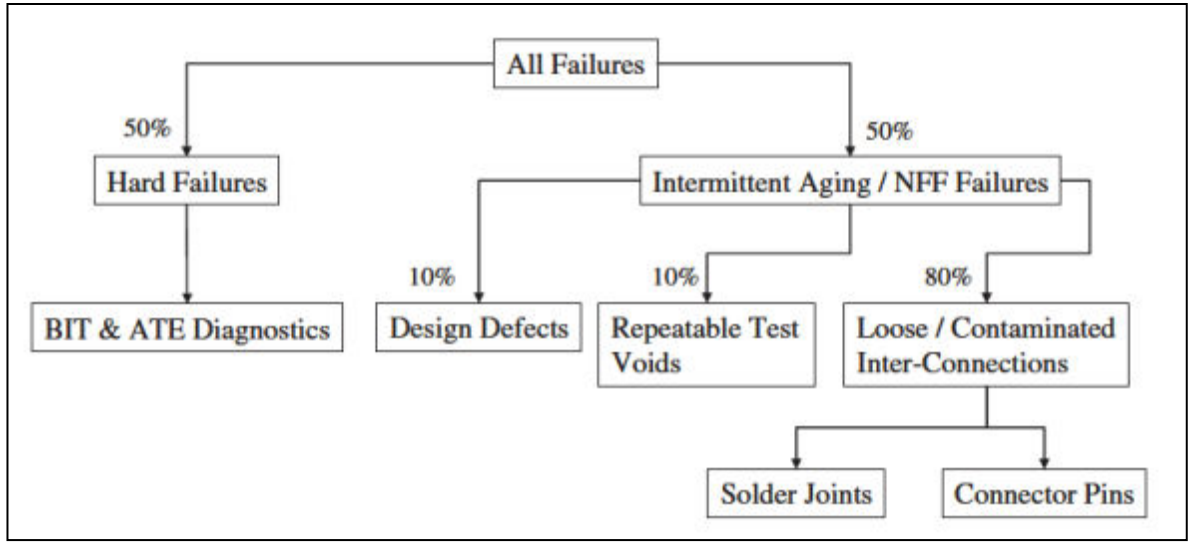


Figure Source: B. Sorensen, "Digital-Averaging-The-Smoking-Gun-Behind-No-Fault-Found", http://www.aviationtoday.com/asw/categories/commercial/Digital-Averaging-The-Smoking-Gun-Behind-No-Fault-Found_2120.html, Air Safety Week, February 24, 2003.

DoD MIL-PRF 32516

MIL-PRF 32516 ***"Electronic Test Equipment, Intermittent Fault Detection & Isolation"***

- Covers the "minimum performance requirements for equipment to detect and isolate nanosecond, microsecond and millisecond conductive path intermittent faults"
- "Intermittent faults can occur in any and all of the hundreds to thousands of LRU / WRA chassis and backplane circuits and their wire harnesses"
- Establishes performance requirements framework for intermittent fault detection test equipment to detect and isolate nanosecond, microsecond and millisecond intermittent faults
- "Not intended to address hard opens, shorts or constant function failures found in routine electronics repair"

Intermittent Faults

- **Hi-Pot testers** rely on the breakdown of the insulation to show if there is a fault. It is well known that this technique stresses the cable under test and in some cases can actually damage the insulation on sites that would otherwise have not caused a problem. Some recognized military forces have banned high voltage insulation testing following the NTSB report into the cause of the loss of TWA Flight 800 in 1996. In addition, Hi-Pot testing can actually mask intermittent faults and can result in a false negative result.

- **Low Energy High Voltage** testers are a better solution for finding some intermittent faults than Hi-Pot testers because they use a low energy pulse. However, depending on the type of intermittent they then need to use higher voltages to expose the fault, which can then lead to the same disadvantages as Hi-Pot testers. On commencing testing it is not possible to know the type of the intermittent being dealt with so it is difficult to determine what voltage level to use. This method also assumes that intermittent faults have an adjacent escape path for the pulse i.e. the airframe, or another adjacent cable with exposed conducting material; this is not always the case and so detection probabilities are low and scenario driven.

