F-16 Modular Low Power Radio Frequency (MLPRF) Performance Analysis

Intermittent Fault Detection Project

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Prepared for:

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Product Support Engineering Division

Submitted by

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Executive Summary

Problem Statement

A significant problem in the aircraft maintenance community are situations where avionics Line Replaceable Units (LRU) fail while onboard an aircraft but then subsequently pass all standard bench tests when removed from the aircraft. This No Fault Found (NFF) problem costs the DoD between $2 to $10 billion dollars annually[1] and adversely impacts Air Force mission readiness. The majority of NFF issues are attributed to intermittent faults that manifest for extremely short periods (micro- or nano-seconds) and often only occur when the LRU is subjected to the extreme temperature and vibration environments of operational aircraft.

In 2009, through a Small Business Innovative Research contract, the depot at Hill AFB purchased an Intermittent Fault Detection and Isolation System (IFDIS) from the Universal Synaptics Corporation, to resolve NFF issues with the F-16 Modular Low Power Radio Frequency (MLPRF) unit.

Unlike conventional automated testing systems, IFDIS continuously monitors all electrical connections while subjecting the LRU under test to the same thermal and vibration environments the LRU experiences during normal flying operation. Despite the success of IFDIS in resolving the MLPRF NFF issues, there is isolated skepticism of IFDIS effectiveness. To date, the use of IFDIS is only at Hill AFB and not part of the standard test procedures at the Depot.

Project Objective

The objective of this effort is to confirm/refute the suitability of the IFDIS to resolve the LRU NFF problem by analyzing the MLPRF data in the Reliability and Maintainability Information System (REMIS) to determine if IFDIS has a measurable impact on MLPRF Mean Time Between Failure (MTBF).

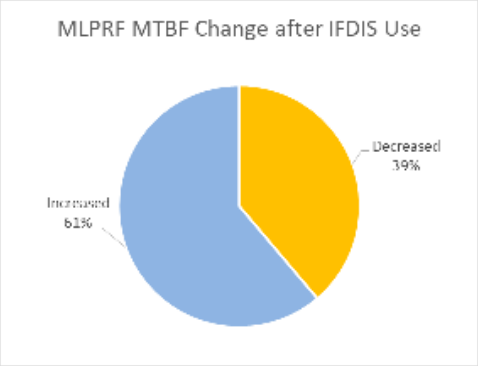

Figure 1 Change in MTBF after IFDIS Testing

[1] Giles Huby, "*US Defence Dept targets billion dollar NFF savings"*, Copernicus Technology,05 November 2015, para 3, *http://www.copernicustechnology.com/index.php/about-copernicus-technology/news/158-usdod-billion-dollar-nff-savings-target*

Results

While the data in REMIS is partially incomplete and contains some errors, there is sufficient data to perform the analysis. This report contains the reviewed maintenance histories of 67 MLPRF units; 17 of which are presented in Universal Synaptics briefings and 50 others that were randomly selected from the REMIS data.

Out of the population of 67 MLPRFs, 41 (61%) showed an improvement in MTBF after IFDIS testing while 26 (39%) did not.

In the case of the 41 MLPRFs with a positive MTBF change, the analysis showed that the average MTBF before utilizing IFDIS was 124 hours. After testing with IFDIS, the average MTBF improved to 406 hours as shown in Figure 2. The average improvement percentage is approximately 410%.

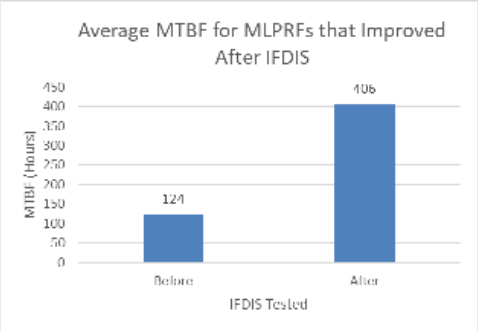

Figure 2 MTBF of MLPRFs that Improved with IFDIS

Inclusion of all 67 MLPRFs analyzed reveals that after IFDIS testing, the overall MTBF of the MLPRFs improved from 165 hours to 285 hours as shown in Figure 3. The average improvement percentage is approximately 230%.

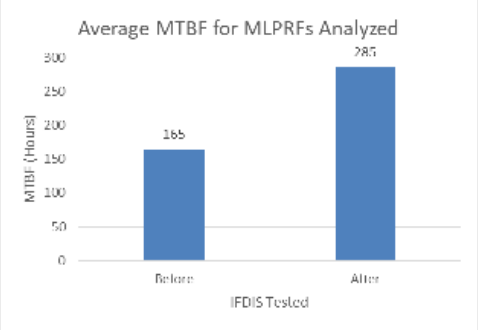

Figure 3 MTBF of All MLPRFs Analyzed

Conclusion

The use of IFDIS demonstrated a substantial positive impact on the majority of MLPRFs that it was used to diagnose and that impact was a dramatic increase in the MTBF of the MLPRF.

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1. Introduction

1.1. Project Description

The Air Force Lifecycle Management Center, Product Support Division (AFLCMC/EZP) is committed to sustainment technology insertion across the U.S. Air Force (AF) sustainment community in an effort to automate Depot operations. This particular project addresses AF's inability to accurately identify intermittent faults of aircraft Line Replaceable Units (LRUs). One sustainment technology with the ability to identify, and isolate intermittent faults is the commercially available Intermittent Fault Detection and Isolation System (IFDIS), manufactured by the Universal Synaptics Corporation. Although IFDIS is able to identify intermittent faults, the AF Enterprise has not adopted this technology at all the Air Logistics Complexes. ALFCMC/EZP is championing the effort to determine why this IFDIS technology is not used in the AF, to resolve IFDIS-related concerns, and if warranted, to implement an intermittent Fault Detection capability.

1.2. Problem Statement

The AF does not have an effective method to accurately identifying and isolate intermittent faults in LRUs. No Fault Found (NFF) due to intermittent faults is a long standing problem that plagues avionics LRU repair. Intermittent faults are frequently caused by cracked solder joints, loose crimp connections, loose wire wraps, corroded contacts, sprung connector receptacles, non-soldered/cold soldered backplane connections, etc.

1.3. Background

These LRUs frequently exhibit built in test (BIT) failures and performance degradation while in flight, however, while in a back shop or Depot environment, these units often pass all standard tests, resulting in a NFF. The impact of non-resolved intermittent faults is wasted man-hours associated with ineffective LRU troubleshooting procedures, increased aircraft maintenance cost due to frequent removal and replacement of LRUs, and the increased cost to procure and sustain greater quantities of a given LRUs in order for the for the supply chain simply to compensate for low mean time between failures (MTBF), etc. NFF is a $2B - $10B non-value added expense to the DoD each year.[2]

In an attempt to resolve an intermittent fault problem with the F-16 Modular Low Power Radio Frequency (MLPRF) LRU, in 2008 Hill AFB procured an IFDIS test platform, manufactured by the Universal Synaptics Corporation. The IFDIS system combines continuous high-resolution monitoring of every electrical path within an LRU chassis and features an environmental enclosure that heats, cools, and vibrates the LRU under test, thereby mimicking the in-flight conditions associated with manifestation of intermittent faults.

[2] Huby, "*US Defence Dept targets*", para 3

The IFDIS is not included in the standard maintenance test procedures for the Depot. That fact combined with isolated skepticism of IFDIS effectiveness has resulted in resistance to adopt this new technology.

1.4. Project Scope

In order to assess the effectiveness of IFDIS, UDRI conducted an in-depth analysis of MLPRF data from the AF Reliability and Maintainability Information System (REMIS). REMIS is the AF Maintenance enterprise system providing operational authoritative information for validating, standardizing and equipment maintenance data, including reliability and maintainability data, on a global level. REMIS is the repository of maintenance records from both the base level maintenance system, Integrated Maintenance Data System (IMDS), and the Depot maintenance system Defense Repair Information Logistics System (DRILS). UDRI examined REMIS to determine the time between failure of an LRU before testing with IFDIS and the Time Between Failure after IFDIS is used.

2. REMIS Data

2.1. Data Request

On 20 February 2018, through AFLCMC/EZP, UDRI requested all MLPRF (Work Unit Code 74AN0) data from REMIS for the F-16C and F-16D aircraft. The date range for the data covered is from January 1999 to January 2018. Over the following week, the REMIS program office delivered twenty Excel files totaling nearly 1.4 Gigabytes of relevant data.

These Excel files are comprised of 83 columns of which only the following 26 fields are of interest to this analysis:

Table 1 REMIS Data Fields of Interest

Column Name	Description
Record Type	ON/OFF Maintenance action was either on aircraft or off aircraft (back shop or Depot)
Serial Number	Aircraft Serial number
Current Operating Time	Aircraft Operating Time in hours
Job Control Number	Job Control Number
Geographic Location	Geographic Location that initiated the maintenance action
Organization	Organization that initiated the maintenance action
Discrepancy Narrative	Discrepancy Narrative
Work Unit Code	Identification code unique to a specific component. This is the component that is the cause of the maintenance action.
Type Maintenance Code	Identifies the type of work that is performed. For example B: Unscheduled Maintenance, R: Depot Maintenance, etc. Full list contained in Technical Order 00-20-2.
Action Taken Code	Action taken codes, when used in conjunction with WUCs, How Malfunction codes, and When Discovered codes, identify a complete unit of work, a maintenance task, or action. For example A: Bench Checked and

Column Name	Description
	Repaired, R: Removed and Replaced, S: Remove and Reinstall, etc. Full list contained in Technical Order 00-20-2
When Discovered Code	Indicates when a need for maintenance was discovered. For example A: Before Flight - Abort, D: In-flight - No Abort, etc. Full list contained in Technical Order 00-20-2.
How Malfunction Code	Indicates how or why a piece of equipment malfunctioned. For example 255: Incorrect Output, 799: No Defect, etc. Full list contained in Technical Order 00-20-2.
Transaction Date	Date record was created
Start Time	Work start time
Stop Time	Work stop time
Performing Geographic Location	Geographic Location that entered the maintenance record
Crew Size	Crew size
Units	Labor units
Labor Manhours	Labor man-hours
Install Equipment Designator	Part number of component being installed
Install Serial Number	Serial number of component being installed
Install CAGE Code	Commercial and Government Entity (CAGE) code identifying the supplier of the component being installed
Remove Equipment Designator	Part number of component being removed
Remove Serial Number	Serial number of component being removed
Remove CAGE Code	Commercial and Government Entity (CAGE) code identifying the supplier of the component being removed
Corrective Narrative	Narrative of the corrective maintenance action
Off Component Part Number	Part number of component being worked on
Off Component Serial Number	Serial number of component being worked on

This data was imported into an Access database for analysis and contains over 660,000 maintenance records of over 1,280 F-16 C/D aircraft.

