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Intermittent Fault Detection

The Wright Brothers of No Fault Found

No Fault Found (NFF) Problem

Testing aircraft electronics result in NFF approx. 50% of the time

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

NFF responsible for 383,000 non-available days of end-item system

(Source: Dr. Vic Ramdass, DASD, Mat. Readiness 2022 memo: "Addressing Electronics Intermittence Across DoD's Sustainment Enterprise")

- Conventional test systems are not reducing the costs attributed to NFF
- Articulates magnitude of NFF problem / OSD's position on need for Intermittent Fault Detection capabilities
- Undetected and hence unrepaired intermittent defects are a readiness degrader and Mx cost driver

NFF is annual $5.5B non-value-added expense to DoD

(Source: GAO 20-116 . . . DOD Can Benefit from Further Sharing of Best Practices and Lessons Learned)

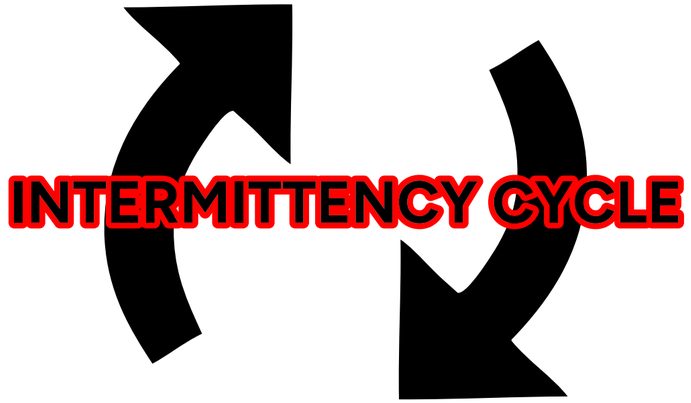
- 47% of DoD electronic maintenance expenditures provide no warfighter value
- U.S. DoD operates 13,300+ Aircraft, 484 Ships, 368,000 Ground Combat Vehicles
- Worldwide Commercial Aviation Fleet is 28,600+ Aircraft ($250k per aircraft per year)

INTERMITTENT FAULTS ARE CONCLUSIVELY LINKED AS THE PRIME DRIVER OF NFF TEST RESULTS

No Fault Found (NFF) Problem

In-Flight Failure

Return to Service
or Disposal if NFF 3x



Ground Test

NFF

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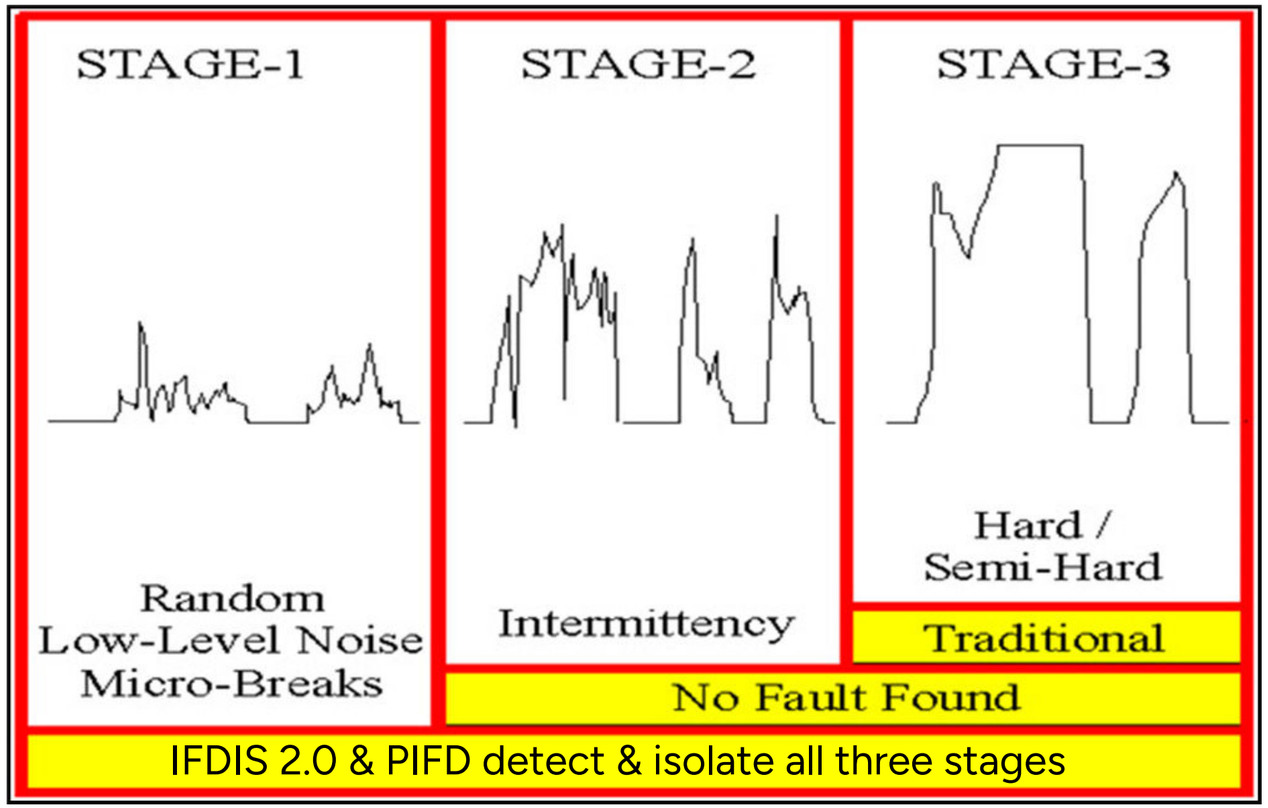
Intermittent Faults



