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A research study of no fault found (NFF) in the Royal Air Force

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Abstract

The No Fault Found (NFF) problem continues to reduce operational availability and have an impact on cost and resources in the RAF. Following extensive research by the Centre for Innovative Manufacturing in Through-Life Engineering Services, access was provided to a significant number of RAF aircraft maintenance personnel under the sponsorship of Air Command at RAF High Wycombe. Maintenance personnel from seven different aircraft fleets, including large aircraft, fast jets and rotary platforms were involved. A number of substantial conclusions were made resulting in 26 recommendations. The paper reviews and substantiates these conclusions and recommendations.

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Keywords: No Fault Found; maintenance; aircraft; repeat arisings; rogue; fault reporting.

1. Introduction

The problem of faults which cannot be confirmed or the root cause cannot be found, has plagued all industries for many years. When a fault is reported by an operator maintenance effort must be used on fault diagnosis but if no fault can be identified the situation is known as No-Fault-Found (NFF). The work done that results in a NFF having to be recorded costs time and effort either at the operator level or further down the repair chain for items that have been removed for investigation [1] ; there is also an inevitable loss in availability of the asset or assets. A definition therefore of NFF is:

A fault that cannot be replicated or where no cause can be identified that would have generated the reported symptoms.

Access to maintenance data is often difficult and particularly at the granularity required to determine the true level of NFF occurring in an organization. Often managers are blissfully unaware as maintenance personnel are prone to hide what they may see as failure to find the fault. Other reasons for the inability to determine the true level of NFF vary from cultural and human factors reasons to process and organizational issues. The true levels of NFF are thus extremely difficult to determine and even more difficult to properly cost.

As part of the Ministry of Defence's (MOD's) membership of the Centre for Innovative Manufacturing in Through-Life Engineering Services, access was made possible for researchers to interview over 70 maintenance personnel working on seven different aircraft fleets. A range of personnel of different rank and experience were interviewed in order to ensure that the results were statistically valid. Following research previously completed by an RAF senior technician, Chief Technician Stuart Roke [2] for his MSc thesis on the NFF problems of the Harrier aircraft and other literature reviews, a questionnaire was developed that specifically tackled previously identified attitudes and processes in the RAF when dealing with the NFF issue [3]. The aim of the questionnaire was firstly to validate both the previous research by Roke which used only one aircraft fleet and the maintenance personnel experienced on that fleet.

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Secondly it was to significantly expand the research in order to provide an assessment of the NFF levels across the whole of the RAF and ascertain if there were any differences between the fleets of multi-engine aircraft, fast-jet aircraft and helicopters. Twenty-six separate conclusions and recommendations were developed from this research [3]. Whilst the personnel interviewed were currently working on seven different aircraft, the range of ranks and experience was quite diverse. Many of those interviewed had worked on other aircraft and brought that experience to their responses. Inevitably however, there were a high number of junior ranks particular on the two larger fleets and many of their responses were therefore in the "don't know" category. Nevertheless because of the large number of personnel interviewed overall there were enough responses to each question to provide a significant positive or negative view to be registered. Whilst there were 27 questions, each person was encouraged to complete the questionnaire in isolation and was then interviewed in depth by the two researchers who were able to expand the views and responses to each question and to record additional anecdotal corroboration.

The questions were framed in such a way as to provide an unbiased answer [4]. Whilst each question was then analyzed and reported, the views from interviews often crossed over many different questions so providing a body of evidence under more general topic headings. These more general topic headings then allowed conclusions and recommendations to be formulated, which are explained in the following sections.

Nomenclature

AESO	Aircraft Engineering Standing Order
BIT	Built in Test
LITS	Logistic Information Technology System
LRUs	Line Replaceable Units
MAA	Military Aviation Authority
MOD	Ministry of Defence
NFF	No Fault Found
RAF	Royal Air Force
RAT	Repeat Arising Tool

2. Survey results

2.1. Fault reporting

Despite a general impression that aircrew debrief and report every fault satisfactorily and accurately, subsequent questioning confirmed that there was much variation. Indeed whilst some positives were identified, too many negatives were also described. There were some improvements on the most modern fleet due to improved technology and systems for reporting faults, but even these could be easily improved.

The use of a special fault reporting proforma for the legacy fleets was often cited as a way to capture the relevant information more accurately and provide a step-by-step process that guarantees relevant information for the maintenance personnel is always captured. Ensuring aircrew give a comprehensive debrief as possible to the right level of skilled maintenance personnel was a key enabler to reducing subsequent NFFs.