2.2. Data Concerns

There are issues with the data contained in REMIS. This section describes some of the data issues and actions taken to eliminate, mitigate or establish work arounds.

2.2.1. Aircraft Operating Time

In order to calculate the Time Between Failure of the MLPRF, it is necessary to know both the aircraft operating hours when the MLPRF was installed on the aircraft and the aircraft operating hours when the MLPRF was removed from the aircraft. However, approximately 17% of the maintenance records did not contain valid current operating time values. This suggests that

when the maintenance record was captured, the technician failed to capture the aircraft operating hours. This problem is shown in Figure 4.

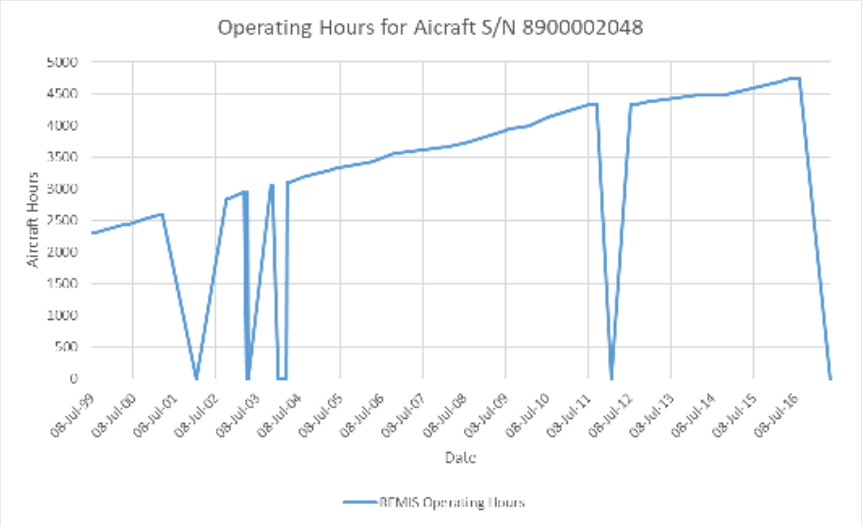


Figure 4 Aircraft Operating Hours with Missing Data

In order to compensate for the missing time data, a simple interpolation was used to calculate the missing hours based on the known good (non-zero) hours occurring before and/or after those records that contain the value zero.

The simple interpolation is shown by examining the first data gap in Figure 4. The event with the missing data is the target event, a valid data point prior to that is Event 0, and the valid data point after is Event 1. Around that data gap is the following data:

- Event 0: Date (D0) 27 Mar 01, reported aircraft hours (H0) is 2591
- Event T: Date (DT) 17 Jan 02, reported aircraft hours (HT) is 0
- Event 1: Date (D1) 11 Oct 02, reported aircraft hours (H1) is 2835

To calculate the estimated hours at Event T, we use the following formula:

$$HT = H0 + \left(\frac{H1 - H0}{D1 - D0}\right) * (DT - D0)$$

In this case, the resulting calculate hours for the aircraft on 17 Jan 02 is 2719. After the linear interpolation, the resulting operating hours for this specific aircraft is shown in Figure 5.

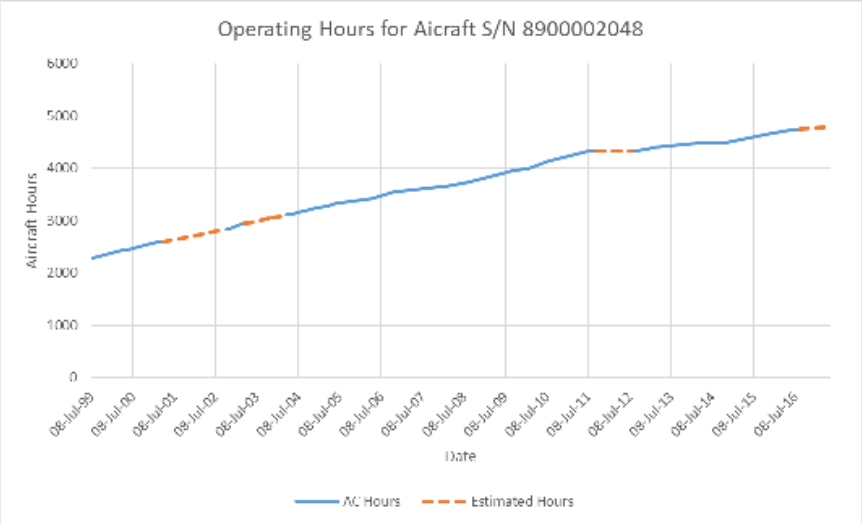


Figure 5 Aircraft Operating Hours after Interpolation

The records where the missing hours are interpolated are noted by the field “Derived” set to true and the statement “AC Hours Estimated” appended to the field “Derived_Notes”.

2.2.2. Missing Install/Removal Records

Analysis of maintenance data, specifically install and removal actions, also shows missing records. It is expected that for every removal of a specific MLPRF serial number, there should be a previous maintenance record that shows the installation of that same MLPRF serial number. In addition, if there is a job control number showing off aircraft maintenance of a MLPRF, it is expected that for that job control number, there should be a maintenance record showing the removal of the MLPRF. Where possible and where needed, a missing record is added only if there is a high degree of confidence based on analysis of related records.

For example, in Table 2, analysis of the maintenance actions related to MLPRF Serial # 11437 shows that on Job Control Number 122277253, on the 15-Aug-12 there is off aircraft maintenance but the removal action was not captured.

Table 2 Sample of Missing Removal Record for MLPRF S/N 11437

Date	Action	Aircraft #	AC Hrs	JCN	Org	Discrepancy	Corrective Action
[missing record]							
14-Aug-12	2 Install	9200003890	4570	122277253	0057 WGH WG	RADAR WOULD NOT DISPLAY ROR CONTACTS. ALL OPS WERE NORM, NO TRACKS OR CONTACTS. NO MFL OR PFL.	R2 MLPRF IAW 94-62-04
15-Aug-12	3 Maintenance			122277253	0057 WGH WG	RADAR WOULD NOT DISPLAY ROR CONTACTS. ALL OPS WERE NORM, NO TRACKS OR CONTACTS. NO MFL OR PFL.	BCFS FAILS TEST 26 PCOF 2A13 FAILS ON R/T NRTS-1

Looking at the related records and in order to capture the Time Between Failure hours, a removal record for MLPRF 11437 is inserted in the data. This is shown in Table 3.

Table 3 Generated Removal Record for MLPRF S/N 11437

Date	Action	Aircraft #	AC Hrs	JCN	Org	Discrepancy	Corrective Action
14-Aug-12	1 Removal	9200003890	4570	122277253	0057 WGH WG	RADAR WOULD NOT DISPLAY ROR CONTACTS. ALL OPS WERE NORM, NO TRACKS OR CONTACTS. NO MFL OR PFL.	** created record **
14-Aug-12	2 Install	9200003890	4570	122277253	0057 WGH WG	RADAR WOULD NOT DISPLAY ROR CONTACTS. ALL OPS WERE NORM, NO TRACKS OR CONTACTS. NO MFL OR PFL.	R2 MLPRF IAW 94-62-04
15-Aug-12	3 Maintenance			122277253	0057 WGH WG	RADAR WOULD NOT DISPLAY ROR CONTACTS. ALL OPS WERE NORM, NO TRACKS OR CONTACTS. NO MFL OR PFL.	BCFS FAILS TEST 26 PCOF 2A13 FAILS ON R/T NRTS-1

Records added for this purpose are noted by the field “Derived” set to true, the statement “Inserted missing mx action record” appended to the field “Derived_Notes”, and the phrase “** created record **” inserted for the “Corrective Action” field. If possible, the Discrepancy field data is copied from the other records.

2.3. Data Analysis Approach

To calculate the Time Between Failure, the maintenance records for removals were reviewed and categorized as removal for maintenance or removal for some other reason based on the discrepancy narrative. If the removal was for a problem specific to the MLPRF, the aircraft hours from when that MLPRF were installed are captured. If MLPRF removal was not due to an MLPRF problem, such as a cannibalization event or removal to facilitate other maintenance, the hours are accumulated.

The data for MLPRF serial number 11347 covers from 04 May 01 to 31 Aug 17. However, to show the method used to calculate Time Between Failure, Table 4 just shows the install and removal events over the dates of 13 Oct 04 to 05 Dec 05. The MLPRF was removed four times; the first for a problem after being flown for 31 hours, the second was a troubleshooting exercise after flying for 188 hours, the third was for a problem after 0 hours and the fourth was for a problem after 34 hours.