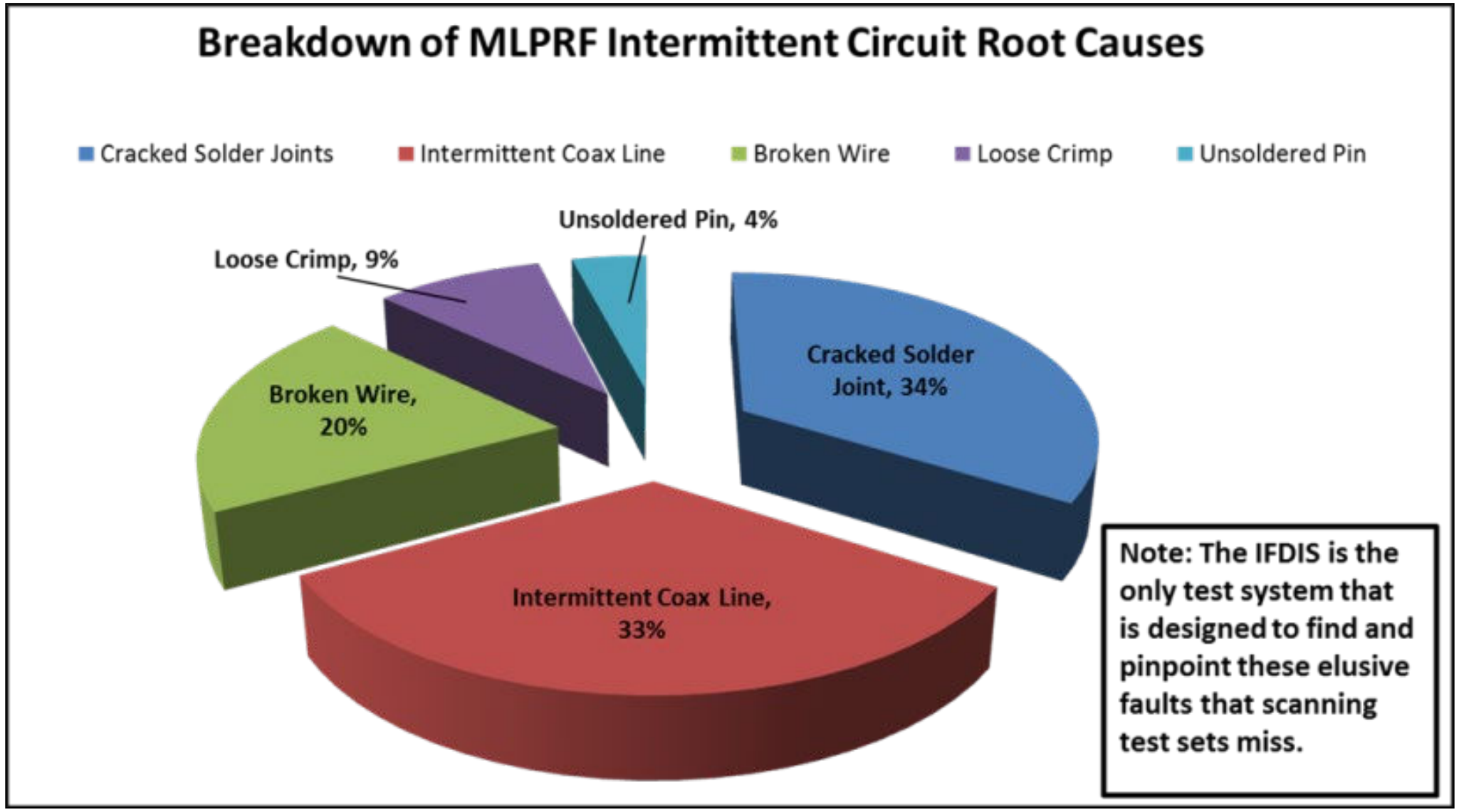
Intermittent Faults

- **Spread-Spectrum Time Domain Reflectometry** (SSTDR) technology is very advanced at detecting cable changes using complex signals, reading reflections and carrying out post-analysis. However, the detection rate is limited to approximately 50 millisecond changes, which means that not all intermittent faults below this threshold can be detected. Furthermore, as a stand-alone tool, SSTDR can be applied to just one wire per cable loom at any given time and this 'switching' approach between wires in the loom introduces more opportunities to miss the intermittent fault than it does to find it.

