Fiddly Fussy Finicky Failures can Deviously Evade Detection

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***Abstract* -** Why do fiddly fussy finicky failures (F^3 Failures) occur is a puzzling question. It could be classified as a natural sequence of events that are eventually going to happen. On the other hand, it should be stated that some failures never occur even though there is a potential they might occur.

Preventative maintenance can keep puzzling failures from occurring. Preventative maintenance should not only consist of a set of standard well defined routines but should include a set of routines or tests that might detect and analyze an inevitable failure.

There is almost always a point between a healthy condition and an unhealthy condition. An unhealthy condition can be classified as a hard failure. During the time between a healthy and unhealthy condition, puzzling failures tend to occur. Puzzling failures detection can be very useful in determining what is about to happen and what action we need to take to prevent a total or hard failure. Detecting F^3 Failures and their true meaning is an elusive science.

Another factor is the so-called cascading effect. Sometimes a cascading effect takes place and multiple circuits become defective when inserting faults or probing or when a unit comes in from the field for repair. This occurs even though the so called non-destructive faults are at times impossible to predict or an event occurred in the field. This is not an engineering short come nor is it a technician short come; this is strictly the nature of the beast where theory and reality as far as diagnostics is concerned is not completely understood. This paper will discuss possible repair scenarios for cascading failures.

Another problem is taking invalid measurements. Invalid measurements are more common than one might suspect. Determining whether or not a measurement is invalid can be tricky but there are critical steps which must be considered when your repair action does not work.

INTRODUCTION

The elusive science of puzzling failure detection can be further broken down to achieve a useful and meaningful diagnosis. This diagnosis technique is a selection process. The selection process involves a determination of a technique by which one feels might generate a rational result.

Questions about fiddly fussy finicky failures might be:

1. What are the symptoms associated with a puzzling failure?
2. Should we ever dismiss the symptoms of a puzzling failure?
3. Can a puzzling failure be classified as an intermittent failure? Answer: yes
4. Are puzzling and intermittent failures for real?
5. Can you utilize puzzling failure data to evaluate a condition?
6. What is occurring out of the norm?
7. What is the duration of the failure?
8. What is the severity of the failure?
9. What external events occur during the failure?
10. Can the failure be classified as a known failure condition?
11. How do I determine the optimal way to detect a fiddly fussy finicky failure?
12. What is a meaningful algorithm?
13. Can we develop an algorithm for every puzzling event?
14. Can we develop an algorithm which focuses on a diagnostic solution?
15. Is the whole of everything setup so that random or arbitrary failure events occur?
16. What is the overall theory of randomness?
17. Does randomness equate to failures?
18. Are random failure events a natural occurrence?
19. Should we ever dismiss a random failure event?
20. If randomness equates to failures then what is meaningful?
21. Can intermittent events predict what will happen in the future?
22. What sensors are available to detect intermittent failures?
23. Will weak test equipment contribute to failure detection problems?

24. Can Software be designed to ignore invalid data?
25. When is a measurement not valid?

These questions will be addressed. The questions deserve an answer and will be answered but the answer is not necessarily the only answer to each question. Also, puzzling and intermittent failures are more or less failures that might occur in anything or everything. Figure 1 shows how a puzzling failure might be evaluated.

Although weird failure detection were never considered to be incorporated as a test in a Test Program SET (TPS) they are real. Incorporating such a test can not be readily determined and requires thinking out-of-the-norm. Thinking out-of-the-norm or pursuing some unique test is not something new for an engineer. In fact, this is what engineers do; "Engineers figure it out and make it work."

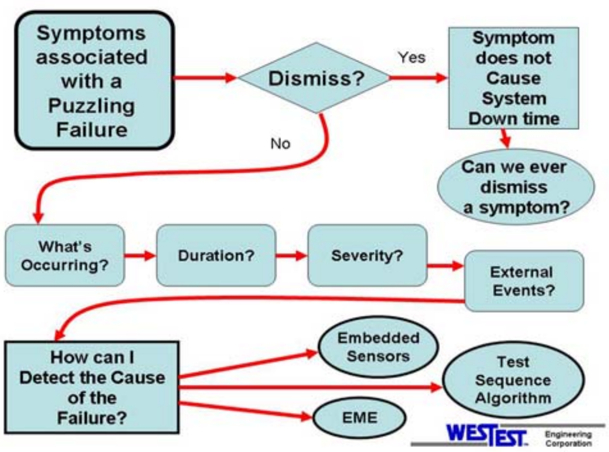

Figure1. Puzzling Failure Analysis

As our scientific understanding of how and why things function and fail continues to grow, we should be open to changes in our diagnostic processes. Current diagnostic processes are valuable and useful but things can always be done better and smarter. Computerized robust algorithms can highlight conditions or occurrences that we might normally dismiss. The diversity of sensors can be very useful in our diagnosis of an intermittent failure.