Stage 1

- Random low-level nanosecond micro-breaks
- Likely not yet operationally evident
- Faults are on the early curve of degradation
- Becomes exacerbated over time based on Op Tempo & conditions
- Will graduate to Stage 2

Stage 2

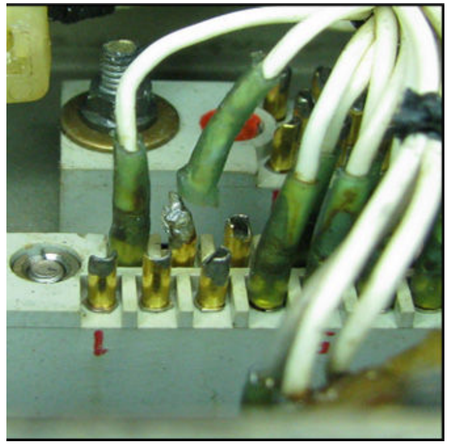
- Fails intermittently in operation
- Passes ground tests and labeled NFF
- In-flight failures are evident to the pilot
- Reported to the ground crew as:
  - "Radar lost lock"
  - "Heads up Display (HUD) blanked or blinked out"
  - "Gun Controls didn't work"
- Will eventually become Stage 3

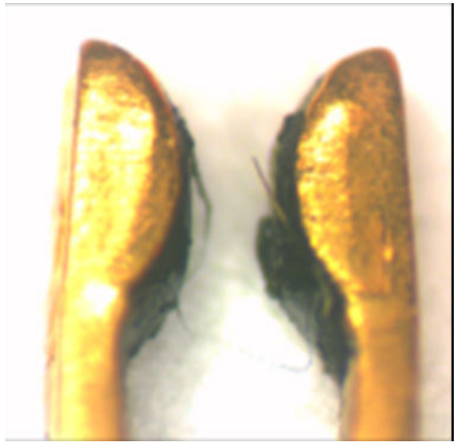
Stage 3

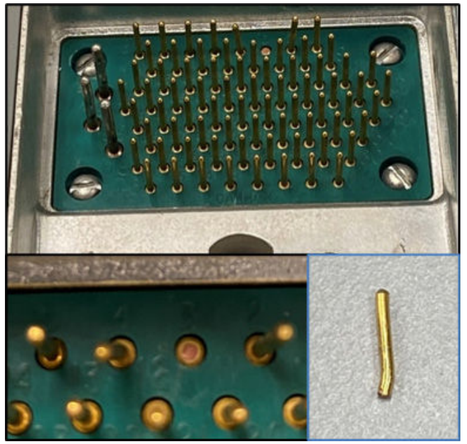
- Semi-hard or hard failures
- All the currently fielded Automatic Test Systems (ATE) are designed to detect hard faults (open circuits or shorted circuits)
- DoD currently maintains $50B worth of ATE all designed to detect hard failures
- "Conventional" ATE was not designed to detect and incapable of detecting momentary faults that cause NFF

