# Testing for Systems Readiness—A Perspective for the Future

Tony Pombo and Floyd Berghout
Total Quality Systems, Inc.
4066 South 1900 West, Roy, Utah 84404
Phone: 801-731-2150, Fax: 801-731-4457
Email: fberghout@tqsinc.com

Larry Kirkland
810 West Sheppard Lane
Farmington, Utah 84025
Phone: 801-451-9191
Email: LarryK@westest.com

***Abstract*** *This paper emphasizes the opportunities afforded by current and emerging technologies that could elevate the effectiveness and relevance of shop testing to the higher purpose of improved systems readiness. Current testing philosophy is reviewed to establish a baseline from which testing processes can be fashioned that will bring the shop testing environment more in line with the realities of the operational world. We explore the impact of current logistical processes on the state of readiness of both test equipment and the units under test by monitoring replacement parts compared to the engineering bills of material (BOM). The benefits of capturing and archiving the test results for each serialized assembly for analytical comparison, when needed, to the test results for each next higher assembly up to the system level, are discussed. Examples are presented in which significant impacts on system availability were resolved through analysis of test results captured at progressive levels of testing. These examples of performance based test results analysis have lead to the correction of test program anomalies which were the root cause of costly no faults found (NFF) rates.*

*A case study demonstrates the cost benefit of measuring performance in the testing environment as well as system operational environment.*

***Keywords*** *– Serialized Asset Management, No Fault Found, intermittent faults, Unit Under Test.*

## I. Introduction

Removal of equipment from (aircraft) service for reasons that cannot be verified by the maintenance process are a significant burden for aircraft operators. The phenomenon is commonly referred to as No Fault Found (NFF), which has become so pervasive that the Commercial Airline Maintenance Committee (AMC) formed a working group with the goal to provide ... a structured process to identify, analyze and resolve NFF issues. (ref. 1) Some airline MRO facilities report NFF rates as high as 70 percent for avionics boxes that they repair.

Let's think about how we evolved to the intolerable situation in which we find ourselves. As aircraft became more complicated and flying schedules more demanding the aircraft designers applied more modular designs to accommodate rapid removal and replacement of faulty components (especially avionics boxes) in order to ready the aircraft for the next scheduled launch. However, that very design technique intended to improve system readiness is, at least in part, driving some very high NFF rates. Since scheduling pressures are unlikely to diminish in the foreseeable future and funding pressures continue to mount on all fleet operators, we need to explore how the testing community can be part of the solution in reducing this ubiquitous problem. The Keynote speaker at the 2008 AMC in Tulsa OK pointed out that the current business model w

With all of the advances that have been made in Automated Testing Equipment (ATE) technology and all the investment made in testing precision over the past 30 years, why do the majority of avionics boxes removed from aircraft "pass all tests"? Why do we still have so many NFF avionics boxes from both civil and military aircraft? We have done our best to improve testing precision, tighten test specs, control the testing environment, but we still spend the majority of our time chasing ghost or phantom faults. With all the controls and precision that has developed around ATE could it be that we are not focused on the right objectives? Should we refocus, at least part of our energies, on the end result that we wish to achieve with all this testing effort? Is the basic testing philosophy that has prevailed for more than thirty years that essentially says "an airworthy box is one that passes the ground tests" still adequate in the fly by wire age?

*We question the idea that test measurements run under near laboratory conditions should be declared the reference standard for systems that, by their very nature are operated in a highly variable or hostile environment.*

This paper emphasizes the opportunities afforded by current and emerging technologies and practices that could elevate the effectiveness and relevance of shop testing to a higher purpose of improved systems readiness.

When an aircraft maintainer needs a replacement avionics box from supply, he requests the part by its National Stock Number (NSN). It's pulled from a shelf in the supply room, delivered to the maintainer who then installs in on the aircraft. What does this scenario tell us about that part? What do we know about its system readiness? All we know at this point is that the item was tested in a shop in a lab environment and that it passed those tests that were in the test program. We don't know where the part has been in the past, how it performed on other aircraft, what the last repair or test results were or what parts might be in the box. What do we really know about its readiness to perform a specific mission?

Several steps can be taken to expand current shop testing to include testing for system readiness. These include:

- Upgrading the shop test conditions to better simulate the operation environment
- Monitoring the state of the test equipment
- Collecting serialized test results at all stages of testing and analyzing test and repair data for the root cause of problems
- Monitoring the replacement parts

## II. Upgrading the shop test conditions to simulate the operational environment

Traditional testing for aircraft Line Replaceable Units (LRUs) and Shop Replaceable Units (SRUs) is done under a controlled laboratory environment. The unit is place on a solid work bench in a comfortable climate controlled room. These methods do not usually test for how the units will perform when placed in an aircraft and flown under operational conditions. The aircraft operates in extremes of temperatures ranging from sitting on the tarmac in desert heat to that of extreme cold temperatures experienced at arctic sites or during high altitude flight. Even though the unit passes the shop test, it will often fail when placed in an aircraft and flown in an operational mission with variations in temperatures at various altitudes as well as vibration stresses. When a plane returns having experience a fault in flight and was checked good on the ground test, the suspect unit is again returned to the repair shop where the problem may not be duplicated. As aircraft age, it becomes more difficult to isolate problems which are not hard failures. This may be due to intermittents caused by various components of the aircraft. Even new aircraft may experience these problems due to manufacturing defects yet to be discovered.