TRUE PUZZLING FAILURES

An intermittent is a problem for which there is no known procedure to consistently reproduce its symptom[1]. However, one might suggest a true puzzling failure is a random failure which can be difficult to reproduce or diagnostically detect. Perhaps many intermittents can never be isolated or reproduced but there are methods to isolate certain intermittents or puzzling failures and their causes. It might be stated if a failure can be reproduced then it is not a true intermittent. Another definition might be a true intermittent can be defined as a random failure occurring during system usage. Typical test and diagnosis routines were never setup to detect true intermittents and puzzling failures. Advanced algorithms and sensors have a greater capacity to detect fiddly fussy finicky failures.

What are the symptoms associated with true puzzling failures? The symptoms range from inconsistent somewhat meaningless glitches to overall system shutdowns or failures for a duration of time. Certainly, the symptoms are associated with an abnormal functioning or condition for a duration of time. The fact is a failure is a failure whether it is hard or pernickety.

Pernickety failures tend to be very elusive but can occur quite often in certain systems. These types of failures although elusive are detectable. The proper way to detect these failures can vary depending on many factors.

Should we ever dismiss the symptoms of a puzzling failure? Failures in weapon systems should never be dismissed. Some might argue a failure which is not catastrophic need not be addressed. Non catastrophic failures can evolve into catastrophic failures. Also, failures tend to proliferate into cascading failures.

Can a puzzling failure be classified as an intermittent failure? Yes, a puzzling failure can be classified as an intermittent failure. A puzzling failure is a failure which is kind of devious. The deviousness occurs by tricky variances in signal integrity. Signal integrity problems always exist but can be solved by proper programming or instrument setups. Software can be designed to ignore invalid data. In hardware physical filters can block unexpected or out of tolerance signals.

Are puzzling and intermittent failures for real? Puzzling failures are absolutely real and they show themselves in unusual ways. They can cause diagnostic variances which can show different faults each time a probe sequence is performed.

Can you utilize puzzling failure data to evaluate a condition? Puzzling failures are real and the conditions associated with puzzling failures are vital to Unit Under Test (UUT) repair. These conditions need to be categorized and used for future test and repair routines. Categorization should be further processed by robust algorithms.

What is occurring out of the norm? What is the duration of the failure? What is the severity of the failure? What external events occur during the failure? Can the failure be classified as a known failure condition? These questions give rise to the development of an algorithm with each factor being evaluated and processed. Any indication of a failure or pending failure must be tackled.

Although, the could not duplicate (CND) response to a failure is used when a puzzling failure can not be diagnosed. This is actually not acceptable since the failing condition has not been resolved. If nothing else, the cause of the failure needs to be resolved at some point and action must be taken to diagnose the problem when similar events occur in the future.

How do I determine the optimal way to detect a fiddly fussy finicky failure? This is an outstanding question. The answer is at best "Figure it out." So, how do I figure it out? You must evaluate each and every significant or insignificant circumstance contributing to the failure. Things you dismiss as unimportant might be crucial information about the fault.

What is a meaningful algorithm? Can we develop an algorithm for every puzzling event? Can we develop an algorithm which focuses on a diagnostic solution? A meaningful algorithm can be "To me, an algorithm is any piece of automated code that accepts some number of variables and data, [then] uses those variables and data to make decisions.[3]" A meaningful algorithm is useful for failure analysis, but the data must be available and must be interpreted. Puzzling events can have obscure and unknown symptoms, so you can not develop an algorithm for every puzzling event. However, you can develop an algorithm for a specific event.

