Integrating Experience with Built-In Test (BIT) to Improve First-Time-Fix Performance[1]

Phil D'Eon
President and Chief Technology Officer
One Kenview Boulevard
Brampton, Ontario L6T 5E6
CANADA

pdeon@casebank.com

Robert Hastings
Director, Gas Turbine Laboratory
NRC Institute for Aerospace Research
1200 Montreal Road
Ottawa, Ontario K1A 0R6
CANADA

bob.hastings@nrc-cnrc.gc.ca

ABSTRACT

"Field experience" is knowledge acquired by people during troubleshooting.

Although today's state-of-the-art, machine-based prognostic and diagnostic systems can automatically identify a high percentage of faults and their causes, human expertise remains an essential part of the troubleshooting support system. When the machine-based diagnostics and the Fault Isolation Manuals fail to resolve the problem, it is an expert person (or persons) that will solve the problem, ultimately – and new, valuable knowledge is generated in doing so.

But can that knowledge be re-used practically for the benefit of others in solving that problem? For that to happen, the knowledge must become part of the troubleshooting workflow such that it is used to identify the problem before expensive and ineffective repairs are attempted, no matter where or when, nor to whom that particular problem next appears.

Traditional attempts to get value from field experience have included strategies such as updating the FIM, creating searchable databases, publishing technical letters, and staffing a Technical Assistance Centre with the most experienced people. CaseBank's analysis of first-time-fix performance on certain commercial aircraft (who use all the above to some extent) indicates that thirty to fifty percent of all troubleshooting attempts fail to resolve the problem.

SpotLight® is a guided diagnostic reasoning system that places field experience directly in the troubleshooting workflow, where it is integrated with BIT results, trend analysis results, electronic technical manuals, and help escalation channels. In applications with mature knowledgebases it sustains a "hit rate" in excess of 90%.

SpotLight technology is being used to share field experience on aircraft old and new – from the C130 to the Joint Strike Fighter – with the necessary confidentiality and security.

1.0 THE PROBLEM

There exists a "reliability-complexity conundrum" with modern aircraft.

Aircraft are highly reliable, generally speaking. But aircraft are also very complex, with a great many parts. The conundrum is that failures are not uncommon occurrences, yet those failures tend to be distributed over a wide variety of causes, each of which happens infrequently. As a result, no single person can have complete knowledge of all failures, and the relative rarity of each fault makes it difficult to cost-justify an expensive engineering remediation for all those faults.

The weaknesses in a design, as implemented in an operating aircraft, become evident through operations, showing up as "the things that fail".

Certain failure modes are exacerbated by factors such as operating environment (heat, cold, sand, humidity, salt), age, equipment configuration, maintenance error, coincidence, operator error, etc.

Engineering analysis can predict many failure modes, but there are significant challenges. First, it is well recognized that unpredicted failure modes will happen, and second, not everything that is predicted to fail will fail exactly as predicted.

The end result is that human intellect is called upon to solve very tricky problems, and in significant numbers. Accordingly, the people who troubleshoot those problems gain valuable experience.

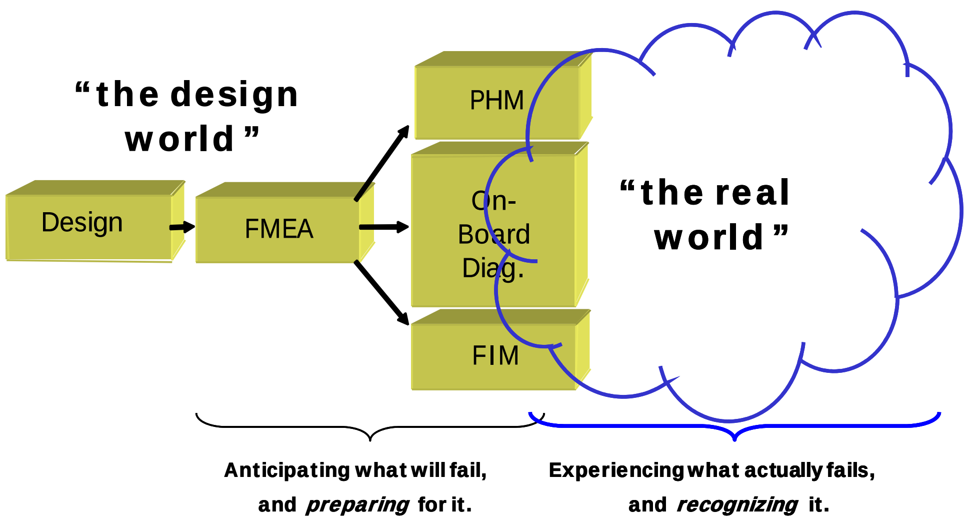

Figure 1: Anticipating and recognizing failures.

Where does this experience reside? The technician greeting the aircraft typically represents a very narrow slice of the entire body of available experience. In the user's organization, there is usually a "fleet specialist" who is familiar with his own fleet problems, and communicates frequently with his peers in other organizations. The manufacturer typically has experience reflecting the problems that are serious enough for operators to seek out their assistance. But every fault that has happened to that type of aircraft has been seen and resolved by somebody out there in the operator community. So, in fact, it is the "global fleet of aircraft operators" that has the greatest experience.

