eXpress™ Newsletter

Volume 21, Number 1 | Fall 2015

Evaluating PHM
As an Integrated System Capability

In recent years, defense and aerospace programs have dedicated significant resources toward research in prognostics—developing sensors and measurements that they hope will not only improve system readiness, but also reduce the costs of product sustainment. Designed to identify incipient failures at the lowest levels of the system architecture, prognostic sensors are typically the end result of extremely detailed, yet extremely localized, physics-of-failure analyses. Moreover, the actual parameters of each prognostic measurement emerge only after extensive laboratory testing. Because prognostic sensors are so difficult to develop and assess, the usefulness of these efforts tends to be evaluated in terms of success or failure, rather than on its relative impact upon system readiness or sustainment decision-making.

When Prognostics Health Management (PHM) is evaluated within ***eXpress***, the essential prognostics "data points" are seamlessly integrated with the full system diagnostics. As a result, the overall prognostic capability is assessed from a system perspective, giving us insight not only into the overall impact of prognostics, but also the relative value of individual prognostic measurements. Moreover, we can select whether or not prognostics should be taken into consideration when examining the diagnostic capability of the system. Whereas "prognostics-informed diagnostics" might give us a better sense of the expected behavior of the system in the field, the evaluation of diagnostics without prognostics allows us to account for the fact that the performance of fielded prognostics does not always live up to laboratory predictions.

So, before we get too excited about implementing prognostic solutions that have been proven to be "successful" under laboratory conditions, we must ask ourselves the tough questions, such as "What will actually be gained through the implementation of this solution?" and "What impact will this solution have upon the overall system readiness and/or sustainment?" Of course, at this point, it may be too late to ask the most important question of all: "Will the gains reaped from prognostics be worth the cost of their development?"

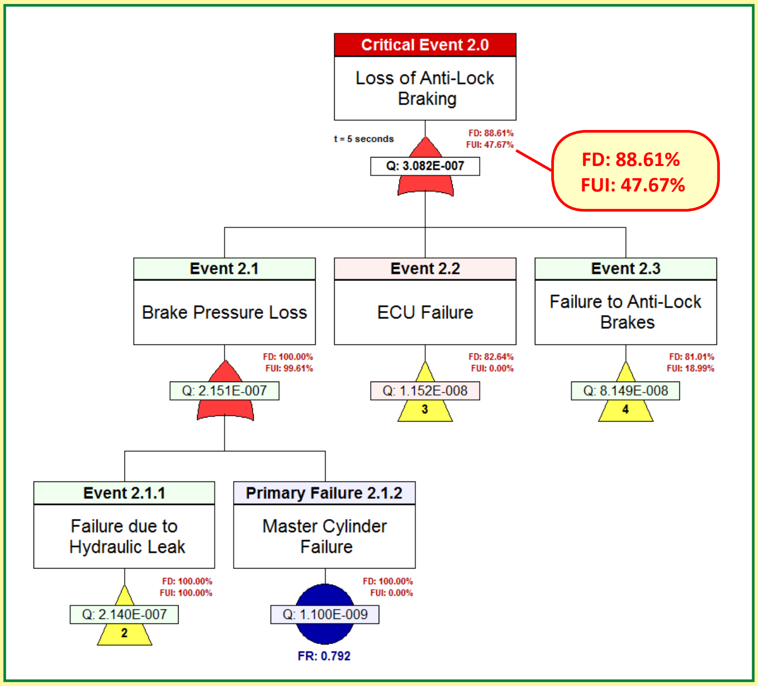
What is missing from most prognostic development efforts is the ability to determine, up front, the expected behavior of an overall health management solution (including the combined performance of corrective, condition-based and reliability-centered maintenance). The expected benefits of proposed prognostic sensors and measurements must be evaluated as part of a total maintenance "package", and compared not with one-dimensional maintenance "straw men", but rather with other viable, multi-faceted maintenance solutions. Moreover, these evaluations had best be performed relatively early in the development life-cycle—well before project resources have been committed to lengthy (and costly) physics-of-failure studies.