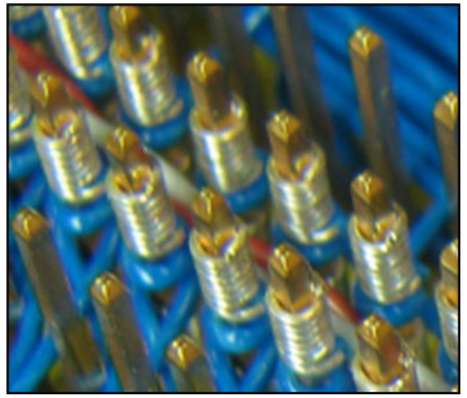
Intermittent Fault Root Causes

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









PHYSICAL MANIFESTATIONS, NOT ELECTRONIC COMPONENT FAILURES

No Fault Found (NFF) Operational Impact

Department of Defense 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 More Expensive / Less Responsive

- Each LRU sent to depot for non-fix, 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

No Fault Found (NFF) Mx & Supply Impact

Tools provided to maintainers are not sufficient

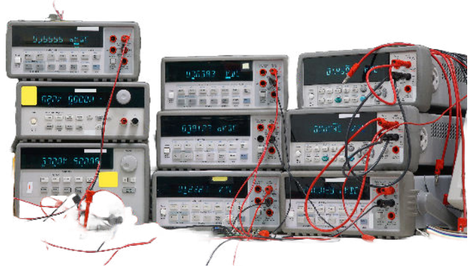
- LRU or wiring system can pass BIT or ATE tests multiple times
  - Does NOT mean intermittent problems do not exist in the system
- BIT / ATE testing does not monitor all circuits / functional paths / connections to circuit card assemblies of an LRU
- Conventional ATE does not test in an operationally 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

Conventional Wire Testing

- 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 - 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 vs. Innovative

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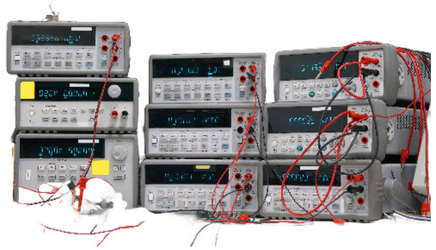

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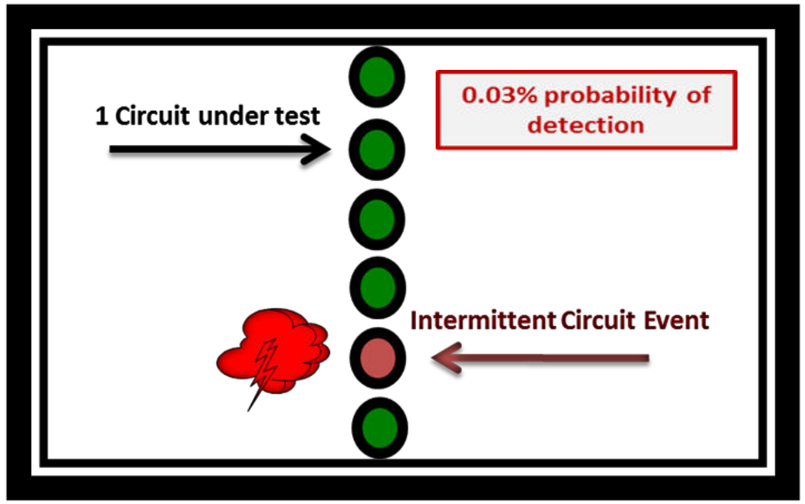
Conventional Approach = Conventional Results

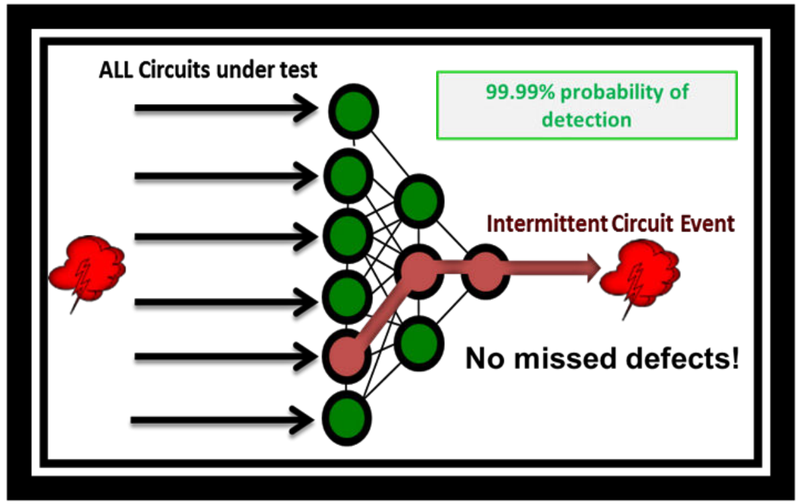
Conventional vs. Innovative

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)

