Universal Synaptics

Intermittent Fault Detection & Isolation System™ (IFDIS™)
And
Voyager Intermittent Fault Detector™ (VIFD™)
Summary of Field Usage
Summary of Field Usage, Test and Demonstration Results

**CASE STUDY 1: F/A-18 Generator Convertor Unit (GCU) Weapon Replaceable Assembly**

**Problem:**
- Top Ten Degrader, one of the poorest performing WRAs on the F/A-18
- High A-799 "No Fault Found (NFF)" rate
- BCM & I-Level AVDLR costs were $161.22M in FY14
- Most cannibalized WRA at O-Level
- No means or equipment to detect intermittence or reduce NFF

**Results from IFDIS testing:**
- Intermittent Fault Detection & Isolation System™ (IFDIS™) delivered to Fleet Readiness Center Southwest (FRC SW) in January 2016.
- 27 GCUs have been IFDIS tested
- 21 GCUs failed IFDIS testing (over 74% failed)
- 6 GCUs passed IFDIS testing
- 64% reduction in AECTS (sell-off test) test time
- 400% Time on Wing (TOW) improvement
CASE STUDY 2: F-16 AN/APG-68 Radar System MLPRF LRU

Problem:
- One of the poorest performing LRUs on the F-16
- Had many cracked ribbon cable solder joints
- Massive re-soldering program was implemented
- No means or equipment to detect intermittence

Results from IFDIS testing:
- 403 MLPRF LRU chassis IFDIS tested (as of 31 Aug 2013)
- 138 had been considered "un-repairable" and were completely out of service
- 34 had been in the repair depot for over one year
- 11 had been in the repair depot for over three years
- 60% had one or more intermittent faults

All of these defects had been missed by conventional depot Automated Test Equipment

Cost of a replacement MLPRF LRU chassis is $307,000 each
- Over $42 million worth of flight hardware has been recovered and counting
- Mean Time Between Depot Repairs (MTBDR) has increased from 290 hours (before IFDIS testing) to 926 hours and growing (after IFDIS testing) this increase in operational availability has produced an additional cost saving of $20 million dollars
- $62 million Return on Investment (ROI) achieved on one LRU chassis P/N on one aircraft platform
- Total Government investment of $2.2 million, produced over 28 times ROI (and growing) since deployment of initial IFDIS capability in February 2009
- AFSC/FZC “Total cost avoided over 10 years: $156M”
Figure 1: Performance Improvements
Sample of “Before” and “After” IFDIS tested MLPRFs by Serial Number

<table>
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<tr>
<th>Serial Number</th>
<th>Average Hours Between Depot Repair</th>
<th>IFDIS Test Date</th>
<th>After IFDIS Testing</th>
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Average number of MLPRF depot inductions before IFDIS testing was 54.9 per month; Average number of MLPRF depot inductions after IFDIS testing is 17 – a reduction of 69%.

Figure 2: MLPRF Depot Inductions
Figure 3: Intermittent Fault Root Causes
Breakdown of MLPRF intermittent circuit root causes detected and isolated by the IFDIS

Figure 4: Operating Time Improvement
MLPRF Operating Time has \textit{tripled} as a Direct Result of IFDIS Testing.
Figure 5: Return On Investment
CASE STUDY 3: F-16 AN/APG-68 Radar System PSP LRU

Problem:

✓ Top Ten Degrader LRUs on the F-16
✓ At or near the top of the MICAP list
✓ 54% No Fault Found (NFF) rate
✓ Complex LRU with over 8000 chassis backplane interconnections
✓ USAF depot and OEM unable to improve availability or reduce NFF rate
✓ No means or equipment to detect intermittence

Results from IFDIS testing:

✓ 8,448 test point IFDIS™ delivered to Hill AFB in January 2015 - contract value $7.1M
✓ 24 PSP LRU chassis slated for condemnation IFDIS tested (as of 15 June 2015)
✓ All 24 PSP LRU chassis have been recovered, 23 of the 24 had intermittent faults that went undetected using conventional test methods by the USAF depot and OEM
✓ In six months the PSP IFDIS has produced an $8M return paying for itself plus a net positive of $1M in six months
✓ All PSPs IFDIS tested to date have had one or more intermittent circuit faults (100%)
✓ Anticipated return on investment of $35M within three years
Problem:
- High No Fault Found (NFF) rate
- High Mission Incapable (MICAP) rate
- No means or equipment capable of detecting intermittent / NFF

Results from Intermittent Fault Detection & Isolation System Testing:
- 71% of the AIC-45s IFDIS tested had one or more intermittent circuits that went undetected using conventional ATE

Intermittency was also detected and isolated in the front-panel cannon plug connectors due to only seating the connector approximately seven “clicks”. This critical information was reported to Fleet Readiness Center South East (FRC SE) personnel, who informed Universal Synaptics that many NFF / CND issues were due to the front-cannon plug connectors. FRC SE informed the EA-6B community that full non-intermittent seating of the front-panel cannon plug connectors would require 10 “clicks” when installed on the aircraft. Without IFDIS testing this long standing intermittent installation problem would still exist.
CASE STUDY 5: F-16 AN/APG-68 Radar System Az/El Ribbon Cable