Is the whole of everything setup so that random or arbitrary failure events occur? What is the overall theory of randomness? Does randomness equate to failures? Are random failure events a natural occurrence? Should we ever dismiss a random failure event? If randomness equates to failures then what is meaningful? The whole of everything is setup so that arbitrary failure events occur. It has been theorized that randomness can not occur in complex systems, but is it also true that a perfect complex system does not exist? The overall theory of randomness could possibly be classified "The definition of random in terms of a physical operation is notoriously without effect on the mathematical operations of statistical theory because so far as these mathematical operations are concerned random is purely and simply an undefined term.[4]" Whether a symptom is classified as random or not random or arbitrary, the symptom does exist and should be analyzed. We should not debate words or meanings to fix our systems.

Can intermittent or puzzling events predict what will happen in the future? Arbitrary events can predict what will happen in the future. Certainly, a short duration system failure event is very serious. Dismissing failure events can not be justified. We should evaluate all failure events and work on the problem resolution until it is resolved.

CASCADING FAILURES

Cascading failures can or might begin when one part of the system fails. When this happens, nearby nodes must then take up the slack for the failed component. This can overload these nodes, causing them to fail as well, prompting additional nodes to fail in a vicious cycle.

Corrective action for a cascading failure involves finding the component which produced the effect (see figure 2). Normal testing procedures can be non-productive in this scenario. All the defective components in the cascade failures circuits need to be replaced at the same time. Determining all the defective components might require usage of a non-standard technique like EME technology. Also, once a repair technician or engineer has determined the faults for a cascading circuit the repair procedure can be placed in the TPS.

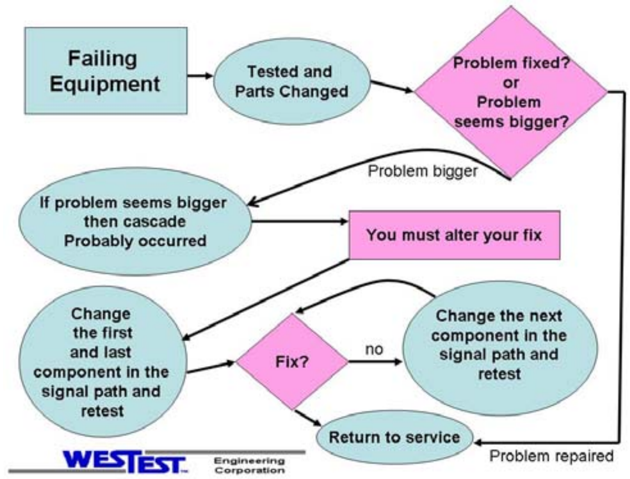

Figure 2. Cascading Failure Analysis

Repair procedures for cascading failures range from complete component replacement to one component replacement. Although it is not fully understood, the node at which the cascading failure occurred must be isolated. To isolate the node is tricky business. A suggestion might be:

1. Follow the circuit to the last component in a failure region.
2. Determine the first component in a failure region.
3. Don't assume it is the first or last component, however replace the first and last component and determine if they fail again.
4. Should the first or last component withstand changing without failure, then, change the next component in the sequence and so on.
5. When a unique set of circumstances arise then focus on that circuit area and determine what is causing the cascading effect.
6. Once you have determined the circuit area then change the components in that area.
7. Remember, an initial cascading failure will cause component damage outside the cascading failure

area due to instantaneous current deviations which are usually only experienced once.

8. It can be stated the initial cascading effect is due to residual weaknesses in circuit areas not in the cascading failure area.
9. You might say; outside the cascading circuit area component failures are a kind of prognostic failure due to component weaknesses which naturally occur over time.

BEWARE, BOGUS MEASUREMENTS

Throughout the realm off measurements, conditions often arise which produce a bogus measurement. If this measurement is stored and used to evaluate UUT health then the whole process is corrupted. Corrupted information is useless and should never be used for any reason.

Examples of unforeseen bogus measurements are:

1. Re-probing without power-down
2. Mis-probe (with or without power-down)
3. Connections
4. Switching (especially defective switches)
5. Environment
6. Sensor malfunction
7. and many others

So, the system should be capable of determining or notifying the user of possible bogus measurements when a measurement(s) is invalid. Especially, when analyzing a failing measurement, it is important the software attempt to determine if the measurement is valid. Determining if a measurement is valid is quite an abstract science.