Continued on Page 2

Inside this Issue...

Diagnostic Risk Assessment
Using the *eXpress* FTA Module

The new ***eXpress*** Fault Tree Analysis module is finally here! Using FMECA data (failure modes and effects) in your existing ***eXpress*** models, you can automatically build preliminary fault trees for critical top-level effects. These initial fault trees—which at first are simply "inverted FMECAs" (FMECA data presented in a tree-like format)—can then be systematically modified to address redundancy, external events, and other system characteristics that must be taken into account when performing a Fault Tree Analysis.



The ***eXpress*** FTA can display diagnostic metrics for each event in a fault tree. In the example above, the primary (root) failures that can result in the top-level critical event will be detected 88.61% of the time. Unfortunately, diagnostics will be able to determine the precise failure that occurred only 47.67% of the time.

FD = Primary Failures Detected
FUI = Failures Uniquely Isolated

Because the ***eXpress*** FTA utilizes the same data that is used for diagnostic engineering, cross-disciplinary guesswork is eliminated. Reliability, Risk & Safety assessments can thus take into account the behavior of the actual diagnostics that will be fielded for that system. This can reveal new areas of risk that result when diagnostics are unable to adequately identify or isolate the root causes that lead to critical failure.

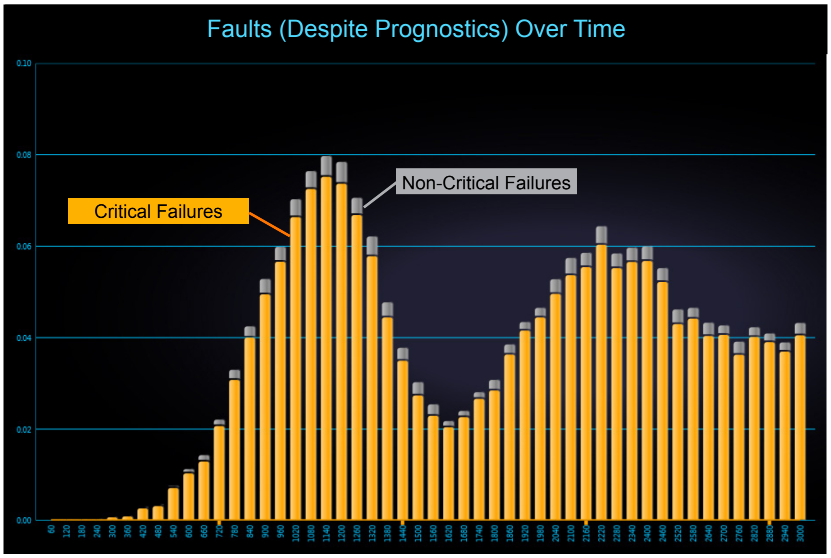
Continued on Page 3

Extensive Data Analytics

From Page 1 (Evaluating PHM)

Using STAGE (which provides simulation-based data charts for the analysis of system diagnostics and support), your overall PHM solution can be assessed and optimized through the comparison of different maintenance *cocktails*. STAGE provides a platform upon which to evaluate the various trade-offs between the development of expensive (and often unproven) prognostic sensors, the use of ineffective ("tight") or wasteful ("loose") maintenance schedules, and the addition of space or weight-consuming hardware redundancy. Moreover, because STAGE directly utilizes data developed in ***eXpress***, the analytics can be produced, analyzed and acted upon long before project resources have been allocated to endeavors that may not result in the desired system benefits.

STAGE provides over 300 different graphs (alternatively viewable as reports)—many of which have been specifically designed for use in maintenance trade studies. Among the system characteristics examined are fault detection & isolation, false removals, mean time to repair, mean time between unscheduled maintenance, false alarms, false system aborts, system availability, likelihood of critical failure, critical failures prognosed, faults that occur despite prognostics, remaining useful life on replaced items, extra cost associated with premature replacement, costs associated with each maintenance category and overall costs (both non-recurring and recurring) of the maintenance solution.