An example of best practice was a computerized fault reporting process that had been developed for the Tornado. It was in effect a computerized debrief proforma, which ensured that as much relevant information and symptoms were captured as to what the aircraft was doing when the fault occurred. This allowed the engineers to have as comprehensive picture as possible for their fault diagnosis.

Experience of both aircrew and engineers were clearly a factor in both fault reporting by the aircrew and the interpretation of the report by the engineers. Inexperience by the aircrew might highlight irrelevant factors or might have caused the fault in the first place. Inexperienced engineers might make incorrect assumptions on the diagnostic path to take. All were likely to end in a NFF.

2.2. Fault history

It was clear that there was inconsistency across the RAF with the ability for all engineers, regardless of rank to have access to fault history and this limited the ability of the more junior ranks to show initiative and resourcefulness in fault diagnosis and to show their development potential. In some areas it was a lack of maintenance data terminals but there was a general policy of not being trained and authorized to access the terminals and therefore the fault history until achieving the rank of corporal. Without the ability to investigate fault history adequately, it was inevitable that many diagnostic tasks would merely repeat past failed maintenance tasks or replace the same item that had clearly not solved the problem on the previous occasion. This maintenance task would consequently appear as a fault being rectified but was in fact nugatory work and was hiding the true level of NFF.

There was consequently a reliance on diaries monitored by the trade manager, but such diaries rely on the thoroughness and availability of the manger and are less than perfect.

Fault history also relies on the quality of information written on the job cards, which was deemed to be extremely variable particularly as equipment travels further down the supply chain for subsequent test and repair. If the original fault information is not comprehensive the original fault may be missed and be dormant, so occurring subsequently when the item is returned to service.

2.3. Repeat arisings

Certain units or components have intermittent faults or faults which defy all attempts by test and repair organizations to solve them; they are so-called "rogue units". Any diagnostic process should therefore first check whether the reported fault is a repeat arising, yet the study showed there was a general lack of awareness of both the need for and of the benefits of tracking repeat arisings as a vital aid in the identification of "rogue" items. Whilst the MOD's maintenance data system (LITS) does have a facility - the Repeat Arising Tool (RAT) - for checking for a repeat arising, it was not enabled for every fleet and was in itself difficult to use and access. Navigation was required through numerous levels before the correct page was presented.

Other systems in use included a local database where units being tested and repaired were all monitored on a locally produced database that specifically tracked how often the item had been through the facility and such information as to work done during its last visit and numbers of hours operated between visits. This identified "rogue units" successfully among other things and the rogue units could be quarantined.

2.4. Human factors

Human Factors issues were clearly an over-arching reason for personnel avoiding to declare NFF. In the past there had been more of a blame culture but there was now more recognition of the need for honesty in admitting mistakes or the inability to find a fault. Consequently, whilst human nature would always be prevalent in not wishing to admit failure, this was less of an issue in the modern RAF. Time and pressure, however, were still perceived to be reasons that effective diagnosis would or could not be carried out. Again the more "just culture" that now existed had reduced the number of occasions that time or pressure would cause a NFF.

2.5. Policy and procedures

The research showed that there was an inconsistent policy across the RAF for the management of NFF. There was currently no general, overarching, policy for dealing with NFF. The accepted policy document, AP100B-01 would be the natural place for such a policy for the management of NFF in general terms. It would direct each aircraft fleet to have a local order for the management and resolution of NFF in the form of an Aircraft Engineering Standing Order (AESO). The general top-level policy was needed to provide consistency where none existed at present. If true that in some circumstances that a NFF was a potential safety issue, then this was a serious issue needing to be resolved.

On stations where there was an AESO, it was clear that if it was too complicated it would not be applied properly or thoroughly, so there was a case for a balance to be struck between it being too simple and too bureaucratic and complicated. An AESO at station level provides the structure for dealing with NFF and is an excellent and effective management tool with which to highlight the impact of NFF and the need to identify and track repeat arisings.

2.6. Management information

The research results highlighted more and more about the need for quality management information. As with human factors where there is often a reluctance to declare NFF and to consequently code it as NFF in the management information, the research showed that this resulted in the inability of management to realize the true level of NFF. Reasons for this reluctance were established as complex and ranged from reluctance to admit defeat to the pressure caused by needing to show something had been done. Nevertheless, it was seriously reducing the management information as to the exact impact and cost of the NFF problem. Education was thus required to explain the need for coding and declaration of NFF which was essential if management was to be able to monitor the true impact and costs.