Robust software can determine if measurements seem skewed or out of the realm of known factors. Specific algorithms or techniques will probably vary and might actually be UUT dependent. Generic algorithms have their applications but since the test and measurement situation is so diverse they might not be effective over a wide range of applications.

EME SENSORS

What sensors are available to detect intermittent failures? EME technology is very promising at prognostic determination. The information content and intelligence contained within EME measurements can point to the existence of and the location where electronic, mechanical and electromechanical UUT faults exist. Further, EME anomalies can reveal the existence of marginally performing components that may fail prematurely. Figure 3 outlines some of the benefits that could be derived from using EME technology.

Considerations for test must include a software factor. Can your test software function with various technologies? Can you software function call other run-times? Can your software interact with a diagnostic assistant?

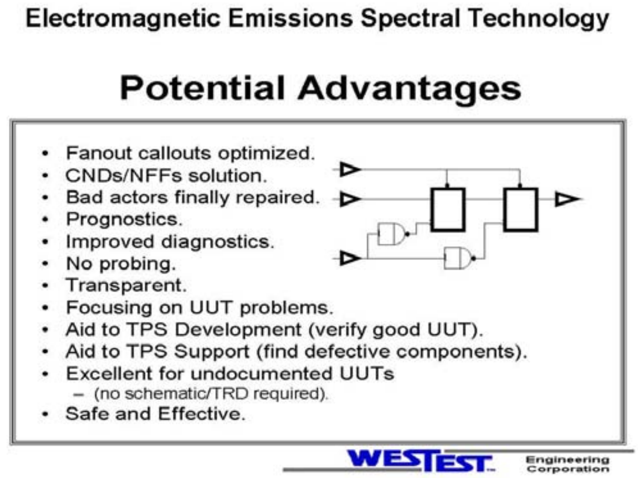

Figure 3. EME Technology Potential

Sensors mounted on the weapon system and the BIT reported failures can be very beneficial in fault determination and prognostics. These should always be used to aid in fault determination, especially when analyzing fiddly, fussy, finicky failures. This information is great when developing robust algorithms. Figure 4 shows a likely sensor and BIT analysis routine.

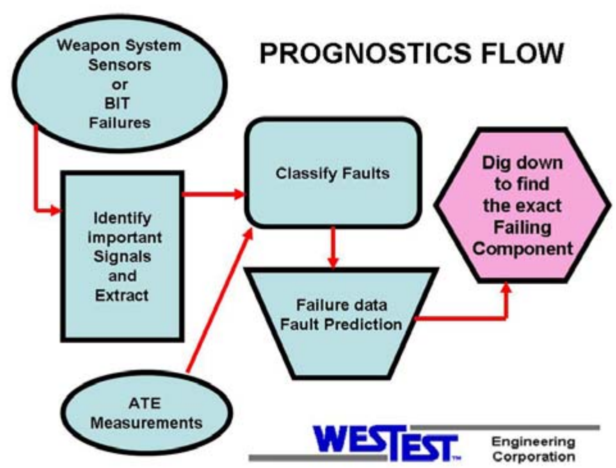

Figure 4. Sensor or BIT Analysis

Will weak test equipment contribute to failure detection problems? Weak test equipment has been a problem from the inception of Automatic Test Equipment (ATE). If the test equipment can't generate the required stimulus and/or perform the required measurements for a UUT then the test is useless. Weak test equipment includes weaknesses in functional characteristics or analyzing measurements and resolution. Also, it should be noted, many pieces of test equipment have characteristics which contribute to finding puzzling failures.

Can Software be designed to ignore invalid data? Software can be very effective at ignoring invalid data. Looping or repeating tests can be very helping at finding puzzling failures. Also, software characteristics quite often need to be employed to determine if a system is functioning properly. This becomes a requirement when the ATE can't trigger on an exact event. The bottom line is software can be designed to detect both good characteristics and puzzling characteristics.

TECHNIQUES

Most of the problem arising from timing glitches can be resolved by properly setting-up quality test equipment and performing proper signal analysis. Timing problems can be puzzling if they occur randomly. Detecting random timing problems can be performed by using certain algorithmic routines like pattern looping or signal looping as shown in figure 5. Also, signal adjustment can be utilized to detect finicky timing failures.