Intermittent Fault Detection (IFD)



- **Deterministic Testing**
  - All circuits under test monitored at the same time
- **Makes no assumptions**
  - If a fault is present, it is detected and isolated
- **Similar to Oscilloscope on every circuit under test**
- **Test component in a simulated operational environment (3G, -20C to +70C temp range)**

UNIVERSAL SYNAPTICS CORPORATION

Solutions

Proven NFF Solutions

Universal Synaptics is the industry leader in detecting and isolating elusive intermittent faults, the prime driver of the No Fault Found (NFF), that plague aerospace, defense, and commercial industries. The massive digital testing void that exists today with scanning test equipment led to the development of the patented PIFD™, IFDIS™, and IFDIS 2.0™ Intermittent Fault Detectors. Our mission is to help our customers maximize the reliability and performance of their critical systems and equipment while significantly reducing maintenance costs.

- Fully Automated and Engineered Test Suite - Continuity, Shorts, Intermittence, Fault Isolation, Reporting
- Simultaneous & Continuous Monitoring: 50ns detection on all circuits
- AutoMap™: No Test Program Set (TPS) Development Required

Significant reduction in No Fault Found (NFF) occurrences
Cost-effective readiness

Substantial reduction or elimination of MICAPs
Reduction in repair cycle-times

Proven reduction in maintenance cost
Eased workload forecasting and forcasting

Increased operational availability
Improved maintenance processes and procedures

Proven NFF Solutions

Portable Intermittent Fault Detection (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)

- MIL-PRF 32516 Compliant
- Detects: intermittent faults, open circuits, shorted circuits, mis-wiring
- AutoMap™ (No TPS development)
- Easily expandable in 1280 test point increments
- TRL 9

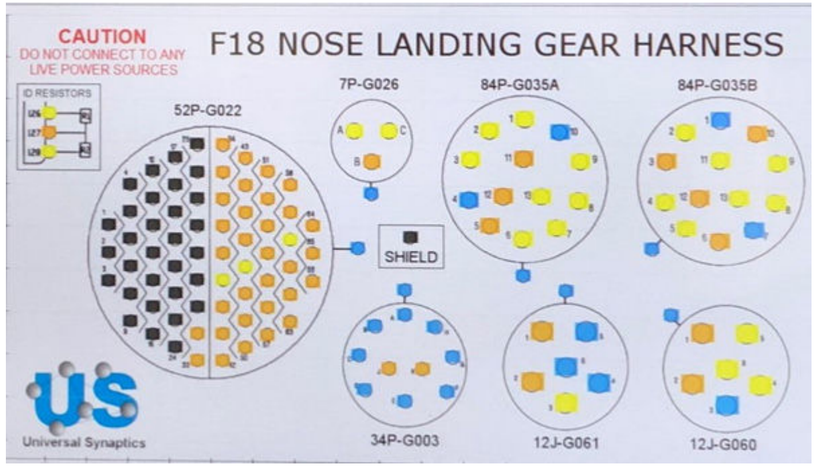
DoD Mx Symposium "Great Ideas" Competition Winner 2010 & 2012

Proven NFF Solutions

AutoMap™ - Plug & Play Test Setup

- **AutoMapTM leverages artificial intelligence algorithms to discover as-wired configuration**
  - Discovered Map “gold” wiring configuration eliminates high cost and months of software coding to develop a TPS
- **AutoMapTM teaches / shows technicians true as-wired configuration of LRU/WRA or harness**
  - Technicians learn more about system under test
- **Technician is independent, capable of QA manuals, schematics match discovered map**
- **IFD technology stores all maps for any platform, aircraft, or LRU/WRA boxes real time**

Easy-to-Use
No TPS Development



U.S. 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
- 2022 – DASD (MR) issues memo identifying Intermittent/NFF cost is $5.5B annually
- 2023 – First batch of PIFDs delivered to F-35 program
- 2024 – Intermittent Fault Detection technology included in FY24 NDAA

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

(source: GAO-20-116)

C-130 PIFD Test Results

C-130 Grounded for 11 months. Over 500 maintenace hours to replace 30+ components. NATEC unable to identify problem with AWTS.