The shop testing environment can be upgraded to be more in line with the realities of the operational world. It is common for a problem, especially an intermittent to only manifest itself when encountering extreme temperature conditions or changes. In addition, vibration can also induce an error condition. The current testing philosophy is to repair the unit as rapidly as possible and return the unit to service. No Fault Found

(NFF) conditions are often not a concern to the repair technician. He is often under pressure to repair the box and return it to service so that an aircraft can return to flying status and be productive. By cleaning or reseating an item which then passes the bench top test, it is often assumed that the problem has been fixed. An expansion of the test scenario will aid in detecting and isolating these problems.

TQS Inc has demonstrated the effectiveness of this approach with the development of an Intermittent Fault Detection and Isolation System (IFDIS) for and aircraft RADAR avionics box. The avionics box currently being tested is the F-16 Radar System, Modular Low Power Radio Frequency (MLPRF) which has over a thousand interconnect points. This box also has a multilayer ribbon cable with hundreds of soldered and crimped pins. The MLPRF is experiences numerous NFF problems. Analysis of the data showed that only a few of the total number of assets were bad actor LRUs. The first attempt to address this problem was a shotgun troubleshooting approach of re-soldering the suspected bad ribbon cable and pins. This fixed some of the problems on some of the MLPRFs; however, after a couple of resolder procedures on the same cable, other problems began to develop such as lifted traces and/or solder pads.

An intermittent fault detection system was developed which could monitor all of the paths and connections points continuously and simultaneously. The active SRUs were removed and replaced with an Interface Test Adapter (ITA) which brought each of the available connection points out of the box to the fault detection equipment. This equipment is based on an analog neural network which can detect intermittents as short as 100 nanoseconds (0.0000001 seconds) in any monitored path. The systems measures very short interruptions in the current flow through each circuit path to detect the presence of an intermittent. Since the system is analog based, there are not problems with sampling rates. Also, since the system monitors all points all the time there are no problems with switching between different lines that are being monitored at the exact time an intermittent occurs. Added to the intermittent fault detector is an environmental chamber to provide a close match to the thermal and vibration environment that the Unit Under Test (UUT) experience during actual flight operations. This chamber is capable of heating the Unit Under Test (UUT) between -40 degrees C and +70 degrees C. The chamber has an electro-dynamic vibration system which is supplied a sine wave (KHz) and random profiles to emulate environmental conditions found in a flight.

Finally, an integrated control program performs the UUT test and data collection while identifying which connection and circuit path experiences an intermittent in that particular path. To date, over 40 avionics boxes have been tested with intermittent problems being identified in 37 of these boxes. These boxes were identified for this special testing by examining the depot repair records for the LRUs which exhibited a higher than average NFF rate. In addition, some of the boxes have been in the depot repair shop for several months and were considered unrepairable. These MLPRFs have now been tested, repair, retested and placed back into service where their performance will be tracked.

## III. Monitoring the state of the test equipment

Collecting condition based data for the test equipment itself can lead to early detection of problems developing in the tester. If the system is becoming unstable, early detection should become possible. Instead of calibrating the test equipment on a calendar based schedule, calibration can be performed when the stored and analyzed test data indicates a problem is developing.

## IV. Collecting serialized test results at all stages of testing

The benefits of capturing and archiving the test results for each serialized assembly are numerous. The test technician is empowered to make more informed decisions as to what tests for repairs should be performed. The data can be used to update the test specification and align the "cone of tolerance" values for each level of testing. Often the specification is never update by the lessons learned at the repair level. By later analyzing this data we should be able to identify problems common to family of parts or individual parts which have a higher than average failure rate. If we test for system readiness, we should have a clue as to the condition of the part and what we may expect from it when installed in an aircraft. To accomplish this goal, we need to first track the item by its serial number or unique identification number. This accomplishes several desirable results. We will know when it was last tested, what the test results were, what the repair results were and how long the part performed correctly in the aircraft. In addition, if test results are collected along with repair data, a more complete performance history of the box will be available.

By collecting results at each level to maintenance, we are able to identify testing problems between test systems. These can include test voids, test differences and test tolerance differences.

An example of the benefit of collecting test results is illustrated again with a problem with a RADAR SRU which consistently tested NFF when removed from its parent LRU. The LRU test indicated a problem with the SRU. Seventy percent of the time the SRU would pass all shop tests even though the LRU test stated to remove the SRU. These LRU and SRU test results were collected. Analysis of this data indicated one test in particular. When the Test Program Set (TPS) code was compared between these two different shop tests, we found the LRU test was being run at a frequency of 10 KHz and the SRU test was being conducted at 2 KHz. Examination of the specification indicated that the 2 KHz requirement was correct. After modification of the LRU test program, the

NFF rate for this item dropped to ten percent. Therefore, collection of not only test data, but also repair data is useful in identifying NFFs and other problems for any particular part family.

## V. Monitoring the replacement parts

When a part is tested on a bench in a laboratory controlled environment and then placed on a shelf for later retrieval, the individual status and performance of that part is lost. It becomes a generic National Stock Number (NSN) item. When it is later pulled from the shelf and placed into an aircraft, we have no knowledge of its past performance or probable future performance. It becomes just another part, and is one of many identical parts. Tracking test, repair, and performance data by serial number to unique identification number will let us know when we pull a part from supply whether it is likely to perform as a "bad actor" or whether it has a probability of being in a state of readiness to perform its intended function. Since a piece of avionics electronics is never build to a National Stock Number (NSN) description, why should we rely on the NSN as the only requirement for selecting a part for replacement in an aircraft.

## VI. Summary

Current testing effectiveness can be improved by testing for systems readiness. This can be accomplished by upgrading the test environment to reflect the realities of the operational world. By storing test results and repair information by serial number, the status and suitability of a part to perform a particular mission can be better understood. Knowing the status of the test equipment itself will contribute to system readiness of the item under test. Finally analyzing the results of testing and repair can lead to improvements in the overall system readiness.