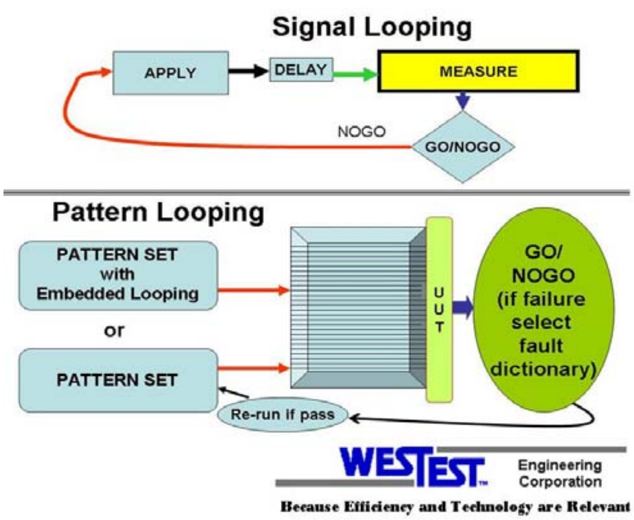

Figure 5. Looping

Input stimulus signal stepping can be characterized as a output signal tested during ramping up the stimulus. Ramping up the stimulus is shown in Figure 6. The main characteristic of this technique is the application of a signal until the measurement falls within a certain range. This could be adjusted such that the range could be set on the limits of chip specifications so as to exercise the chips at the peak of their performance rating. This type of testing does not weaken the component as long as specifications are not exceeded. It must be noted that the test is aborted or fails if the output measure exceeds a specified threshold. You need to keep a tight measurement monitoring routine when doing this type of testing and employ the right test equipment with adequate resolution so that circuit damage does not occur. It is advisable not to ever exceed maximum specs but rather only approach the specs. Signal stepping can show weaknesses at certain levels. A puzzling failure can be linked to specific signal levels.

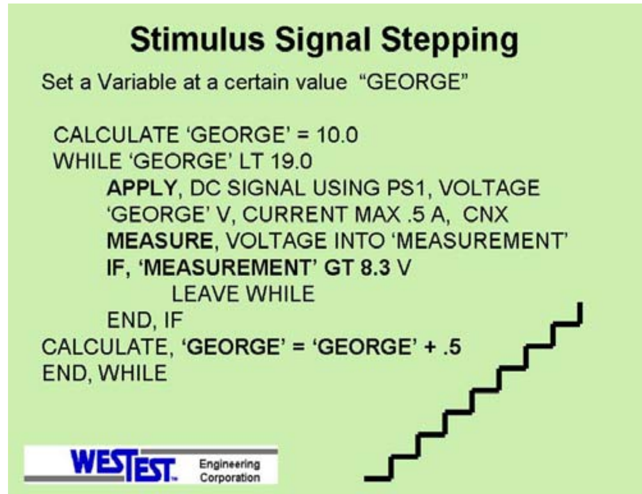

Figure 6. Stimulus Stepping

Frequency variance is similar to stimulus signal stepping. Frequency variance is the application of frequency in a semi-random sequence. The idea here is to monitor circuit changes due to a capacitance effect which might be caused by shorts or opens. The variance can be programmed by what the Test Program Set developer feels exercises the circuits properly for failure detection. Figure 7 is merely an example of code that might be used. Frequency variance is somewhat unique but it must be setup to achieve optimal results. Variations to this type of testing are subject to the developer's findings during integration testing.

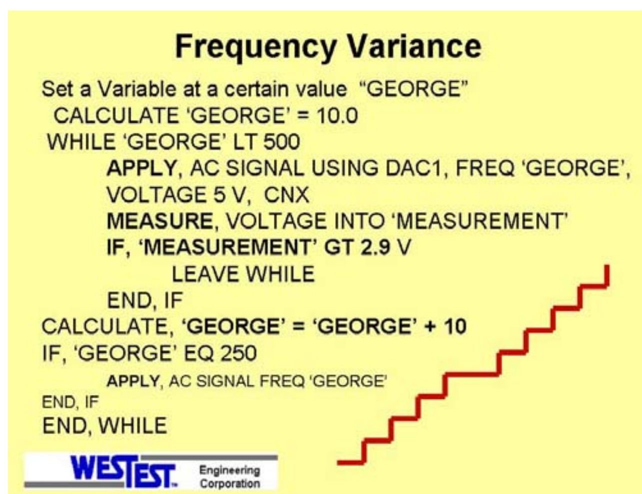

Figure 7. Frequency Variance

Other beneficial methods which can be used to detect puzzling failures include:

- Pattern Adjustment in critical areas
- Signal Strength Variation
- Current Path Duplication

- Measuring Capacitance Variations
- Vcc Adjustments
- Resistive/Impedance Rebounce
- Temperature Change Application
- Noise Dissimilarity Testing
- Etc.