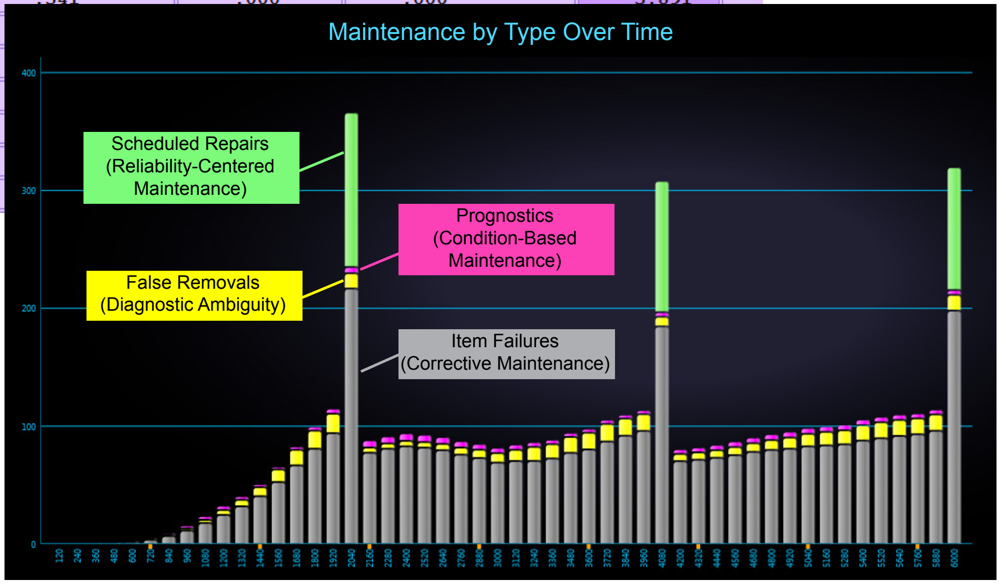
The chart above depicts the rate at which certain faults are expected to occur—despite prognostics having been developed to help predict those faults (these unprognosed faults result from prognoses having a confidence less than 100%). Critical and non-critical failures are categorized separately.

Reason for Replacement Cost Per Item (Number)

##	Items	Replacement Cost (Item Failure/Wear out)	Replacement Cost (Diagnostic Ambiguity)	Replacement Cost (Prognostics)	Replacement Cost (Scheduled Maintenance)	Totals
1	Master Cyl	52.244	204.057	.000	.000	256.301
2	Brk Pedal	27.322	36.938	.000	.000	64.260
3	FR Line	21.295	26.689	.000	.000	47.984
4	RR Line	21.211	26.618	.000	.000	47.829
5	BL Sw	.334	23.764	.000	.000	24.098
6	BL Sw Adj	.503	23.595	.000	.000	24.098
7	Brake Fluid	18.647	17.340	.000	.000	35.988
8	RS Line	37.478	15.731	.000	10.017	63.227
9	FS Line	37.481	15.716	.000	10.030	63.227
10	ECU	1.065	11.834	.000	.000	12.899
11	GF Sense	1.073	11.664	.000	.000	12.737
12	LF Valves	4.296	2.314	.000	.000	6.610
13	RR Bulb	5.550	.341	.000	.000	5.891
14	Fluid Low LED	.011				
15	LR Valves	5.154				
16	F Damp Chmbr	12.627				
17	Pump Relay	.005				
18	R Damp Chmbr	12.628				
19	RF Valves	3.504				

The report above lists the cumulative replacement cost for each item, categorized by the reason that the cost was incurred (in this example, the items have been sorted to show those for which the greatest cost was due to diagnostic ambiguity).