Table 4 Generated Removal Record for MLPRF S/N 10752

Date	Action	Aircraft #	AC Hours	Discrepancy	For Mx?	Hours Diff	Time Between Failure Hours
13-Oct-04	2 Install	8500001562	3944	FCF INOP MFL 275			
08-Dec-04	1 Removal	8500001562	3975	HAD TO RECYCLE FCR POWER W/ MFL'S 021, 028, 270	Yes	31	31
10-Mar-05	2 Install	9300000540	2241	338 MFL FOR FCR. MLPRF FAIL			
12-Oct-05	1 Removal	9300000540	2429	REMOVE MLPRF TO TROUBLESHOOT A3542	No	188	
12-Oct-05	2 Install	9300000542	2423	REMOVE MLPRF FOR TROUBLESHOOTING			
13-Oct-05	1 Removal	9300000542	2423	"FCR RECYCLE POWER" IN AIR RECYCLED POWER AND GOT FCR XMTR FAIL. FCR MFL'S 341, 087, 095, 088, 094 WOULD NOT CLEAR.	Yes	0	188

Date	Action	Aircraft #	AC Hours	Discrepancy	For Mx?	Hours Diff	Time Between Failure Hours
20-Oct-05	2 Install	9100000387	3078	FCR DEGR AND FREQ1 DEGR. PFLS W/ 055, 056, 057, 058, 059, 060, 061, 062, 276 MFLS. TRIED RESET INFLIGHT. RADAR UNUSABLE DUE TO NUMEROUS FALSE RETURNS.			
05-Dec-05	1 Removal	9100000387	3112	FCR WOULD SWEEP BUT NOT DETECT ANYTHING REGARDLESS OF MODE. FCR DEGRADE PFL FCR 041,046,053,056,057,059,064,065	Yes	34	34

According to the Universal Synaptics presentation, Figure 8, Page 8, this particular MLPRF went through IFDIS testing on 13 May 08. A plot of the hours flown at removal vs date for this unit is shown in Figure 6. An alternative view of the data is to present the removal for maintenance as an “event” regardless of date. Treating the IFDIS test date as event 0, post IFDIS events count up and pre IFDIS events count down as shown in Figure 7. The data shows that in the six and half years prior to IFDIS testing, MLPRF S/N: 11347 was removed for a maintenance issues seven times with an average flying time of 103 hours. In the nearly eight and half years after IFDIS testing, it has been removed twice with an average of 812 flying hours.

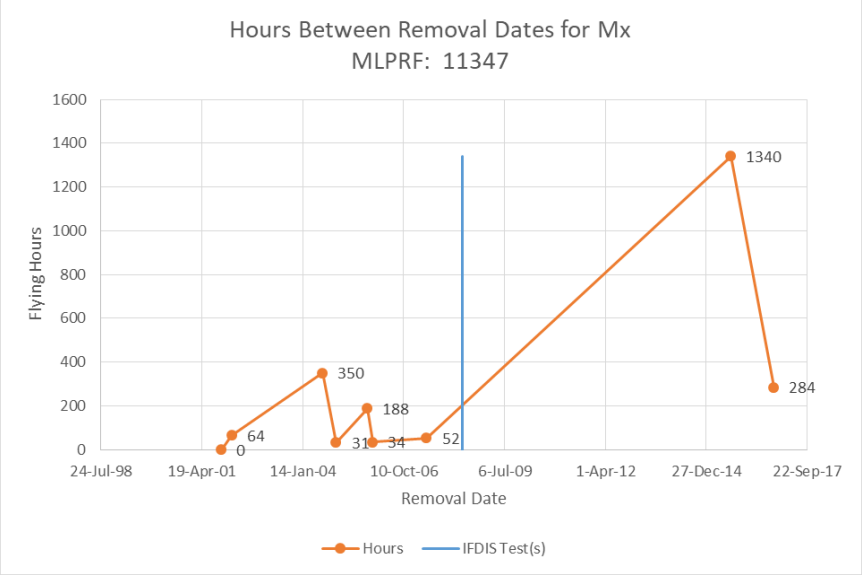


Figure 6 Hours Between Removal Dates for Mx for S/N: 11347

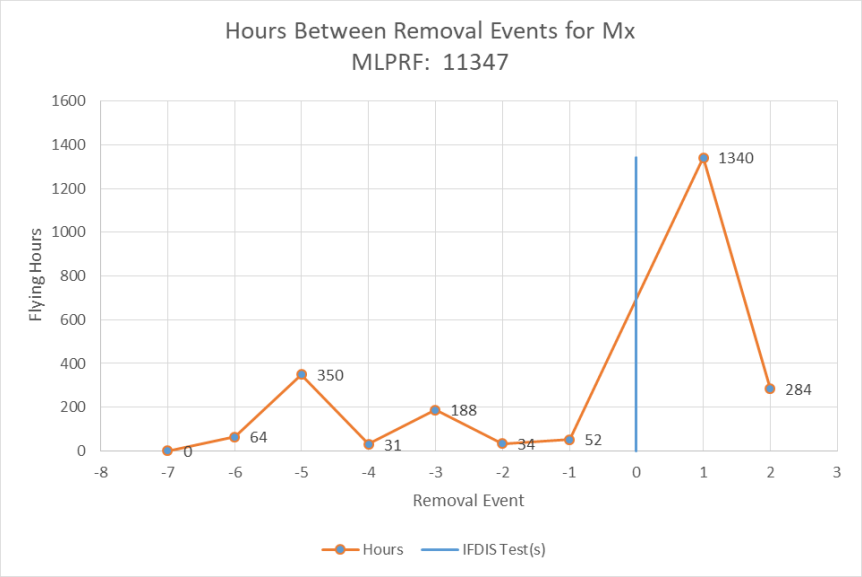


Figure 7 Hours Between Removal Events for Mx for S/N: 11347

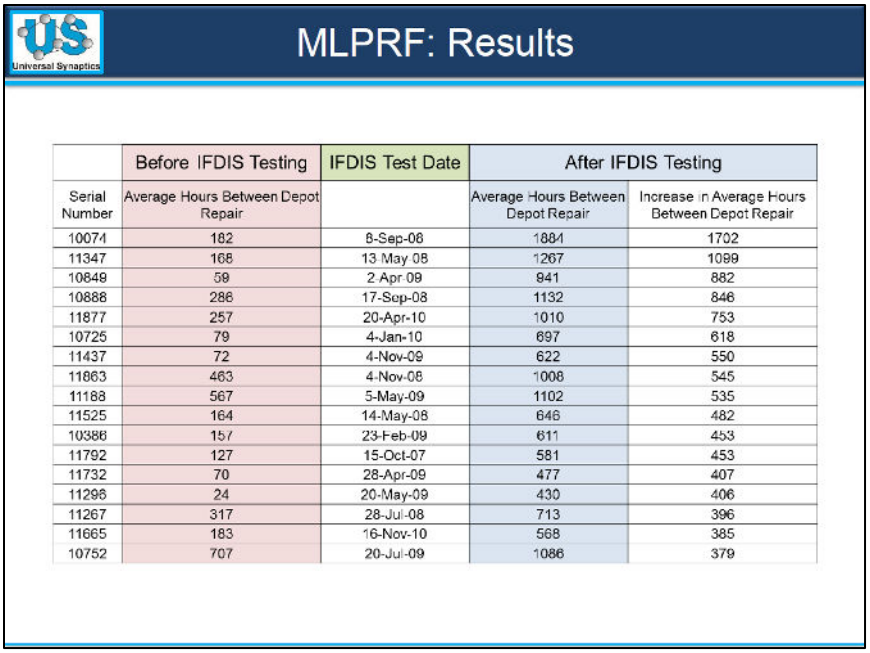
2.4. REMIS Data Validation of 13 LRUs from Universal Synaptics Study

There are over 2,500 MLPRF serial numbers in the REMIS data. Rather than examine all 2,500 records, a more rapid approach was to use the REMIS data for the MLPRF units presented in the Universal Synaptics report.

2.4.1. Universal Synaptics Presented IFDIS Performance Results

The Universal Synaptics presentation[3] is shown in Figure 8.

[3] Ken Anderson, *Intermittent Fault Detection & Isolation Reduces No Fault Found (NFF) and Enables Cost Effective Readiness*, Universal Synaptics, 12 October 2016, 22



MLPRF: Results

	Before IFDIS Testing	IFDIS Test Date	After IFDIS Testing	
Serial Number	Average Hours Between Depot Repair		Average Hours Between Depot Repair	Increase in Average Hours Between Depot Repair
10074	182	8-Sep-08	1884	1702
11347	168	13-May-08	1267	1099
10849	59	2-Apr-09	941	882
10888	286	17-Sep-08	1132	846
11877	257	20-Apr-10	1010	753
10725	79	4-Jan-10	697	618
11437	72	4-Nov-09	622	550
11863	463	4-Nov-08	1008	545
11188	567	5-May-09	1102	535
11525	164	14-May-08	646	482
10386	157	23-Feb-09	611	453
11792	127	15-Oct-07	581	453
11732	70	28-Apr-09	477	407
11298	24	20-May-09	430	406
11267	317	28-Jul-08	713	396
11665	183	16-Nov-10	568	385
10752	707	20-Jul-09	1086	379

Figure 8 Universal Synaptics MLPRF Performance Report

The source document for Figure 8 does not contain an explanation on how the hours shown were calculated. Instead of trying to validate those hours, we focused on the Time Between Failure in REMIS. Note that Time Between Failure information is sent to REMIS from IMDS and not DRILS, so the data presented is from the perspective of base maintenance.

2.4.2. Analysis of MLPRFs in Universal Synaptics Presentation

The data contained in Figure 8 is repeated in part in Table 5. Columns 1 through 4 are the same information presented in Figure 8. Columns 5 through 7 are the results of the REMIS data analysis. Column 5 is the MTBF of the MLPRF leading up to IFDIS testing. Column 6 is the MTBF of the MLPRF after IFDIS testing and column 7 is the percent change (calculated as (col6-col5)/col5). The detailed charts for these MLPRFs are in Appendix A. Note that MLPRFs that show an increase in MTBF following IFDIS testing are highlighted in light green.