Problem:
- Grounding F-16s
- Current testing methods and equipment unable to identify defects
- Non-reparable item
- Purchase price $1,600.00 each
- IFDIS testing required for GO / NO GO determination

Results from IFDIS testing:
- 95 AZ/EL ribbon cables IFDIS tested
- 76% tested bad and were discarded
- 24% tested good and were reused
- IFDIS is effectively identifying good and bad cables so that good cables are not unnecessarily discarded, and bad cables are not installed on the F-16 aircraft.
- IFDIS testing of AZ/EL ribbon cables saved the U.S. Air Force over $35,000.00 in just six weeks
The Tornado Multi-Role Combat aircraft has been the RAF principal strike weapon system for over three decades. It is a variable geometry, two-seat, day or night, all-weather attack aircraft capable of delivering a wide variety of weapons.

**Problem**

This project focused on an individual trainer variant (a GR4T aircraft) which had experienced an intermittent fault in the Secondary Power System’s Cross-Drive Clutch (CDC) for over 5 years.

The CDC should engage when selected by the pilot or when a mismatch occurs between both engines’ RPM; however, this aircraft’s CDC was engaging in flight without any of these conditions being present.

Since 2006 the problem had directly caused the abort of over 30 sorties and incurred the speculative replacement of over 30 components and the consumption of over 500 maintenance man hours at O-Level maintenance alone.

**Solution**

An analysis of the fault-maintenance history was conducted, along with an intermittent fault diagnosis of the system. As most of the system LRUs had already been replaced it was determined that the condition of the CDC wiring should be tested. The system’s wiring integrity was tested with a portable Voyager Intermittent Fault Detector™ (VIFD™) (illustrated below) and this found that 12% of the cables tested had intermittency/noise/continuity issues.
Result

The faulty cables were repaired by the RAF and then the CDC wiring was re-tested with the VIFD, which confirmed that the system’s wiring integrity had been fully restored. VIFD testing has directly enabled the RAF to eliminate all the CDC LRUs and the system from the fault diagnosis, and so additional external influences were investigated. The next system layer outside the CDC was the Circuit Breakers (CBs) and engine ground running of the aircraft indicated one of the CBs may be a causal factor. The CB was immediately tested by the VIFD and confirmed as being intermittent and unstable. Replacement of the CB immediately rectified the fault.
The intermittent fault analysis VIFD testing conducted vastly accelerated the timeframe for isolating the fault, hence a ‘No Fault Found‘ which had persisted for five years was ultimately resolved by just a few days’ worth of Voyager Intermittent Fault Detector (VIFD) testing.
**CASE STUDY 7: UK RAF Chinook Mk 2/4**

**Problem**

Voyager Intermittent Fault Detector™ (VIFD™) testing has been contracted by the UK MOD for 2 testing problems.

- Project 1: To support the technical investigation of a safety incident involving a mission-critical system
- Project 2: To test wiring integrity of an airworthiness-critical system to evaluate the implications for fleet operational availability and reliability

**Solution**

For the Project 1 safety investigation the VIFD was used to test the wiring, switch panels and Circuit Breakers (CBs) of the affected system. The switch panels and CBs were tested off-aircraft in a test bay – testing took two days to complete. The system’s installed wiring was tested on-aircraft in the O-Level maintenance hangar - testing took one day to complete.

For Project 2, VIFD testing of the system’s installed wiring and CBs was tested on-aircraft in the O-Level maintenance hangar – this covered approximately 450 test points and on-aircraft testing took two days to complete.

**Results**

For Project 1 the VIFD detected that the system’s main switch panel’s connecting wiring harness was affected by electro-magnetic interference (EMI), which had major implications for
safe operation of the system. This resulted in the OEM introducing a fleet-wide modification to revise the shielding of the wiring harness concerned. In addition VIFD testing rapidly identified intermittent system CBs which, again, had major implications for safe operation of the system.

Project 2 testing is ongoing, to test the specific system’s wiring on an aircraft with a known ‘good’ reliability history and a known ‘bad’ aircraft. Testing of the ‘good’ aircraft found a number of intermittent faults which the RAF is in the process of rectifying. The ‘bad’ reliability aircraft testing project is on-going.

As a consequence of both of these test projects the MOD has now issued a contract for VIFD testing of rogue serial numbers of the main computer (from the system featured in Project 2).
The main component of the Airborne Stand-Off Radar system is the Sentinel R1 aircraft – a Bombardier Global Express aircraft modified to carry mission systems from Raytheon Systems Ltd – which provides long-range, battlefield-intelligence, target-imaging and tracking radar for the RAF and the British Army and has surveillance applications in peacetime, wartime and in crisis operations. The Sentinel R1 fleet has been a significant Force Multiplier on active operations in Afghanistan, Libya and Mali hence the need to maintain the capability of its mission sensors is paramount.