Given the opportunity to perform advanced data analytics during the planning phases of a project, decision-makers can ensure that limited engineering resources are allocated to activities that will have the greatest positive impact upon system performance, readiness and sustainment.

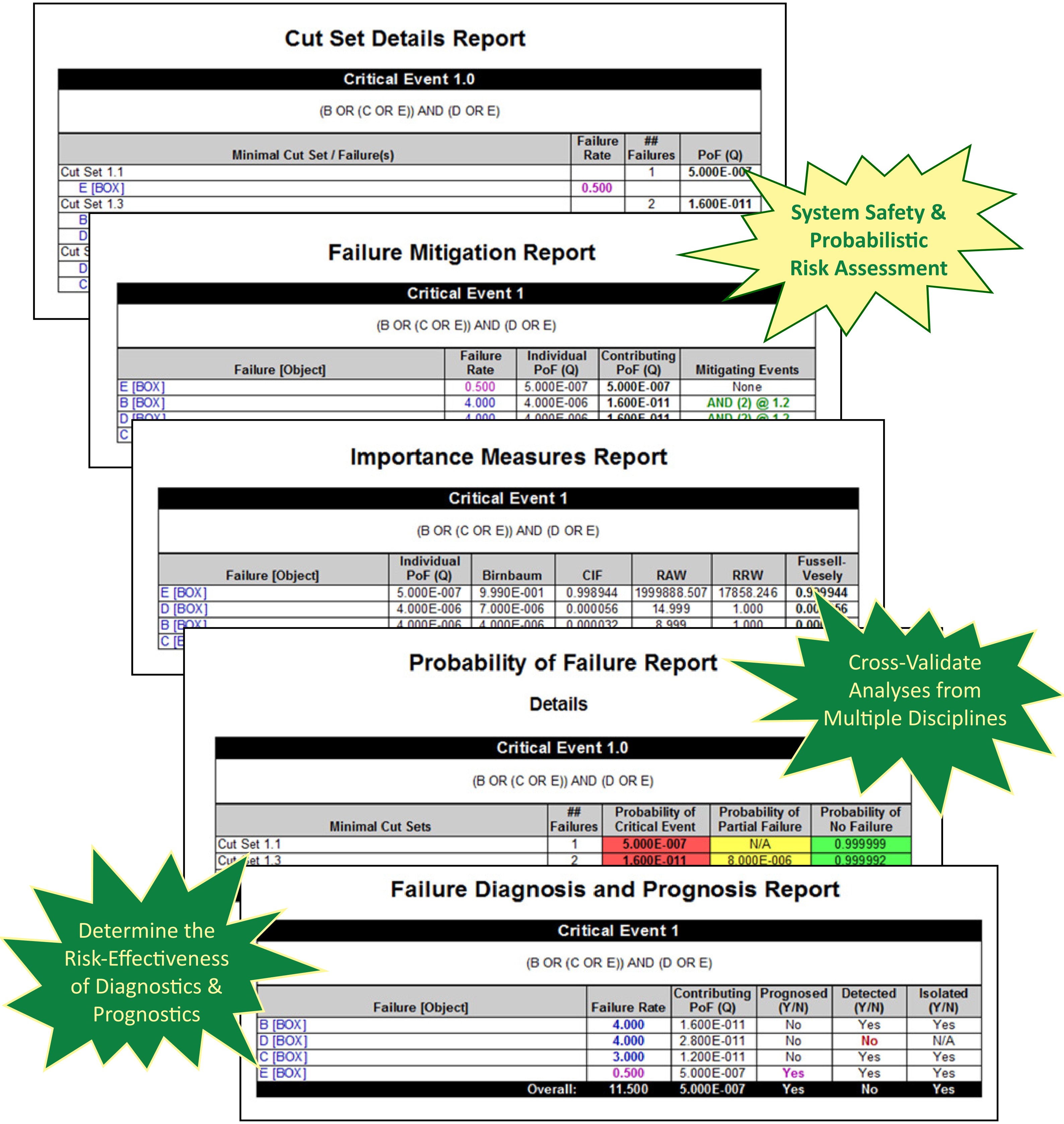


In this graph, incremental replacement costs incurred over time have been categorized by maintenance type (note the periodic spikes as scheduled maintenance is performed.