Much of the management information required was being hidden by the prevalent use of alternative phrases which avoided the need to declare NFF. The use of descriptive phrases, such as "tested satis," in fact hide the fact that a test has been carried out and no fault shown; so this must be coded as a NFF in order for the management information to be correct.

There was clear evidence that personnel believed that NFF was being under-recorded; it was partly an education issue where it was necessary to emphasize that it was acceptable to declare NFF and this should be seen as part of the wider "just culture" attitude and not something bad.

The research showed that regular monitoring and analysis of NFF rates system by system and subsystem by subsystem was regularly needed on all fleets in order to identify and reduce NFF rates.

2.7. Reasons and contributory factors for NFF

The experience of both aircrew and engineers was highlighted as being a significant factor in causing NFF. On the other hand NFF was often not declared due to personal pride in trying to locate a fault. Lack of sufficient and clear debrief information from aircrew was also cited as a cause.

Technical 'manuals' were also frequently mentioned as a cause of NFF due to inaccuracies or procedures that were hard to interpret and to apply.

'Time', 'Pressure' and 'People' factors were also identified by the research as inextricably inter-related in causing NFF to be declared (Figure 1). 'Pressure' was often self-induced and there was still some pressure being experienced by some engineers, usually in order to deliver operational availability [5] to meet the flying programmes. 'Time' and 'Pressure' were, however, often cited as reasons for NFF due to the shortage of assets, which meant aircraft availability was often critical requiring the changing of something, e.g. a component or subsystem, that was available.

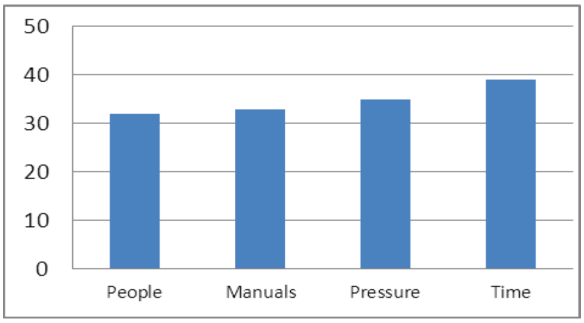

Figure 1 – Main reasons for NFF problems on fleet

The improved safety culture (post Haddon-Cave) has, nevertheless, established that in general 'Pressure' is not felt in the same way as it used to be. 'Time' was cited as a contributory factor because if everything is done in accordance with the published procedures it would take too long. Consequently, NFF might be the result of procedures that were short cut or not done thoroughly. 'Other' reasons cited were, spurious faults on computer systems with NFF being caused by software nine times out of 10 occasions. A common theme across all the fleets analyzed was that NFF was most prevalent in general avionic systems and that it was often software that was suspected as the main cause.

2.8. Engineering practice

Post Haddon-Cave and the creation of the Military Aviation Authority (MAA) meant that the culture or behaviours had indeed changed for the better with maintenance personnel now more at ease with resisting pressure and spending the correct amount of time on diagnostics and with no fear of stating an NFF.

Research showed that on some fleets where there were insufficient spares, it did generate attitudes of changing an item just because it was in stock. This would inevitably usually generate an NFF. In most fleets surveyed, the availability of the required spares was a problem and so it did generate a higher level of changing what was in stock rather than what should be changed. This generates what is known as "Phantom Supply Chain," where changing what is in stock is the norm and so the supply system sees a higher turnover of those items and therefore procures more. Meanwhile the real item that is required is not available and is not changed and therefore no more are procured. The supply system, therefore, can be said to be having an impact on the type and effectiveness of maintenance being conducted.

Research also showed that the practice of changing multiple Line Replaceable Units (LRUs) to solve a particular fault is quite often done usually as a way of saving time to declare the aircraft as serviceable and available as soon as possible (Figure 2). As the subsequent NFF costs are hidden (further down the repair chain) there is no incentive to avoid this practice; it nevertheless places excess strain on the supply and support system and causes extra cost that could be avoided.