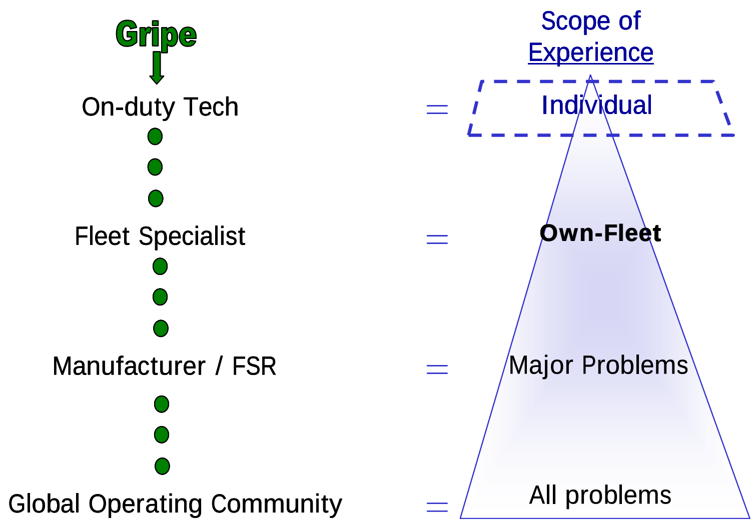

Figure 2: The broad distribution of experience.

That experience needs to be integrated back into the diagnostic system efficiently and effectively. Unfortunately, because of the reliability-complexity conundrum, that "field experience" is spread broadly across the global community of operators of that aircraft type. The goal should be to put the benefit of global experience directly into the troubleshooting process of every technician (represented by the dashed trapezoid above).

After several years in service, the number of truly "new" failure modes that occur to an aircraft are greatly diminished. We start to see repeat instances of "the things that really fail". Most failure modes noted in any given aircraft maintenance log will have been seen and solved already by someone operating that aircraft type somewhere in the world.

Traditional approaches to collecting and re-using that knowledge are updates to databases, to troubleshooting procedures and to sensor-based fault detection methods. These approaches have their own well-recognized challenges, evident in the fact that we are still trying to solve the problem today.

In particular, the challenges faced by sensor-based diagnostic systems are well known. Notably, Built-In-Test ("BIT") is not always able to produce unambiguous results.

Here is an example of a failure mode that is known to exist, but the failure mechanism itself is not well understood. This type of aircraft experiences a failure mode which generates a STALL FAIL message. There are many failure modes that could generate that message, but one of them is, in fact, a faulty boost pump! The boost pump itself performs flawlessly, except that it has a failure mode that generates electrical noise during start up. If one pilot happens to be running a Stall System preflight test while the other is starting the engines, the STALL FAIL message is generated. That is very valuable field experience, and it is very important to bring that knowledge into consideration during troubleshooting.

The following are situations in which field experience is invaluable as a diagnostic aid in conjunction with the machine-based diagnostics:

- The root cause of a fault code is a maintenance error, and not a valid component failure.

- A fault is indicated in one system, but the root cause is in a different system.
- A fault exists, but there are no codes.
- A code exists, but there is no fault.
- Multiple codes appearing simultaneously may indicate a cause other than the intended meaning of each code individually.
- Trend alert is ambiguous regarding the cause – some external causes can create indications of deterioration that are very similar to internal causes.

What is needed is a system that catches the problems that BIT and Prognostics fail to identify correctly, and it needs to be invoked before good parts are needlessly changed.

2.0 THE SOLUTION

Field experience must be (1) captured, (2) integrated with existing diagnostic resources, and (3) delivered as "guided diagnostics".

CaseBank's SpotLight® provides such a solution.

2.1 Knowledge Capture

Field experience is stored in a knowledgebase. The seed knowledgebase is created by capturing documented experience. Typically aircraft logs are mined to discover "the things that really happen".

There is overlap with BIT and FIM (Fault Isolation Manual) results where those resources are correct in identifying the cause of the failure. That knowledge becomes a better interpretation of what the fault codes really mean – multiple possibilities, depending on code combinations, fault modes, etc.

Each failure mode (not each failure event) is represented as a "SpotLight Solution" in the knowledgebase. Each failure is researched, confirmed, described with discriminating symptoms, sanitized of user-identifying information, and enriched with helpful content such as references to maintenance instructions, tips, and explanations.

BIT codes, cockpit messages, and trend alerts become "symptoms of the problem", as opposed to conclusions.

A technician consulting SpotLight creates a "Session" that stores the details, and that session is shared only within the user's own organization – no operator can see another operator's troubleshooting sessions.

Troubleshooting Sessions for which there is no solution in the knowledgebase are captured, investigated, and the results used to prepare a new solution, sanitized of user-identifying information. It is added to the knowledgebase after a quality approval process.