The *eXpress* FTA Module

From Page 1 (Diagnostic Risk Assessment)

The ***eXpress*** FTA module offers a variety of user-customizable reports, each relating to a different aspect of Fault Tree Analysis. These reports are designed to address key concerns for a variety of disciplines, including (but not limited to) Reliability Analysis, System Safety Analysis, Probabilistic Risk Assessment and Diagnostic Engineering. All reports created by the ***eXpress*** FTA module can be generated as RTF documents, exported as Excel spreadsheets, or saved in XML format.

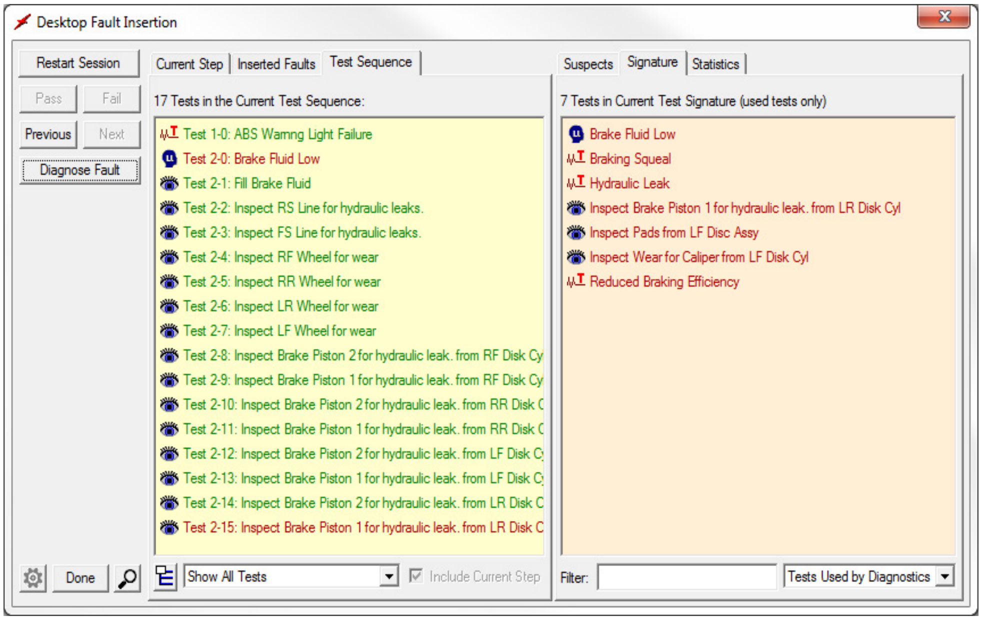


Full System Diagnostic Validation is Here!

Desktop Fault Insertion

In ***eXpress*** 6.5.0, a new Desktop Fault Insertion feature has replaced the Strategy Automation dialog that appeared in earlier versions of the tool. Although similar in concept, this new capability consists of a more fully-featured two-paned dialog and an accompanying report. The dialog and the report can be used separately or in tandem to address a variety of Diagnostic Validation scenarios, including:

- "Sanity Check" explorations of diagnostics in the process of being developed.
- In-house reviews and validation of calculated diagnostic procedures.
- Customer demonstrations of diagnostic strategy deliverables.
- Troubleshooting of diagnostic issues identified during maintenance demos.
- Isolation and resolution of problems that arise with fielded diagnostics.