Table 5 MLPRF Performance Before and After IFDIS (Universal Synaptics Brief)

Serial Number (1)	IFDIS Test Date (2)	Vendor-Reported average Hrs Before IFDIS (3)	Vendor-Reported Average Hrs After IFDIS (4)	REMIS MTBF Before IFDIS (hours) (5)	REMIS MTBF After IFDIS (hours) (6)	% Change (7)
10074	8 Sep 08	182	1,884	194	1,088	461%
10386	23 Feb 09	157	611	66	663	905%
10725	4 Jan 10	79	697	356	410	15%
10752	20 Jul 09	707	1086	699	383	-45%
10849	2 Apr 09	59	941	23	491	2,035%
10888	17 Sep 08	286	1,132	103	812	688%
11188	5 May 09	567	1,102	223	201	-10%
11267	28 Jul 08	317	713	45	132	193%
11296	20 May 09	24	460	329	200	-39%
11347	13 May 08	168	1,267	103	812	688%
11437	4 Nov 09	72	622	200	32	-84%
11525	14 May 08	164	646	190	244	28%
11668	16 Nov 10	183	568	107	1129	955%
11732	28 Apr 09	70	477	43	129	200%
11792	15 Oct 07	127	581	100	570	470%
11863	4 Nov 08	463	1,008	79	791	901%
11877	20 Apr 10	257	1,010	87	522	500%

2.4.3. Interim Conclusion

The resulting analysis shows that based on the time between failures, 13 of the 17 MLPRFS in the listed show an increase in MTBF following IFDIS testing. The average MTBF prior to IFDIS use is 115 hours and after is 600 hours. The average improvement is 618%.

Below is additional information on the four MLPRFs that exhibited a decrease in MTBF:

- S/N 11437: Minimal data - There was only one install/removal event after IFDIS testing and the last entry for this unit was August of 2012.
- S/N 11188: This unit has not returned to the Depot since 2012 and has remained at base level. Last record is an install on 18 January 2018.
- S/N 11296: This unit has returned to the Depot 3 times since IFDIS testing on 20 May 2009. Last record is an install on 22 August 2016
- S/N 10752: This unit has returned to the Depot once since IFDIS testing on 20 July 2009. Last record is an install on 1 November 2017

2.5. REMIS Data Analysis on other IFDIS-tested MLPRFs

To provide a more complete analysis, it is necessary to look at the MTBF of other IFDIS tested MLPRFs. While it is not known how many of the 2,500 MLPRFs in the REMIS data have been IFDIS tested, approximately 425 of them contain the phrase “IFDIS Tested” in the corrective action entry.

2.5.1. Analysis of Random Sample

Using randomly selected records, fifty additional MLPRFs were analyzed and the results are shown in Table 6. Note that MLPRFs that show a positive MTBF change following IFDIS testing are highlighted in light green.

Table 6 MLPRF Performance Before and After IFDIS

Serial Number	IFDIS Test Date	EMIS MTBF Before IFDIS (hours)	REMIS MTBF After IFDIS (hours)	Percent Change
10949	04-Jan-10	193	63	-67%
11592	14-Sep-11	218	65	-70%
10484	18-Nov-10	127	80	-37%
10419	12-Jun-14	188	366	95%
10435	29-Nov-07	55	380	591%
10167	07-Dec-12	162	265	64%
10166	22-Aug-11	73	58	-21%
10922	13-Sep-11	127	48	-62%
11993	04-Oct-11	166	249	50%
10165	25-Oct-11	117	154	32%
11617	04-Oct-11	114	70	-39%
10083	04-Aug-11	275	708	157%
10168	13-Sep-11	67	210	213%
11614	31-Aug-11	136	76	-44%
11316	12-Aug-11	303	223	-26%
11651	08-Jan-08	44	69	57%
10558	05-Nov-09	137	175	28%
11099	05-Aug-11	180	210	17%
11484	09-Dec-10	96	158	65%
11131	30-Apr-16	136	26	-81%
11608	23-Jun-11	110	136	24%
11078	03-Aug-09	461	51	-89%
10163	01-May-12	139	88	-37%
11083	02-Sep-10	84	154	83%
10696	26-Jan-12	90	20	-78%
11234	14-Dec-09	149	68	-54%
10311	01-Oct-08	153	223	46%
11861	27-Jan-12	219	237	8%
10439	05-Dec-11	356	201	-44%
11886	03-Aug-11	661	87	-87%
10759	20-May-14	200	255	28%
11180	07-Dec-06	127	121	-5%
10593	08-May-07	98	143	46%
11692	14-Jan-13	59	29	-51%
12042	06-Sep-11	30	26	-13%
10031	02-Feb-09	167	633	279%
11214	27-Sep-11	121	45	-63%
10216	14-Oct-09	213	404	90%
11535	03-Oct-11	29	30	3%
10553	27-Apr-16	145	14	-90%
10855	09-Apr-08	141	429	204%
10712	15-Mar-11	27	227	741%
10934	12-Apr-11	48	640	1233%
11311	24-Feb-10	41	188	359%
11567	25-Oct-11	589	136	-77%
11413	30-Jan-10	143	358	150%
10851	17-Jun-11	44	69	57%
10521	14-Jun-13	125	84	-33%
10777	13-Sep-11	368	594	61%
10611	02-Sep-10	29	1,171	3938%

2.5.2. Interim Conclusion

The results show that 28 of the 50 (56%) MLPRFs exhibited improved MTBF following IFDIS testing. The MTBF of those 28 MLPRFs increased from 129 hours to 316 hours with an average improvement of 310%.

Similarly, inclusion of all 50 MLPRFs shown in Table 6, (although less dramatic) reveals that after IFDIS testing, the overall MTBF of all fifty of the MLPRFs increased an average of 151% – average MTBF improved from 162 hours to 210 hours, indicating that IFDIS testing has significant merit.

3. Final Conclusion

Analysis of REMIS data from 1999 to 2017 shows that of the 17 specifically selected MLPRFs and the 50 randomly selected MLPRFs that 41 out of 67 (61%) showed improved MTBF. And for those MLPRFs that showed an improvement, the MTBF increased from 124 hours to 406 hours with the average increase of 409%.

It should not be surprising that IFDIS did not work for all MLPRFs. The IFDIS tests for intermittent faults in the LRU enclosure (backplane and connection points) only after the shop replaceable circuit card assemblies have been removed from the LRU. Therefore, faults due to defective circuit card assemblies are not detected by the IFDIS. Because of the likelihood of the presence of intermittent faults, it is also not surprising that the MLPRFs selected for inclusion in the Universal Synaptics show dramatic improvement in performance over the randomly selected 50 additional units. Analysis shows that the use of IFDIS does yield substantial and, likely cost-effective improvement in MTBF of the MLPRF.

Appendix A Detailed MLPRF Charts

A.1 S/N: 10074

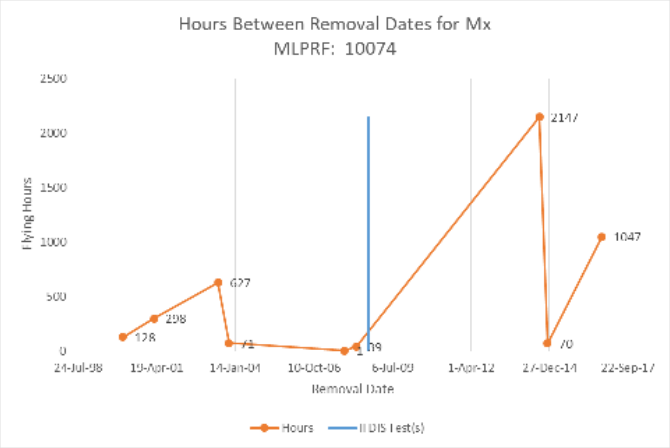


Figure 9 Hours between removal dates for MLPRF 10074

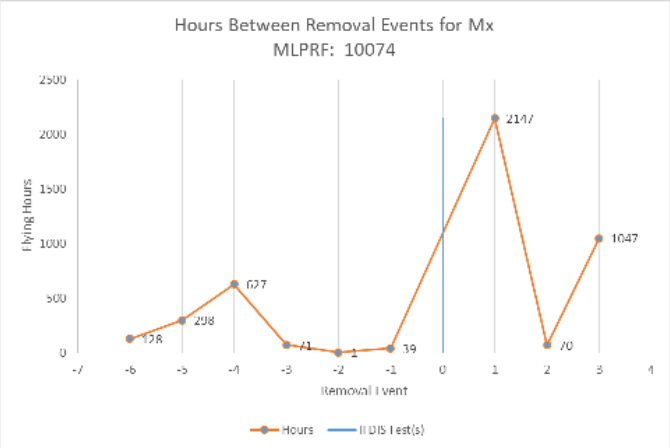


Figure 10 Hours between removal event for MLPRF 10074

Table 7 Hours between failure for MLPRF 10074

Date	Count	Hours	Avg
15-Feb-00	-6	128	
13-Mar-01	-5	298	
10-Jun-03	-4	627	
24-Oct-03	-3	71	
5-Nov-07	-2	1	
5-Apr-08	-1	39	194
8-Sep-08	0		
21-Aug-14	1	2147	
1-Dec-14	2	70	
24-Oct-16	3	1047	1088

A.2 S/N: 11347

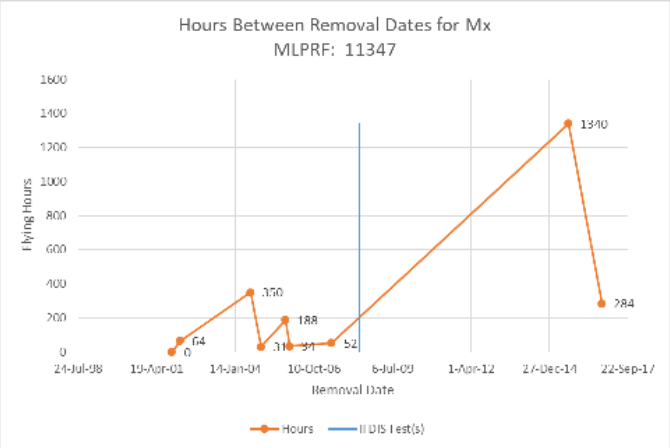


Figure 11 Hours between removal dates for MLPRF 11347

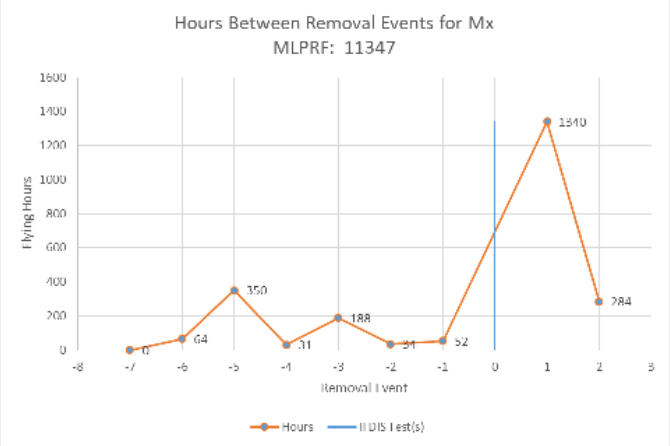


Figure 12 Hours between removal event for MLPRF 11347

Table 8 Hours between failure for MLPRF 11347

Date	Count	Hours	Avg
26-Oct-01	-7	0	
9-Feb-02	-6	64	
28-Jul-04	-5	350	
8-Dec-04	-4	31	
13-Oct-05	-3	188	
5-Dec-05	-2	34	
24-May-07	-1	52	103
13-May-08	0		
27-Aug-15	1	1340	
24-Oct-16	2	284	812