PIFD use from the start would have provided a cost savings of $649,440.

Universal Synaptics' Portable Intermittent Fault Detection (PIFD) test set was installed and up and running within 10 minutes.

Aircraft was Partial Mission Capable for 75 days and Non-Mission Capable for 105 days totaling $19,950,000 - $29,400,000.

Identification and replacement of recessed intermittent connector pin and bent loose pin within 30 minutes.

Within two hours, Continuity, Shorts, and Intermittence testing, repairs, and verification of previous repairs accomplished.

PIFD use from start could have prevented unneccesary man-hours, days of NATEC on site, removing aircraft from detachment, and months of aircraft non-availability since early 2023.

F-35 PIFD Test Results

F-35 Stick and Throttle assemblies are Top 10 NFF Degraders across the Global Program.

Universal Synaptics' Portable Intermittent Fault Detection (PIFD) test set was installed and up and running within **10 minutes.**

100% of F-35 Sticks had one or more intermittent faults.

50% of F-35 Throttles had one or more intermittent faults.

OEM and USG Depot had verified these assets as RFI using conventional test equipment.

PIFD use from the start would have ensured intermittent-free assets before failing in operation.

F-35 Survivability and Lethality requires intermittent-free, operational Stick and Throttle Assemblies

To ensure the F-35 program stays on schedule and within budget, intermittent-free components and systems are required to drive readiness and availability.

F/A-18 IFDIS Test Results

FRCSW established an F/A-18 Generator Converter Unit (GCU) A-D Overhaul and Repair Local Engineering Specification (LES) requiring chassis to be tested on IFDIS

GCU IFDIS testing has expanded and is currently conducted for the fleet at FRCSW, NAS Lemoore, and NAS Oceana

Entire GCU population has experienced a 500% WRA Operational Improvement with a 67% Reduction in Functional ATE test time

FRCSW Depot reduced F/A-18 GCU repair time from 90 days to 30 days.

IFDIS testing has resulted in intermittent fault detection, isolation, and repair of previously undetectable faults, while increasing MLPRF Mean Time Between Depot Repair to 926 hours and growing.

Using IFDIS, the Mean Time Between Failures for GCUs has increased from 104 flight hours to over 400 flight hours..

F-16 IFDIS Test Results

Before IFDIS testing, 138 MLPRF chassis were deemed unrepairable - valued at $307,000 each.

IFDIS testing recovered 138 MLPRF out-of-service assets, equalling $42,000,000 recovered... and counting.

Before IFDIS testing, $45,000,000 worth of MLPRF assets were out of service.

IFDIS testing has resulted in intermittent fault detection, isolation, and repair of previously undetectable faults, while increasing MLPRF Mean Time Between Depot Repair to 926 hours and growing.

MLPRF Mean Time Between Depot Repair due to undectable intermittent faults was 290 hours and declining.

MLPRF was the top degrader across the USAF list and was #1 on the MICAP list for over a decade. IFDIS testing has removed the MLRPE from the MICAP list.

IFDIS & PIFD Defense Implementation

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 (WRAFB)

- EWIS

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 - Rotor Blade De-Ice cable wiring

CH-47

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

M1-A1 - Turret Slip Rings & wiring harnesses

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

Army LEMC - 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, Nationally Stock Listed, F-35 ATO, and Boeing AMM

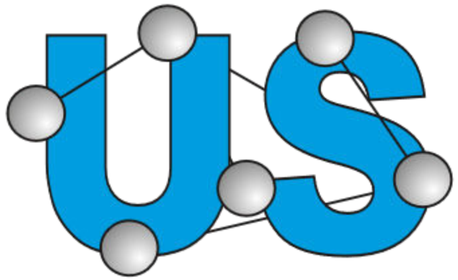
- Intermittent fault detection and isolation capability has proven to reduce NFF, reduce life cycle costs, reduce repair cycle times, improve Time on Wing (TOW), and improve operational readiness

- IFDIS 2.0™ & PIFD™ are objectively proven solutions making a positive impact today and can be utilized on any platform

Questions

Universal Synaptics

Backup



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.