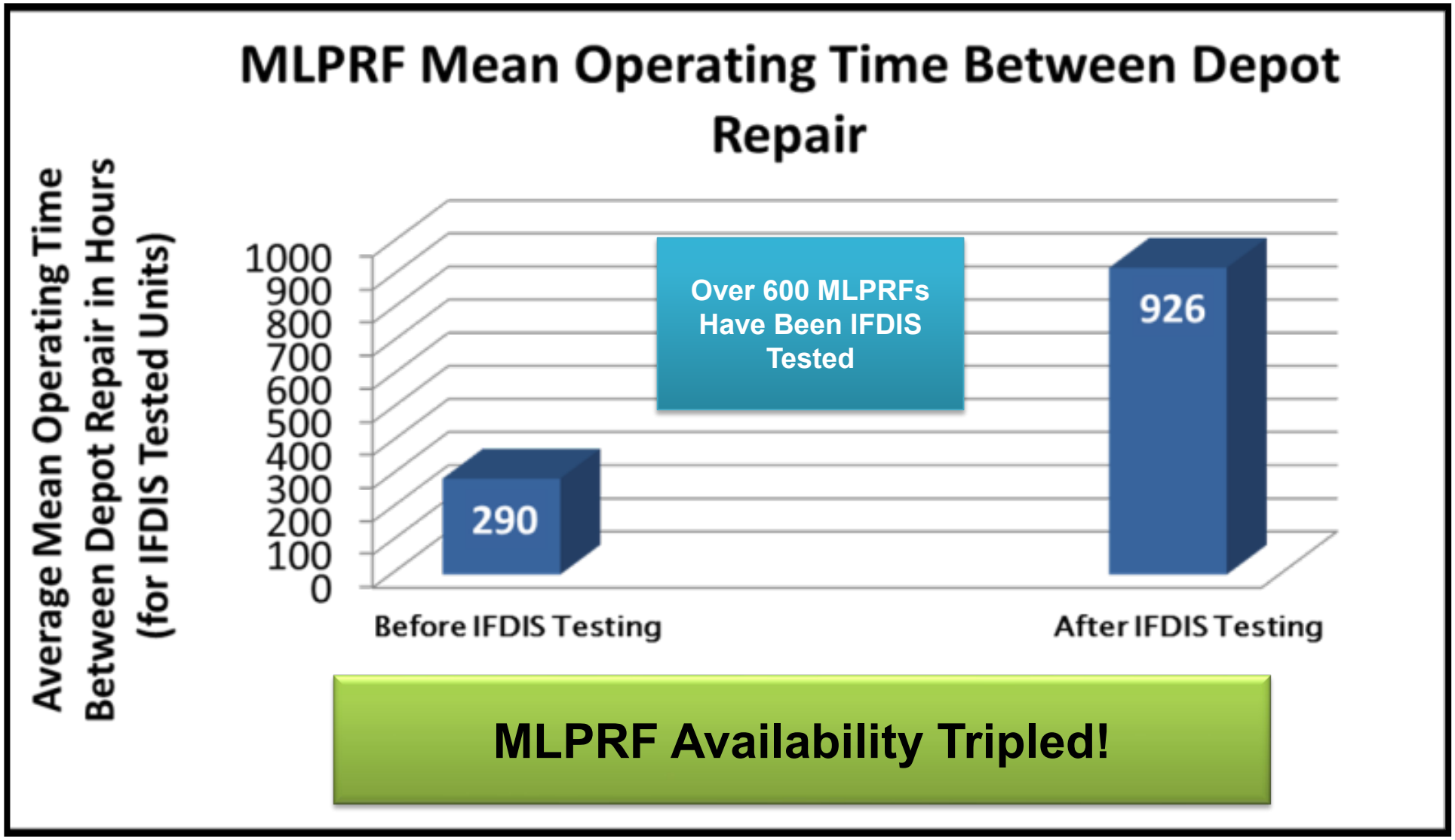
- **Oscilloscopes** can be set up to have a latching trigger and defined trigger parameters to detect and latch a particular condition. Generally, they do not have a self-stimulus and so this needs to be provided as a 3rd party aspect of the test when using an oscilloscope in this mode. Importantly, setting up the triggers and releasing the latching trigger in time for capturing subsequent fault(s) is an extremely complex technique and it would only be applicable for a single line-at-a-time. These approaches could be used on I or D-level applications, but it would be extremely time consuming to apply to each of the suspect lines during fault investigations.