A.3 S/N: 10849

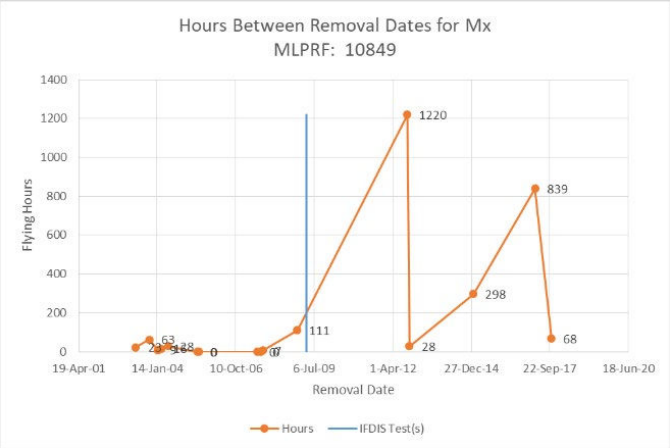


Figure 13 Hours between removal dates for MLPRF 10849

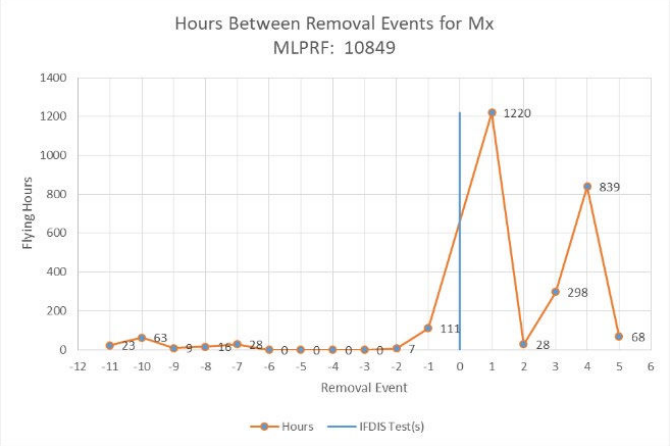


Figure 14 Hours between removal event for MLPRF 10849

Table 9 Hours between failure for MLPRF 10849

Date	Count	Hours	Avg
20-Apr-03	-11	23	
9-Oct-03	-10	63	
25-Jan-04	-9	9	
8-Mar-04	-8	16	
3-Jun-04	-7	28	
15-Jun-05	-6	0	
29-Jun-05	-5	0	
12-Jul-07	-4	0	
24-Aug-07	-3	0	
20-Sep-07	-2	7	
3-Dec-08	-1	111	23
2-Apr-09	0		
5-Oct-12	1	1220	
1-Nov-12	2	28	
25-Jan-15	3	298	
19-Mar-17	4	839	

Date	Count	Hours	Avg
13-Oct-17	5	68	491

A.4 S/N: 10888

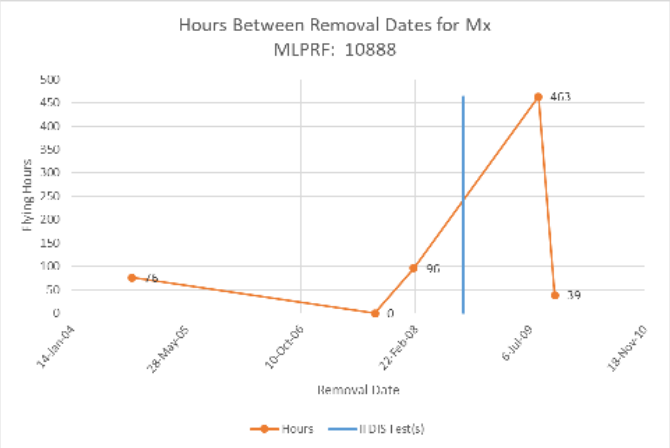


Figure 15 Hours between removal dates for MLPRF 10888

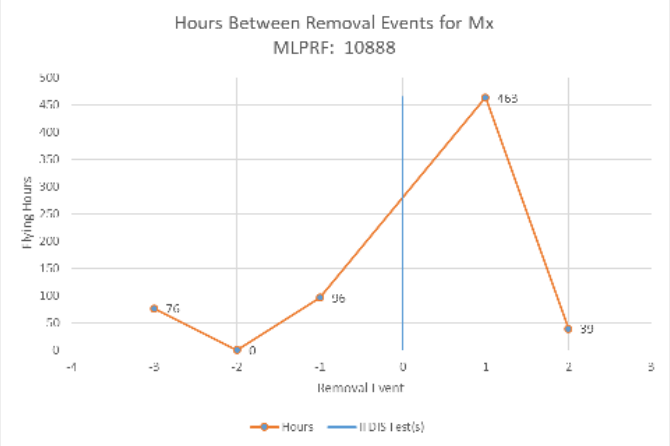


Figure 16 Hours between removal event for MLPRF 10888

Table 10 Hours between failure for MLPRF 10888

Date	Count	Hours	Avg
15-May-04	-6	131	
4-Aug-05	-5	260	
20-Sep-07	-4	11	
5-Mar-08	-3	75	
17-Jul-08	-2	44	
12-Aug-08	-1	0	87
20-Apr-10	0		
1-Dec-11	1	996	
15-Jan-14	2	472	
29-Aug-14	3	99	522

A.5 S/N: 11877

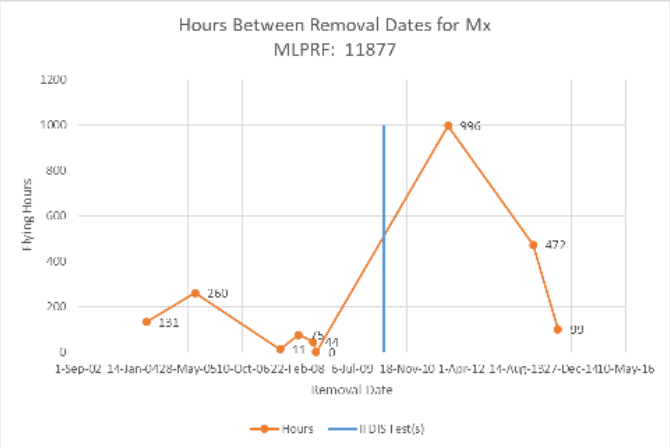


Figure 17 Hours between removal dates for MLPRF 11877

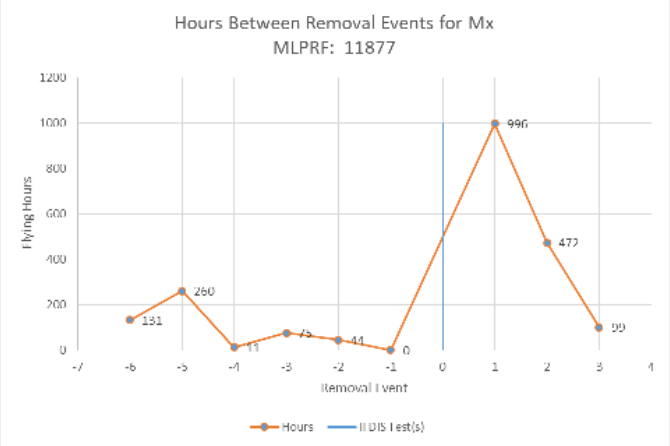


Figure 18 Hours between removal event for MLPRF 11877

Table 11 Hours between failure for MLPRF 11877

Date	Count	Hours	Avg
15-May-04	-6	131	
4-Aug-05	-5	260	
20-Sep-07	-4	11	
5-Mar-08	-3	75	
17-Jul-08	-2	44	
12-Aug-08	-1	0	87
20-Apr-10	0		
1-Dec-11	1	996	
15-Jan-14	2	472	
29-Aug-14	3	99	522