Pattern Adjustment in critical areas involves honing in on the pattern sequence that exercises the specific components in a circuit that experience puzzling failures. Once you have determined the pattern numbers or sequence that exercise the component(s) prone to puzzling failures then add duplicate patterns. Also, you can change the duplicate patterns so that a more robust on/off stimulus is applied. This can cause the output to periodically fail if a puzzling fault is present.

Signal Strength Variation is similar to signal stepping. However, signal strength variation is not isolated to changing the input voltage but also includes changing the current. You will be adjusting two parameters (voltage and current) to test for intermittent failures. A higher or lower voltage coupled with a higher or lower current has the potential of showing weak circuits. You can raise the voltage and lower the current or vise versa.

Current Path Duplication is a technique to track the current through a circuit. This technique involves testing for an abnormal current path using a resistive and/or voltage technique. This technique is employed when testing the output of a circuit path by also testing the output of a path by which current might flow during the same test. If an unusual measurement should occur at the duplicate pin this can be an indication of a puzzling failure.

Measuring Capacitance Variations consists of many different methods. There are patents and papers that provide techniques for this type of testing. If the stray capacitance is large enough to worry about in normal operation a typical LCR meter will measure it. An AC excitation is necessary for sensing capacitance variations in stray capacitance. If your stray capacitance is minor you may need a more sophisticated piece of lab equipment. A LCR meter (Inductance (L), Capacitance (C), and Resistance (R)) is a piece of test equipment used to measure the inductance, capacitance, and resistance) of a component. In the usual versions of this instrument these quantities are not measured directly, but determined from a measurement of impedance. The necessary calculations are, however, incorporated in the instrument's circuitry; the meter reads L, C and R directly with no human calculations required.

The Vcc Adjustments technique is employed by adjusting the component(s) normal bias voltage. Remember, you must not exceed the chip manufacturer's specifications. The Vcc adjustment technique might show output variations from weak or defective components as compared to stable components. By adjusting Vcc you can monitor the output signal pins/paths of puzzling failure circuits and determine if this can be used to identify defective components.

Resistive/Impedance Rebounce is a technique very similar to Measuring Capacitance Variations. Resistance meters can be optimized for high-resistance or low-resistance measurements. An impedance analyzer is the most powerful tool to measure impedance (inductance, capacitance, and resistance) across a range of frequencies. It is important to note the adjustment of frequency. The actual frequency range needs to be determined during integration testing.

Temperature Change Application is exactly as the name suggests. It is the technique of exposing the Unit Under Test to various temperatures during testing. Remember, cold temperatures possibly show intermittent failures more than higher than normal temperatures. You can combine other intermittent techniques with this technique to achieve optimal results. Remember, to always stay within the specifications of the components on the UUT.

Noise Dissimilarity Testing is testing for noise variations on the UUT. Monitoring the noise on the Vcc line is always a good idea. However, monitoring the noise of an output signal on a pin and comparing that noise measurement to the output signal of another pin might show component weaknesses. It is a wise choice to look at noise on UUTs that have puzzling failures. Noise can be a decisive factor and tends to get amplified on weak circuits. Noise can be measured by any quality instrument capable of measuring an AC frequency.

F^3 FAILURES (Fiddly Fussy Finicky Failures)

Should we ever test for an F^3 failure? Should there be a standard set of tests to check for fiddly, fussy, finicky failures? What type of tests should be classified as F^3 failures detection tests? Can we (technician/engineer) enter puzzling failure data into the TPS? Should we approve these entries by a Material Improvement Project?

The questions outlined in the previous paragraph shed light on the need to address F^3 Failures. F^3 failures are not necessarily intermittent failures but all types of unique failures that tend to occur. Detection of these failures has always been difficult.