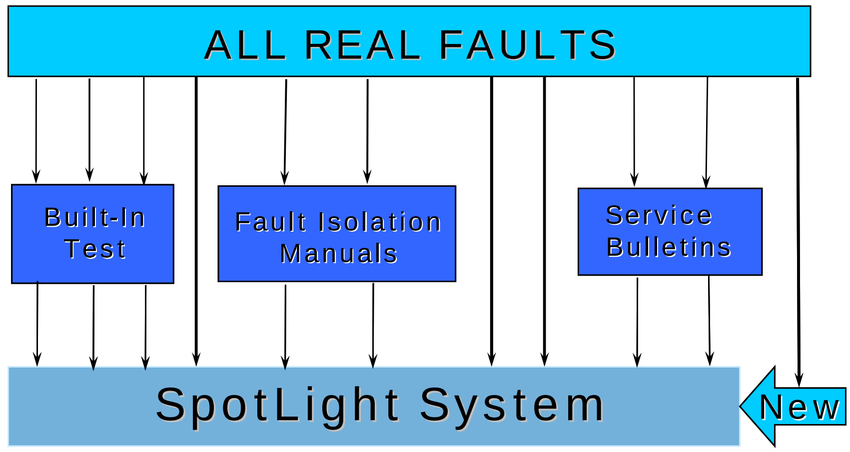

Figure 3: Knowledge capture.

In that way, the knowledgebase content grows as new problems are discovered across the community of users.

Thus each operator organization can benefit from the totality of experience among participating operators, with complete confidentiality.

SpotLight handles vehicle configuration differences, user access controls, privacy issues, and security issues.

To recap: One unified knowledgebase of "sanitized" knowledge is shared by many operators; Troubleshooting "sessions" are not shared – they are private to each operator's own organization; the Sessions will identify gaps in the knowledgebase while at the same time providing most of the information for the new solution.

The maintainer of the knowledgebase (e.g., CaseBank, or Lockheed Martin, or whomever) identifies "new" problems and updates the knowledgebase with quality-controlled new solutions.

2.2 Integration with Diagnostic Resources

BIT: The SpotLight reasoning engine can interact automatically with downloaded data such as fault codes. If a connection to an automated download is not available for some reason, the user will be prompted to provide the information via a diagnostic question. You can think of SpotLight as a system that helps evolve the interpretation of BIT codes and trend results. If a BIT code has never been wrong, SpotLight will not get in the way. But if other causes for a BIT code have been discovered, they will be brought into the reasoning process.

FIM (Fault Isolation Manual): With respect to FIM integration, options are available. Once the available field experience solutions are ruled out, SpotLight can link to relevant FIM procedures, or the content of FIM procedures can be integrated with field experience. SpotLight is, in fact, replacing the FIM in some developing aircraft applications because it eliminates the need for separate FIM creation and maintenance.

IETMs (Interactive Electronic Technical Manuals): SpotLight integrates with IETMs for task support and authorized maintenance instructions through embedded hyperlinks.

HELP ESCALATION: SpotLight has built in asynchronous help-escalation facilities. This provides fault-centric communication that follows the aircraft, and allows collaboration not only within the user's own organization but also with authorized experts from outside the organization, with appropriate controls and security.

2.3 Guided Diagnostics

SpotLight delivers this integrated field experience as “guided diagnostics” that is comparable to the line of questioning that a human expert would follow.

This is generated automatically by SpotLight’s reasoning algorithm and is updated with every new bit of information provided.

The algorithm takes into account:

- The degree of match between the problem conditions identified so far and the attributes of each of the candidate solutions.
- Cost and time of candidate solutions.
- Cost and time of the relevant tests to gather more information (observations, wiring checks, tests, etc.).
- Relative frequency of occurrence of the candidate solutions.
- Operating environment.
- Sounds, smells.
- Recent maintenance activity.

The user is presented with an ordered list of the best diagnostic question to answer next. This provides flexibility, in that the user is permitted to answer only the questions that can be answered in the user’s particular situation.

As more questions are answered, relevant solutions will become more prominent and less relevant solutions will fade from prominence on the user interface screen.

A decision tree can be extracted from the knowledgebase if paper copy is required.

3.0 PERFORMANCE

A key measure of diagnostic performance is SpotLight’s “hit rate”, where a hit means the correct solution is identified. Current aircraft applications are achieving a hit rate in the 90% range after 2-3 years of knowledge capture through use.

SpotLight is applicable to aircraft of any vintage – old and new. The key difference is in the source of the knowledge. For old aircraft, field experience can be captured by mining records. For new aircraft, the knowledgebase can be created from a FMEA database. For example, SpotLight is currently being used on both the C130E and JSF.

It is also applicable to whole aircraft and/or to major subsystems.

For aircraft manufacturers and operators, a SpotLight knowledgebase represents their specific aircraft type with all systems integrated.

For major subsystem manufacturers, the knowledgebase will represent that subsystem as used on many different applications. For example, one engine application supports over 55 different variants installed on over 20 aircraft types.

4.0 SUMMARY

Field experience must be considered an integral element in the diagnostic methodology.

The field experience of a global fleet of operators can be shared through controlled knowledgebases. New knowledge can be captured through diagnostic activities.

SpotLight is a proven system that does this.