Problem

A mission-critical system intermittent faults on Sentinel has affected mission success on numerous occasions and caused significant amounts of repeat repairs. System wiring harnesses, LRU wiring and RF cables and gimbal motors were the main problem areas and had caused major levels of downtime.

Results

VIFD testing for integrity testing and/or troubleshooting reasons has achieved the following on Sentinel R1:

- Detected and isolated incorrect assembly of installed harness’ connectors – as a result of the intermittency it caused - enabling the OEM to issue corrective service bulletin advice.
- Confirmed the integrity of different temporary repair methods on micro-RF cables.
- Detected and isolated intermittents and incorrect wiring installation on the modified internal wiring harness of a major LRU.
- Detected and isolated intermittent faults in gimbal motor windings, which had caused 26 days’ downtime in one 12-month period.
CASE STUDY 9: F-16 AN/APG-68 Radar System Antenna

Problem:

- High MICAP rates
- High NFF rates
- Conventional ATE unable to diagnose intermittent / NFF issues, improve operational reliability or lower MICAP rates

Results from Intermittent Fault Detection & Isolation System testing:

- IFDIS testing quickly identified electronic defects and intermittent faults in the F-16 Antenna
CASE STUDY 10: F-16 Central Air Data Computer (CADC)

Problem:

- Annual maintenance cost of the CADC is $1.3M
- $900K or 70% of the total maintenance cost is estimated to be caused by undetected intermittent connections in the LRU chassis
- CADC has a wire wrap chassis which is inherently prone to intermittent failures
- 76% of CADCs either test NFF at the depot or have no failed components, indicative of undetected intermittent faults

Results from Extensive CADC Analysis

The primary result of this project was the successful delivery to the depot at Hill AFB, Utah, a system necessary to enable the detection and isolation of CADC chassis intermittent faults, opens and short circuits. This capability to test CADCs enables the USAF to repair the root
causes of the intermittent circuit faults that create the “Bad Actor” situation for CADCs exhibiting frequent failures and NFF test results. Experience with other units that have been tested on the IFDIS and subsequently repaired has shown a tripling of their operational reliability as compared to performance before the IFDIS testing. Reduced failures reduces repair demand, which reduces demands on flight line and depot personnel and creates positive opportunities to reallocate maintenance funds to address other needed requirements.

Below are the test results of the first six CADCs tested with the new IFDIS capability by Government personnel in the Bad Actor Laboratory at Hill Air Force Base Depot.

CADCs by SN, Fault Type, and Fault Count Totals

Five of the six CADC chassis were found to have circuit problems, either open circuits, intermittent fault circuits, or both, with no chassis demonstrating short circuits. One CADC, SN 3509, had no chassis circuit problems.

%ages of Circuit Problems Found by Category in IFDIS Tested F-16 CADC Chassis

Percentages of Circuit Problems Found by Category in IFDIS Tested F-16 CADC Chassis
CASE STUDY 11: UH-60 Main Rotor Blade De-Icing Cable Wiring Harness

Problem:

- Poor performing mission critical wiring harnesses
- High No Fault Found (NFF) rate
- High MICAP and mission aborts attributed to the Main Rotor Blade De-Icing Cables
- Conventional test equipment unable to precisely detect and isolate wiring faults

Results from Voyager Intermittent Fault Detector™ (VIFD™) testing:

- Intermittent faults detected and isolated in minutes
- Provides advanced intermittent fault detection test technology to the US Army to ensure properly functioning wiring harnesses
- Pre-installation wiring integrity testing
- Post-mission validation testing
CASE STUDY 12: S-92 Radio Altimeter Wiring Harness

Problem:
- Poor performing mission critical wiring harnesses
- High No Fault Found (NFF) rate
- Conventional test equipment unable to isolate the root cause of the faults

Results from Voyager Intermittent Fault Detector™ (VIFD™) testing:
- Intermittent faults detected and isolated in minutes to the precise location
- Her Majesty’s Coast Guard now able to repair the faults discovered during VIFD testing
Case Study 13: Boeing 757 Auxiliary Power Unit / Engine Controller Unit (APU/ECU)

Problem:
- Boeing 757 Auxiliary Power Unit / Engine Controller Unit (APU/ECU) is a “bad actor” LRU
- OEM “Returned to Service” APU/ECU in Jan 2012
- High NFF and poor reliability history
- Total population of APU/ECU’s removals in the last 12 months for this commercial carrier: 112 removals

Results from Intermittent Fault Detection & Isolation System testing:
- IFDIS tested APU/ECU and found nine intermittent faults that went undetected with OEM conventional ATE. This unit had six prior removals before IFDIS testing
- IFDIS tested the APU/ECU was then installed on the aircraft
- Consecutive operational hours: over 10,000 hours and increasing