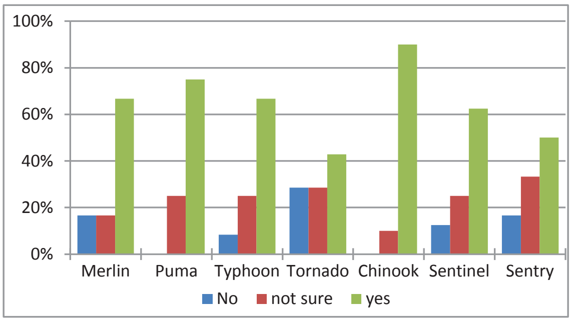

Figure 2 - Are there occasions when multiple LRUs are removed?

2.9. Engineering issues

Research and analysis of questionnaires identified Built in Test (BIT) that is used whilst the aircraft is on the ground is not representative of flight conditions and therefore might not isolate some faults. Whilst fairly obvious it is a continuing frustration for maintenance personnel. Similarly personnel identified that manuals and processes have to be correct so that when a BIT identifies a fault, the correct and reliable process is available to find the root cause quickly.

Representative flight conditions, such as temperature, vibrations and altitude, cannot be replicated on the ground and therefore often result in NFF as the fault is unable to be reproduced. On-aircraft ground tests and off-aircraft bench tests are therefore generally unrepresentative of the true operational or environmental conditions and many examples could be quoted by personnel interviewed. Nevertheless, it is accepted that more representative testing is probably too difficult in most cases, particularly where off-aircraft bench testing is done in isolation of other integral aircraft systems; in this case the tests are unrepresentative of the actual aircraft system operation and the other aircraft system inputs. Vibration and temperature though were agreed as being very useful for many items as well as being able to represent the longer sorties now being completed by some aircraft; it was accepted that "G" is the one condition that cannot be applied to any off-aircraft testing.

Conducting the test and repair of components as close as possible to where the user is operating provides a much better service to those maintaining the operational availability of the user. An example of where improvements in testing and repair procedures were made was shown after testing in an environmental chamber; it identified issues that were unable to be seen by normal testing in the bay and these were able to generate improvements in the repair procedures and processes. It was clear that certain LRUs with high NFF rates and where vibration and/or temperature are suspected as contributory factors, could benefit from being tested in an environmental chamber.

2.10. Training and awareness

One of the most clear and positive results from the questionnaire and subsequent interviews was the need for training and education on a range of issues from basic awareness of the costs and impact of NFF to training on diagnosis techniques (Figure 3). There was a requirement to fully understand what was a NFF. Opportunities were available on the various aircraft Qualification Courses (Q Courses) and on the junior management courses to highlight the impact and costs of NFF. However, training on the general issue and impact of NFF is almost non-existent and was overwhelmingly agreed as being necessary.

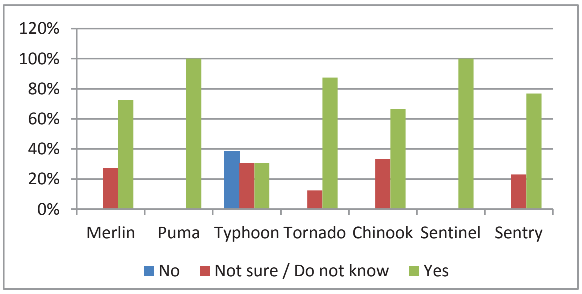

Figure 3 – Would NFF resolution training help?

3. State of the art in aircraft maintenance

Similar research into the human factors issues that impact NFF has been conduct in the civilian airline industry [1] [6]. Topics covered included testing resources, both on and off aircraft, maintenance manuals, organizational pressures and training. The results correlate with those discussed above.

Lack of training on test equipment and unrepresentative test conditions were similarly cited, with some stating they had received no training on test equipment. This analysis had not considered whether the maintainer had received any NFF training so a direct comparison with the RAF cannot be made. However, within the best practice guidelines specific NFF training was recommended. Additionally, “the quality and lack of comprehensive technical content” [1] of manuals affected the ability of the maintenance personnel to conduct adequate diagnostics into the cause of the fault. Time and pressure were likewise given as a reason for not being able to correctly diagnose the fault.

4. Conclusion

The research and analysis undertaken identified was comprehensive and thorough and statistically significant having interviewed over 70 personnel. The range of experience and rank ensured that the conclusions and recommendations would be credible. The foregoing sections have summarized the conclusions and the 26 recommendations for the MOD which if applied would make a significant impact on their NFF costs.

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