A.6 S/N: 10725

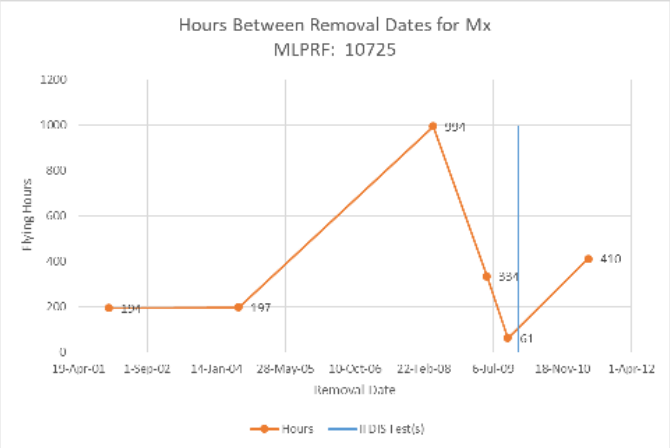


Figure 19 Hours between removal dates for MLPRF 10725

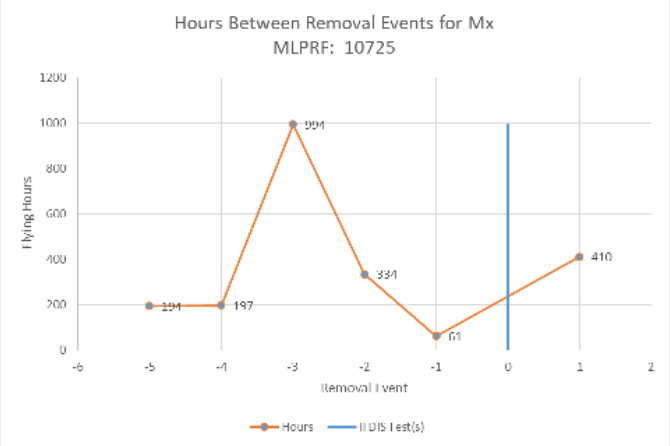


Figure 20 Hours between removal event for MLPRF 10725

Table 12 Hours between failure for MLPRF 10725

Date	Count	Hours	Avg
27-Nov-01	-5	194	
23-Jun-04	-4	197	
29-Apr-08	-3	994	
22-May-09	-2	334	
21-Oct-09	-1	61	356
4-Jan-10	0		
25-May-11	1	410	410

A.7 S/N: 11437

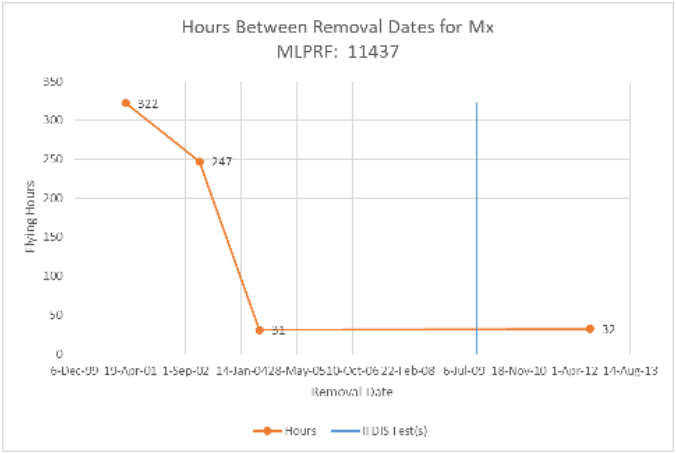


Figure 21 Hours between removal dates for MLPRF 11437

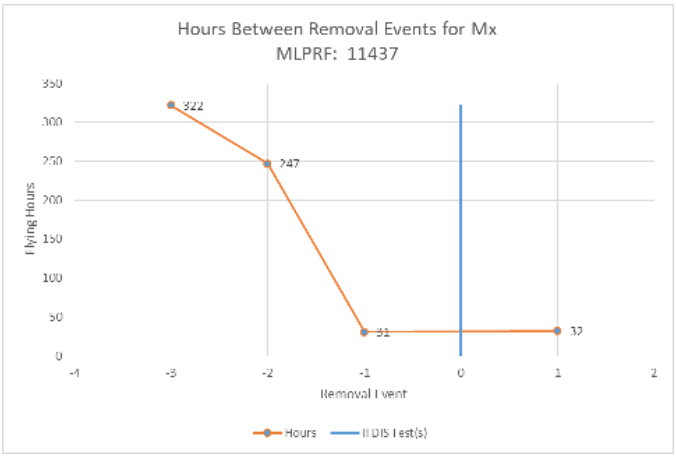


Figure 22 Hours between removal event for MLPRF 11437

Table 13 Hours between failure for MLPRF 11437

Date	Count	Hours	Avg
13-Mar-01	-3	322	
3-Jan-03	-2	247	
25-Jun-04	-1	31	200
4-Nov-09	0		
14-Aug-12	1	32	32

A.8 S/N: 11863

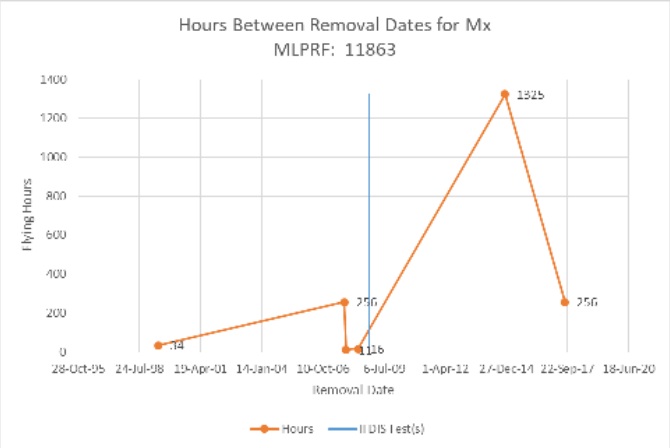


Figure 23 Hours between removal dates for MLPRF 11863

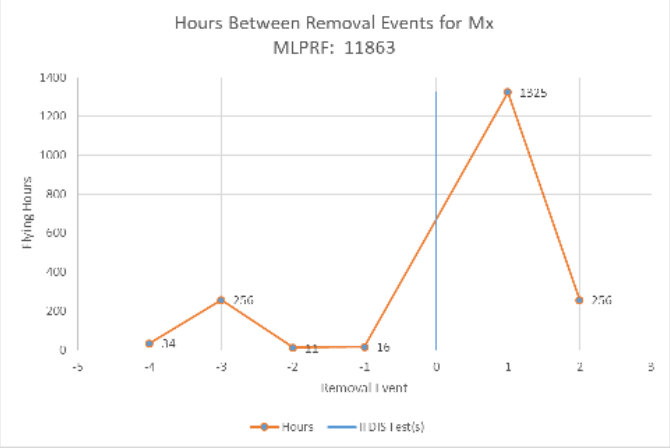


Figure 24 Hours between removal event for MLPRF 11863

Table 14 Hours between failure for MLPRF 11863

Date	Count	Hours	Avg
1-Jun-99	-4	34	
26-Sep-07	-3	256	
26-Oct-07	-2	11	
8-May-08	-1	16	79
4-Nov-08	0		
4-Dec-14	1	1325	
12-Aug-17	2	256	791

A.9 S/N: 11188

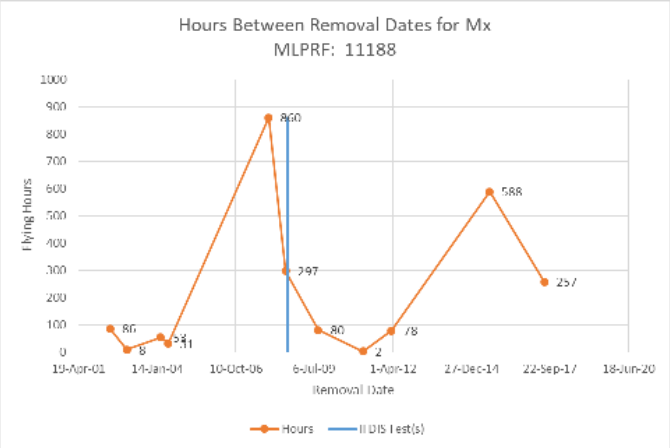


Figure 25 Hours between removal dates for MLPRF 11188

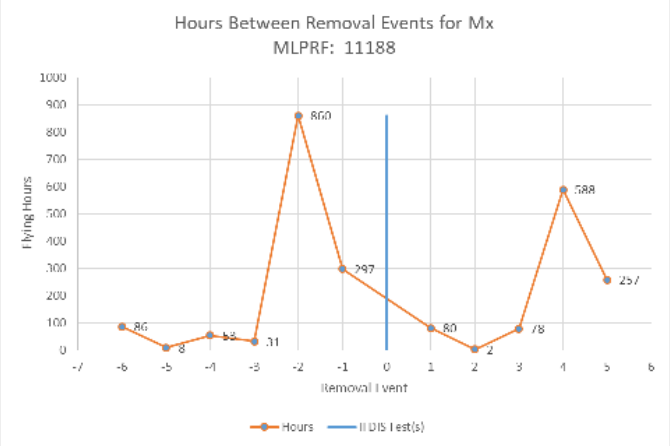


Figure 26 Hours between removal event for MLPRF 11188

Table 15 Hours between failure for MLPRF 11188

Date	Count	Hours	Avg
31-May-02	-6	86	
29-Dec-02	-5	8	
3-Mar-04	-4	53	
8-Jun-04	-3	31	
7-Dec-07	-2	860	
10-Jul-08	-1	297	223
31-Jul-08	0		
28-Aug-09	1	80	
23-Mar-11	2	2	
16-Mar-12	3	78	
18-Aug-15	4	588	
11-Jul-17	5	257	201

A.10 S/N: 11525

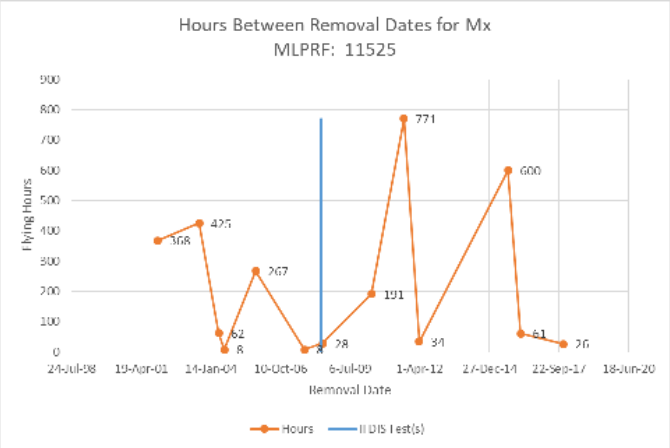


Figure 27 Hours between removal dates for MLPRF 11525

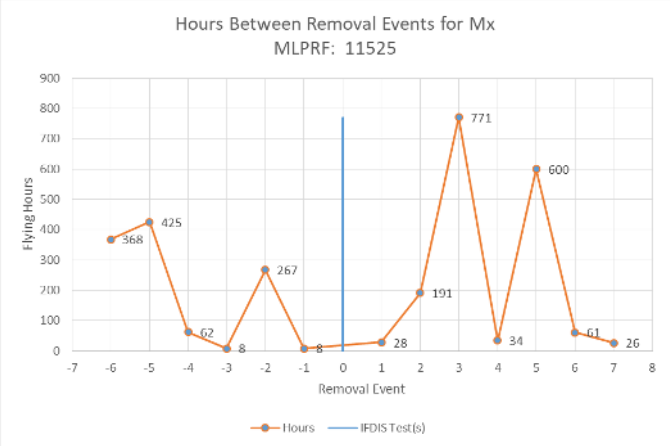


Figure 28 Hours between removal event for MLPRF 11525

Table 16 Hours between failure for MLPRF 11525

Date	Count	Hours	Avg
12-Dec-01	-6	368	
30-Jul-03	-5	425	
5-May-04	-4	62	
28-Jul-04	-3	8	
20-Oct-05	-2	267	
20-Sep-07	-1	8	190
14-May-08	0		
6-Jun-08	1	28	
11-May-10	2	191	
16-Aug-11	3	771	
23-Mar-12	4	34	
24-Sep-15	5	600	
18-Mar-16	6	61	
22-Nov-17	7	26	244