EME[5] would be an excellent technology to hone in on an F^3 Failure. The findings discovered by the EME technology could be utilized to develop a test for the traditional ATE mainline TPS. Figure 7 shows a methodology to determine the cause of an F^3 failure and to derive a test to find an F^3 failure.

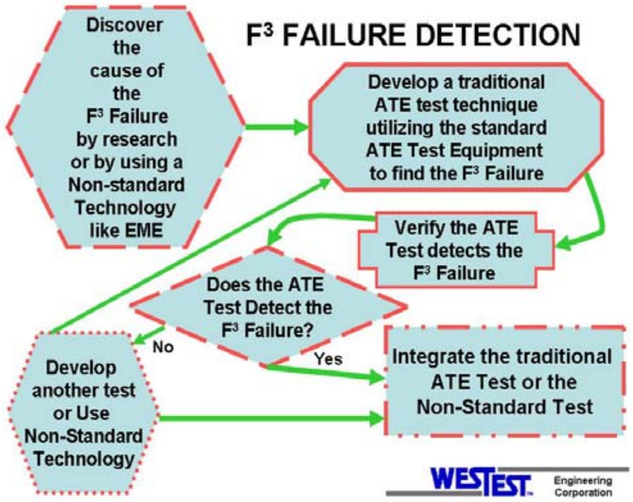

Figure 7. F^3 Failure Detection

Test technology physics is a science often overlooked. Over time we have come to believe that the standard stimulus and response criterion is a must for circuit diagnosis and for determination of ready to use. We tend to think a standard set of tests fulfills the bill. Although the standard stimulus and response test is part of the solution, it may not be the total solution. Our mandate is to discover and pursue technologies or test techniques to improve the quality of a test and reduce test development cost and time and reduce life cycle costs. Puzzling failures occur and do affect the system performance. We need to do things better, more cost efficiently and improve the quality of a test.

Over-testing, mis-testing, not testing, inapt testing, badly chosen testing, or under-testing can be a result of standard stimulus and response. Things like timing, signal strength, duplicating the operating environment, loading, fan-out, and properly interconnecting the UUT are some factors associated with standard testing.

A defective circuit with a puzzling failure is like an infection that needs to be treated. It is one type of analysis that is required to determine that we feel weak and achy, and a completely different type of analysis, using intelligence and insight, that is needed to find the root cause of our ailment. While the former can be achieved simply (anyone can figure out that he/she is ill), the later requires diagnostic insight that doctors train many years to accomplish. In doing so, doctors do not simply rely on the patient's determination, but rather on external diagnostic equipment, such as thermometers, X-rays, Laser Scanners, MRI, robotic nano-technology cameras, etc. We must similarly intertwine our test techniques to fully evaluate the functionality of the Unit Under Test. At times one cannot simply rely on a single ATE instrument set to find all faults. The severity of the puzzling fault becomes the deciding factor. We should have at our deposal a set of techniques to aid in the detection of puzzling faults.

CONCLUSION

We have great understanding about physics as a fundamental science. We do not have a complete understanding of the physics of failing systems. The actual physics of circuit functioning should be considered when determining test philosophies. Physics is the most fundamental science. It involves understandings of the basic principles by which all things in the universe exist and operate. It is the natural basis of all the technology disciplines such as electronics, engineering and computer science and, of course, test and diagnosis. While two different boards can both PASS all the ATE tests, their physical characteristics might be different. The physics behind those characteristics can help us diagnose the root causes behind the Could Not Duplicate (CND) and help us repair even those boards that escaped the ATE tests.

Fiddly Fussy Finicky failures are not always present. Detecting hard failures is a different science from detecting puzzling failures. Puzzling failures do cause CND's and they are absolutely real. Detecting puzzling faults is an elusive science. The exact cause of a fiddly fussy finicky failure may never be found or figured out. This should never be a reason to not pursue detection routines.

Any system will fail or misbehave at some point. It is just a question of when. The effect of the failure or change in performance interferes in different degrees with missions that depend on that system. In critical missions a system failure can lead to catastrophic consequences. Current methods do not always allow for the effects of these factors in the determination of equipment performance tolerances or test limits, resulting in apparent and actual decreases in equipment readiness and test program precision. The overall cost of a failure or malfunction, measured in any standard, is always higher than the preventive action. Therefore, system users are interested in knowing when a system or part is about to fail or is experiencing F^3 failures in order to take preemptive actions.

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