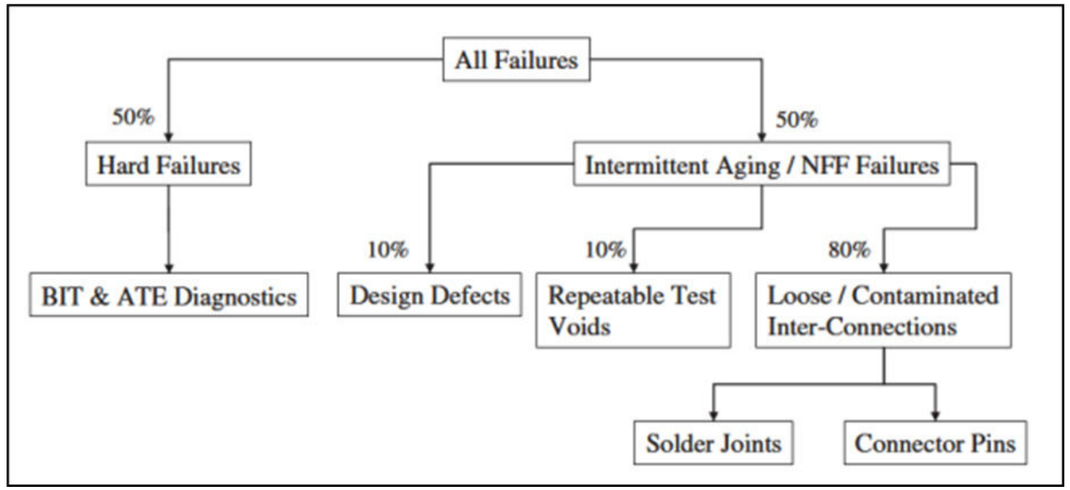


Figure Source:
B. Sorensen, "Digital-Averaging-The-Smoking-Gun-Behind-No-Fault-Found", http://www.aviationtoday.com/asw/categories/commercial/Digital-Averaging-The-Smoking-Gun-Behind-No-Fault-Found_2120.html, Air Safety Week, February 24, 2003.

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”

Conventional Testers

Hi-Pot

- 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

- 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.

Conventional Testers

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.

Market Segments

No other Technology Meets MIL-PRF-32516

Eclypse AWTS

Scanning, traditional, contuinity tester that was deployed by the DoD several years ago. Has not made a dent in the DoD NFF annual waste of $5.5 billion. Exacerbates the waste due to misrepresentation in the market that they can detect and isolate intermittent faults with 1970s technology called 4-wire Kelvin repackaged as Certified Test Protocol (CTP). This is the incumbant technology for the DoD that is the same, run-of-mill scanning technology that hasn't moved the needle with the readiness issues in the U.S. DoD. Very similar technology to the DIT-MCO tester.

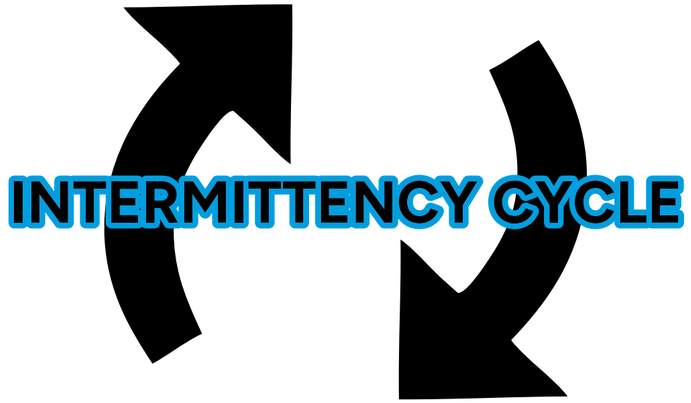
Common Digital Multimeter (DMM), Time Domain Reflectometry (TDR), Oscilliscope, Functional Bench Testers / Sell-Off Testers

Good tools that serve their design function, but lack in one or both of the two main key requirements to detect and isolate intermittent faults - probability and sensitivity.

No Fault Found (NFF) Solution

Stays in Service

Return to Service



IFD Test

Detect & Isolate ALL Intermittent Faults

$ ↓ Readiness ↑