A.11 S/N: 10386

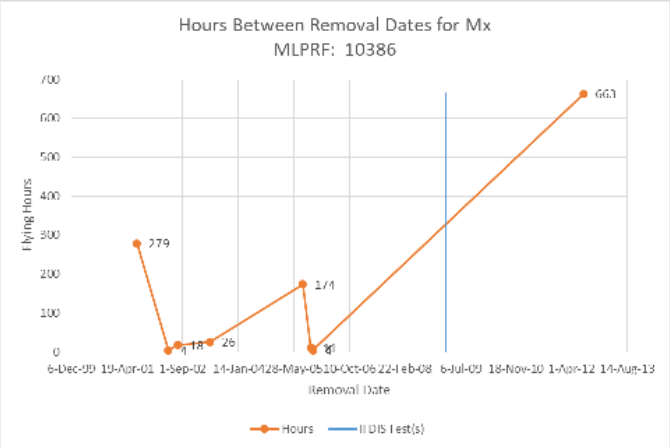


Figure 29 Hours between removal dates for MLPRF 10386

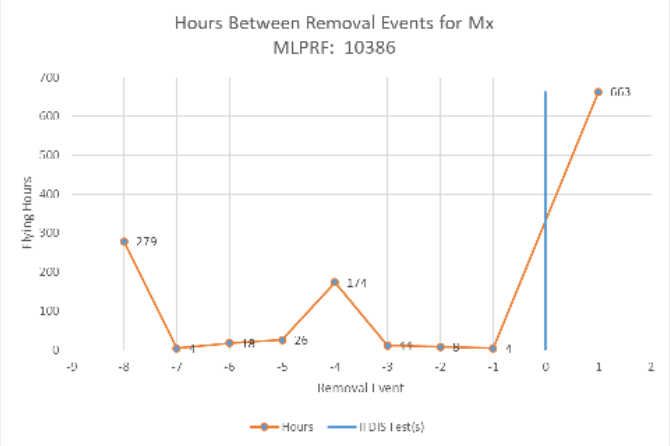


Figure 30 Hours between removal event for MLPRF 10386

Table 17 Hours between failure for MLPRF 10386

Date	Count	Hours	Avg
17-Jul-01	-8	279	
23-Apr-02	-7	4	
17-Jul-02	-6	18	
4-May-03	-5	26	
16-Aug-05	-4	174	
26-Oct-05	-3	11	
15-Nov-05	-2	8	
16-Nov-05	-1	4	66
23-Feb-09	0		
19-Jul-12	1	663	663

A.12 S/N: 11792

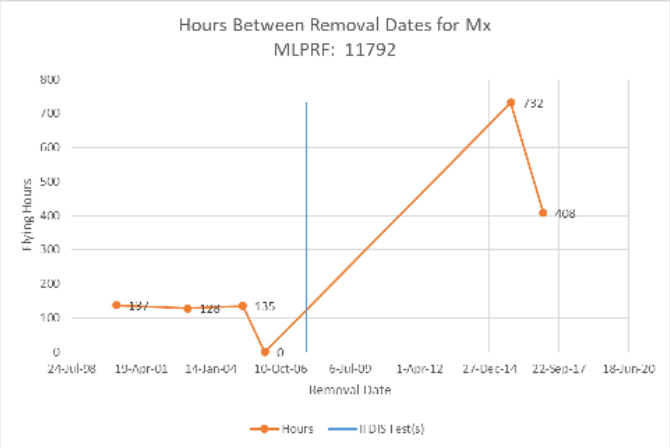


Figure 31 Hours between removal dates for MLPRF 11792

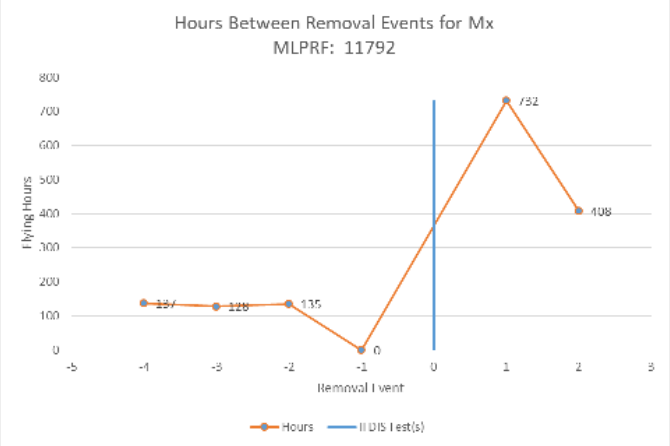


Figure 32 Hours between removal event for MLPRF 11792

Table 18 Hours between failure for MLPRF 11792

Date	Count	Hours	Avg
3-May-00	-4	137	
12-Feb-03	-3	128	
17-Apr-05	-2	135	
28-Feb-06	-1	0	100
15-Oct-07	0		
1-Nov-15	1	732	
10-Feb-17	2	408	570

A.13 S/N: 11732

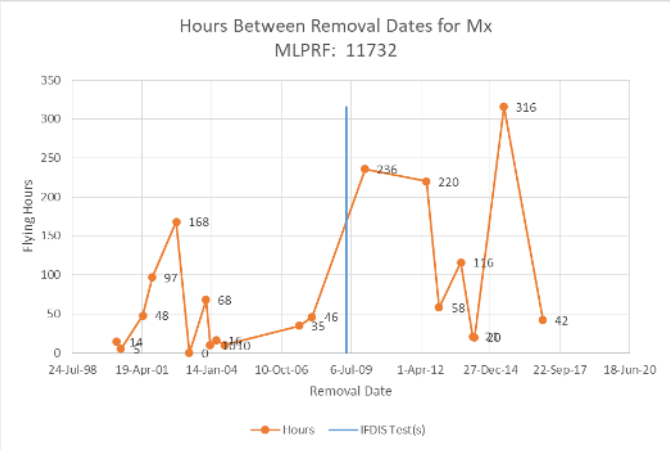


Figure 33 Hours between removal dates for MLPRF 11732

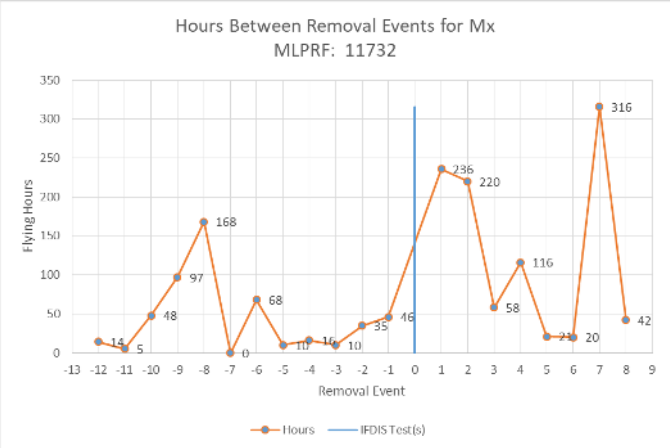


Figure 34 Hours between removal event for MLPRF 11732

Table 19 Hours between failure for MLPRF 11732

Date	Count	Hours	Avg
24-Apr-00	-12	14	
21-Jun-00	-11	5	
30-Apr-01	-10	48	
14-Sep-01	-9	97	
28-Aug-02	-8	168	
28-Feb-03	-7	0	
25-Oct-03	-6	68	
23-Dec-03	-5	10	
19-Mar-04	-4	16	
19-Jul-04	-3	10	
27-Jun-07	-2	35	
26-Dec-07	-1	46	43
28-Apr-09	0		
22-Jan-10	1	236	
22-Jun-12	2	220	
21-Dec-12	3	58	

Date	Count	Hours	Avg
31-Oct-13	4	116	
18-Apr-14	5	21	
16-May-14	6	20	
11-Jul-15	7	316	
18-Jan-17	8	42	129