Universal Synaptics

F-16 MLPRF RESULTS



F-16 MLPRF RESULTS



F/A-18 GCU: Overview

- NAVAIR F/A-18 Generator Converter Unit (GCU) is a Top Ten Fleet Degrader & number 1 cannibalized WRA at O-Level
- GCU Inductions have outpaced production for the last three years
- GCU inventory continues to increase due to aircraft production yet time on wing continues to decrease causing more GCU inductions each year
- BCM & I-Level AVDLR costs were $161.22M in FY14
- GCU G4 upgrade in process as well as multiple SRA modifications / upgrades
- An innovative solution was needed to improve time on wing, reduce BCM & AVDLR costs, reduce A-799 (NFF) and enable cost effective readiness – the solution now exists

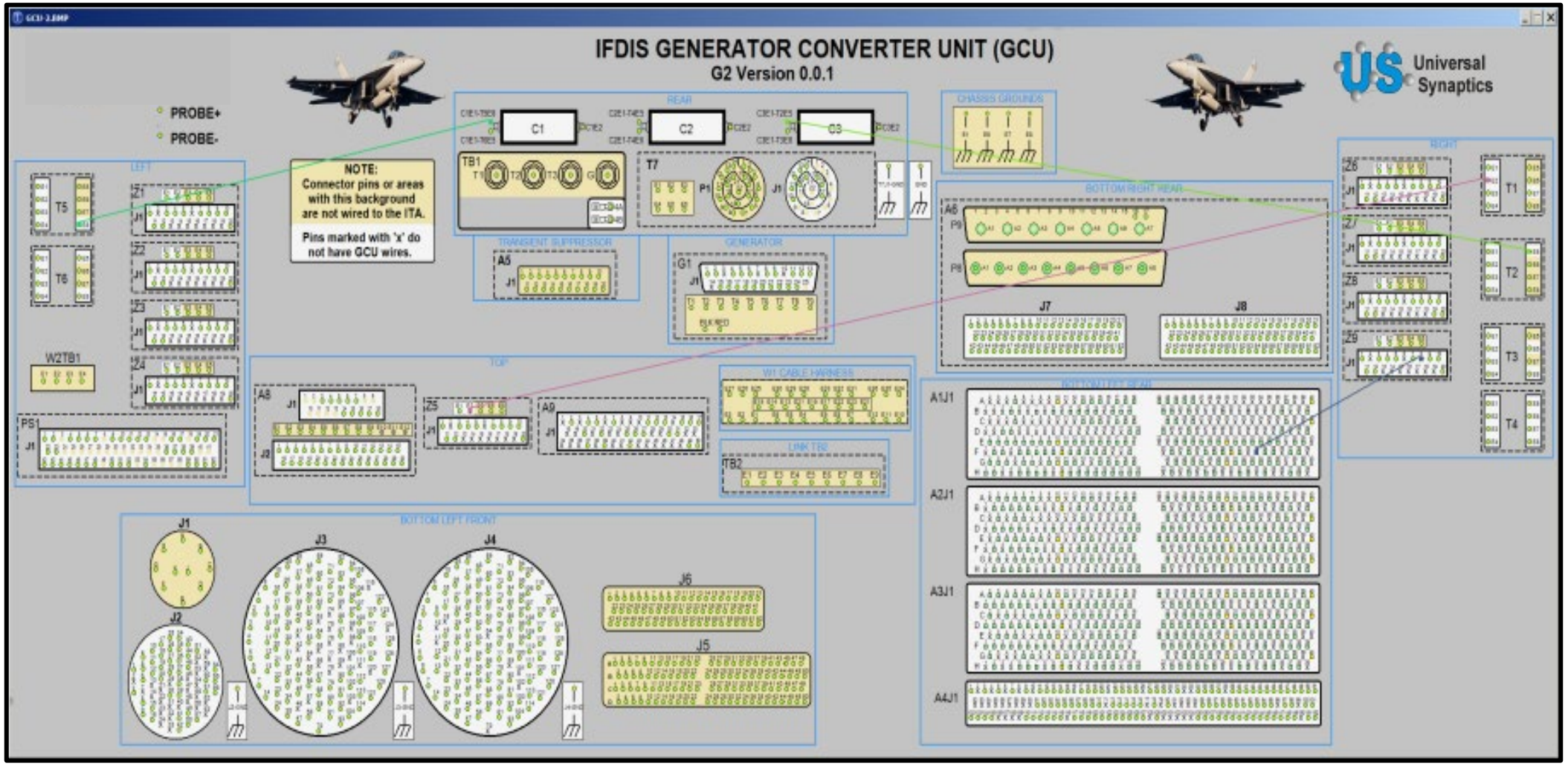
F/A-18 GCU IFDIS Delivered to FRC SW in January 2016