Desktop Fault Insertion Report

Failure Combination	Fault Signature	Test Sequence	Correctly Isolated	Isolated Fault Group
Battery Charge Low [BATTERY] Damaged [LR Wheel]	ABS Light Stays On Brake Fluid Low Check Left Brake Light Failed Check Rear Window Brake Light Failed Check Right Brake Light Failed ECU:Code 41 Low Battery Positive Voltage Inspect LR Wheel for wear	Brake Fluid Low Fill Brake Fluid Test for Pedal Linkage test for Master Cylinder Inspect RS Line for hydraulic leaks. Inspect FS Line for hydraulic leaks. test Sensor Rotor from Left Front Disk Cylinder test Sensor Rotor from Left Rear Disk Cylinder test Sensor Rotor from Right Rear Disk Cylinder test Sensor Rotor from Right Front Disk Cylinder Inspect RF Wheel for wear Inspect RR Wheel for wear Inspect LR Wheel for wear	Yes	Fault Group # 11
Damaged [LF Wheel] Right Front wheel Sensor Connector 2a Wiring Failure [SENS CONN 2A]	ABS Light Stays On Brake Fluid Low ECU:Code 31 Right Front Wheel Speed Sensor Problem ECU:Code 33 Right Rear Wheel Speed Sensor Problem ECU:Code 36 Right Front Speed Sensor Timing problem ECU:Code 39 Right Rear Speed Sensor Timing problem Inspect LF Wheel for wear	Brake Fluid Low Fill Brake Fluid Test for Pedal Linkage test for Master Cylinder Inspect RS Line for hydraulic leaks. Inspect FS Line for hydraulic leaks. test Sensor Rotor from Left Front Disk Cylinder test Sensor Rotor from Left Rear Disk Cylinder test Sensor Rotor from Right Rear Disk Cylinder test Sensor Rotor from Right Front Disk Cylinder Inspect RF Wheel for wear Inspect RR Wheel for wear Inspect LR Wheel for wear Inspect LF Wheel for wear	Yes	Fault Group # 12

This excerpt from the Desktop Fault Insertion Report (in Excel spreadsheet format) shows two random failure combinations, the set of tests that would fail (fault signature) if these failures were to occur, the sequence of tests used to isolate the failure (with the failed tests listed in red), an indication of whether the fault was isolated to a fault group containing the correct repair item, and the ID of the isolated fault group.

Training Course Schedule

Course Number	Pre-requisite	Course Description	Dates	Location	POC
T-100		System Diagnostics Concepts and Applications	November 9	Orange, CA	Denise Aguinaga, DSI
T-110	T-100	Basic Modeling & Introduction to Testing	November 10 - 11	Orange, CA	Denise Aguinaga, DSI
T-120	T-110	Introduction to Testing & Analysis	November 12 - 13	Orange, CA	Denise Aguinaga, DSI
		ADVANCED TRAINING COURSES			
T-200	T-120	Advanced Model Development and Analysis	November 16 - 20	Orange, CA	Denise Aguinaga, DSI
T-205	T-200	Advanced Test Development and Importing	November 16 - 20	Orange, CA	Denise Aguinaga, DSI

World Wide Representatives

United States

DSI International, Inc.
(714) 637-9325
info@dsiintl.com
www.dsiintl.com

United Kingdom

Spherea
Test Engineering Services
+44 (0)1202 868585
chris.gorringe@spherea.co.uk
www.spherea.com

France

Spherea
Test & Services
+33 (0)6 88 61 33 91
michel.schieber@spherea.com
www.spherea.com

Japan

Y-MAX, Inc.
+81-45-789-0701
massayo@y-max.com.jp
www.y-max.com

South Korea

Realtimewave Co, Ltd
+82-2-572-9471/2
sales@realtimewave.com
www.realtimewave.com

China

MTCS
Systems Engineering Co. Ltd
+86-10-5881-6565
sales@mtcs.com.cn
www.mtcs.com.cn

The *eXpress*™ Newsletter is published semi-annually by DSI International