A.14 S/N: 11296

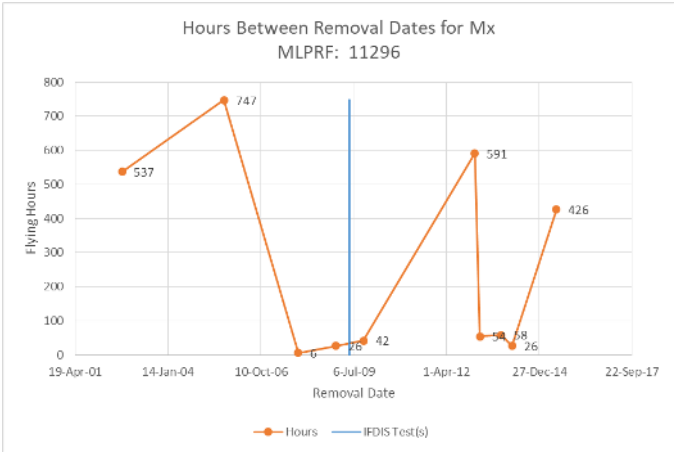


Figure 35 Hours between removal dates for MLPRF 11296

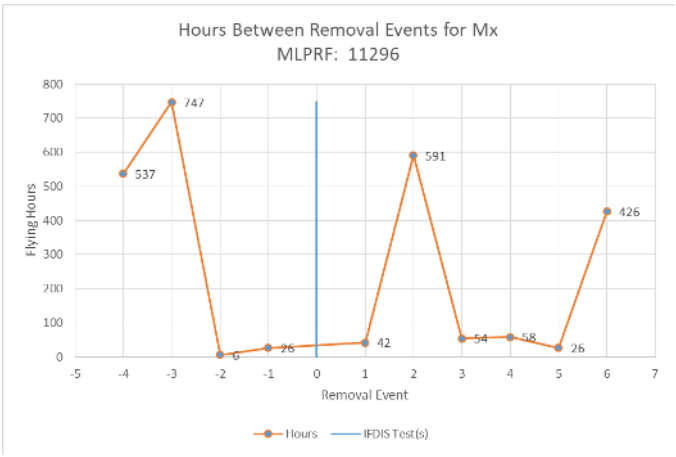


Figure 36 Hours between removal event for MLPRF 11296

Table 20 Hours between failure for MLPRF 11296

Date	Count	Hours	Avg
5-Sep-02	-4	537	
8-Sep-05	-3	747	
16-Nov-07	-2	6	
29-Dec-08	-1	26	329
20-May-09	0		
20-Oct-09	1	42	
30-Jan-13	2	591	
30-Mar-13	3	54	
15-Nov-13	4	58	
9-Mar-14	5	26	
30-Jun-15	6	426	200

A.15 S/N: 11267

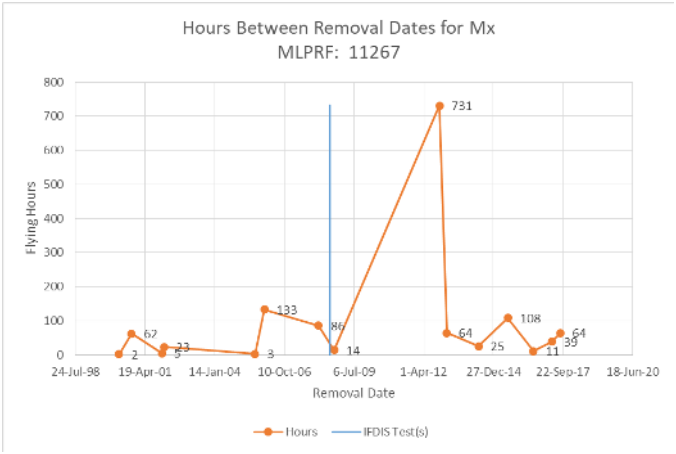


Figure 37 Hours between removal dates for MLPRF 11267

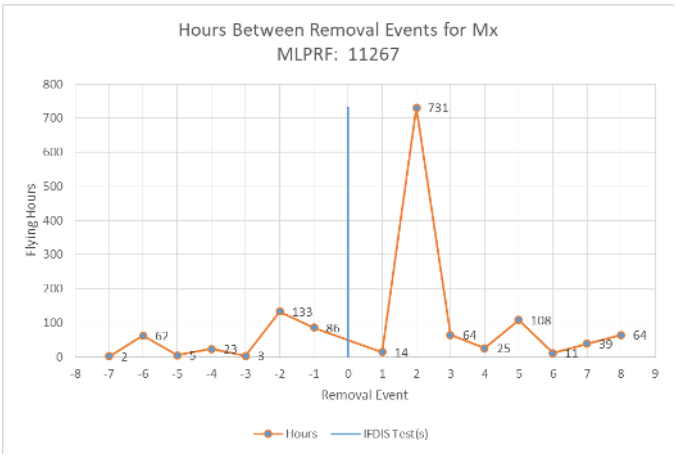


Figure 38 Hours between removal event for MLPRF 11267

Table 21 Hours between failure for MLPRF 11267

Date	Count	Hours	Avg
14-Apr-00	-7	2	
10-Oct-00	-6	62	
19-Dec-01	-5	5	
18-Jan-02	-4	23	
15-Aug-05	-3	3	
29-Dec-05	-2	133	
15-Feb-08	-1	86	45
28-Jul-08	0		
24-Sep-08	1	14	
14-Nov-12	2	731	
26-Feb-13	3	64	
29-May-14	4	25	
22-Jul-15	5	108	
25-Jul-16	6	11	
12-Apr-17	7	39	
16-Aug-17	8	64	132

A.16 S/N: 11665

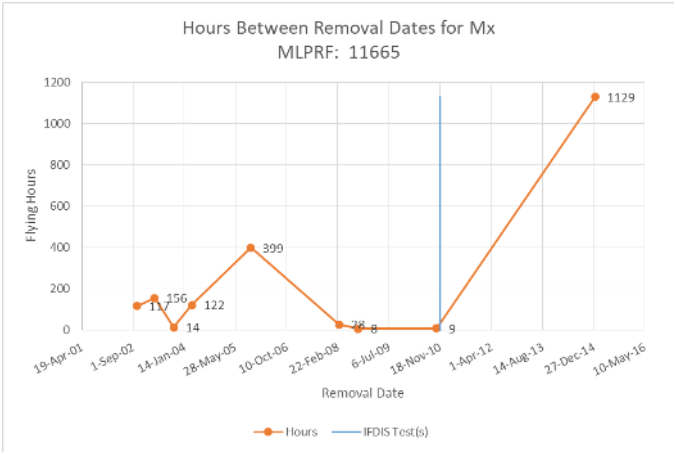


Figure 39 Hours between removal dates for MLPRF 11665

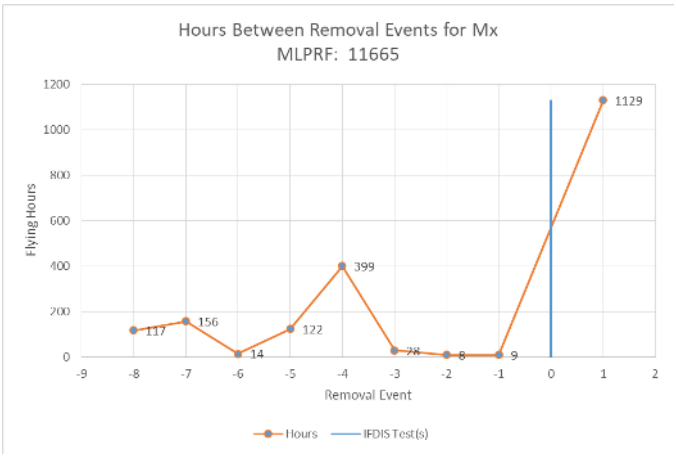


Figure 40 Hours between removal event for MLPRF 11665

Table 22 Hours between failure for MLPRF 11665

Date	Count	Hours	Avg
10-Oct-02	-8	117	
31-Mar-03	-7	156	
5-Oct-03	-6	14	
30-Mar-04	-5	122	
27-Oct-05	-4	399	
6-Mar-08	-3	28	
10-Sep-08	-2	8	
14-Oct-10	-1	9	107
16-Nov-10	0		
12-Jan-15	1	1129	1129

A.17 S/N: 10752

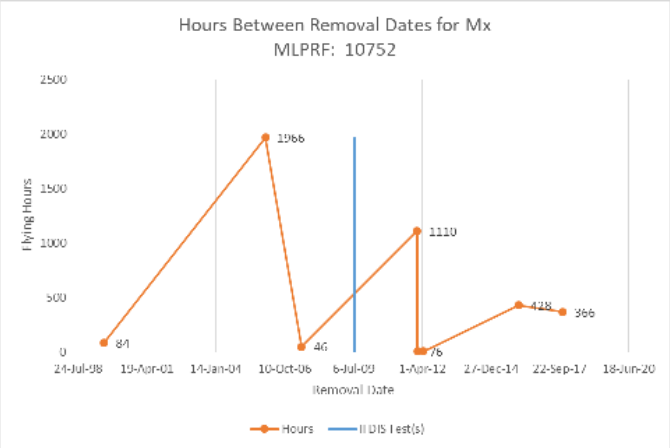


Figure 41 Hours between removal dates for MLPRF 10752

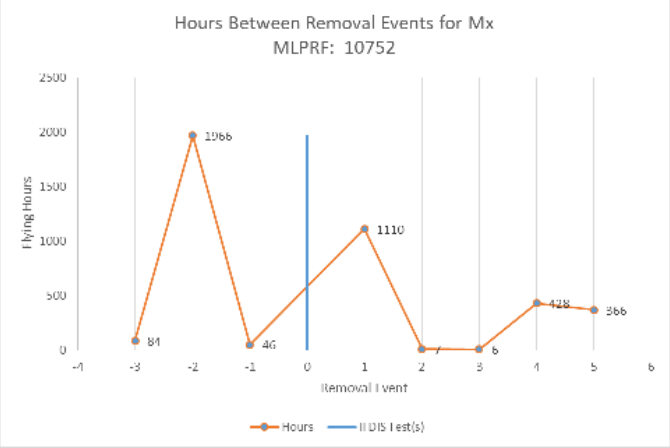


Figure 42 Hours between removal event for MLPRF 10752

Table 23 Hours between failure for MLPRF 10752

Date	Count	Hours	Avg
4-Aug-99	-3	84	
6-Jan-06	-2	1966	
13-Jun-07	-1	46	699
20-Jul-09	0		
18-Jan-12	1	1110	
24-Jan-12	2	7	
17-Apr-12	3	6	
2-Feb-16	4	428	
1-Nov-17	5	366	383

Appendix B Source Documents

Reference	Document
Ken Anderson, *Intermittent Fault Detection & Isolation Reduces No Fault Found (NFF) and Enables Cost Effective Readiness*, Universal Synaptics, 12 October 2016	 ifdis-phm2016-1610 12173402.pdf