F/A-18 GCU: IFDIS Results

IFDIS testing identified chassis intermittent failures in the F/A-18 GCUs

GCU	IFDIS Testing Results & Causes for Intermittent Failures
1	Broken wire Z7-5
2	Motherboard ground wire damaged which caused massive open circuits
3	*No intermittence detected*
4	*No intermittence detected*
5	Broken wire J5-C3
6	No intermittence detected
7	Broken wire: A8H1-19; Motherboard: Intermittent circuits between J3-127, J5-B4, & J4-28
8	*No intermittence detected*
9	Broken wire: J5-D42
10	Broken wires: Z7-20, J5-All, & A5-A13
11	Broken wire: PS1-39
12	Broken wiresA8J1-19, T7J1-14, & T7J1-20
13	Broken wires: Z2-20, PS1-42, & four open circuits; motherboard: several intermittent and one open circuit, damaged, new motherboard required
14	Recorded 617 open circuits due to missing screws at the circuit board receptacle mounting plate; motherboard damaged, new motherboard required
15	Broken wire: J6-21; bad solder joint J5-D6
16	*No intermittence detected*

F/A-18 GCU: Fault Isolation Graphic



F/A-18 GCU: IFDIS Results

- F/A-18 GCU: IFDIS Results to date:

"Collaboration, innovation and forward thinking were key words used to describe the amazing work taking place across the FRC landscape in support of the Naval Aviation Enterprise Vision.

At FRC West, Sailors teamed with artisans to interdict repairs for Generator Control Units—or GCU—using the Intermittent Fault Detection and Isolation System. This resulted in the GCU time on wing to more than double, providing what was a top ten degrader asset, to be readily available for longer periods of time in support of flight operations."

Rear Adm Zarkowski
Commander FRCs
USN
"Holiday Message to the Fleet December 2016"

F/A-18 GCU Wiring Harness Reclamation

- Location: Fleet Readiness Center Southwest (FRCSW) Coronado, CA
- Date: June 2020
- LRU/WRA: Generator Converter Unit (GCU)
- Details:
  - F/A-18 Hornet WRA
  - GCU powers aircraft electrical systems
  - Two GCUs per aircraft
  - Four different versions of the GCU (G1, G2, G3, G4)

- FRCSW has owned and operated an IFDIS for over 6 years testing G1, G2, G3, as well as G3 upgrades to G4
- GCU on MICAP list for G2/G3 Main Chassis Wire Harness – harness is on backorder from OEM
- Team at FRCSW utilized IFDIS and tested 19 harnesses from the GCU shop that were considered unrepairable
- Leveraged AI in AutoMap™
- 17 of 19 harnesses were repaired, and then retested on IFDIS to confirm intermittent free
- Cost of each harness: $16,000 = total of $272,000 of flight hardware IFDIS returned to service in 30 days
- 17 serviceable GCU Main Wiring Harnesses were returned to GCU shop and installed on GCUs

CH-47 Chinook Results

CH-47 Chinook Wiring Harnesses

- High NFF rates, costly to support and sustain
- Conventional ONE circuit at a time wire testers unable to identify and isolate intermittent wiring problems, reduce NFF or improve readiness
- PIFD is detecting and isolating intermittent wiring issues that cause NFF and drive high sustainment costs
- 75% reduction in test time achieved with PIFD