CHAPTER 12

CAUTIONS AND PRECAUTIONS IN THE USE OF IN-SERVICE R&M DATA

CONTENTS

1 INTRODUCTION

"…. when you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot express it, your knowledge is of a meagre and unsatisfactory kind".

Lord Kelvin, Popular Lectures and Addresses, v1 pp 80 Macmillan, London 1891.

1.1 The process of gathering data from in-service equipment is beneficial to the performance of both current and future equipment. However such a process is fruitless unless all the relevant data is collected, stored and analysed. The problem is further complicated due to the scarcity and expense of the collection of high quality in-service data. This often leads to the temptation to use data that has been collected for a particular purpose to be used to meet a similar, but different, requirement. This can be done provided that certain precautions and measures are taken, some of which are discussed later in this chapter.

1.2 There are several measures that can be taken to ensure that in-service data can be used to establish Availability, Reliability and Maintainability (R&M) characteristics of a given system and predict the likely performance of a new system. These measures can be implemented right from the definition of the initial requirements through to the briefing that the maintainers receive prior to and during the in-service trial itself. This chapter aims to highlight some of the issues associated with the data that in-service trials produce and, in particular, the measures that need to be considered both before and after the trial to produce meaningful data.

1.3 Further guidance on in-service trials can be found in Def Stan 21-16 (incorporating Naval Engineering Standard 1016 (NES 1016)): Requirements for the In–service Collection and Analysis of R&M Data For Naval Systems.

2 ABBREVIATIONS

R&M	Availability, Reliability and Maintainability
ERL	Event Record Log
LRU	Line Replaceable Unit
MTBF	Mean Time Between Failure
NES 1016	Naval Engineering Standard 1016

3 CONSIDERATIONS IN THE DESIGN OF EXPERIMENTS

3.1 An R&M data collection trial has to be viewed as a scientific experiment and is subject to the requirement that the conditions and circumstances of the trial satisfy the use of 'scientific method' in the design of the experiment. The design of the experiment should refer to the process of planning the experiment so that appropriate data will be collected. This data would then be analysed using statistical methods to provide valid and meaningful conclusions. The requirements of good experimental design can be summarised as follows:

- The questions to be answered must be correctly formulated;

- The experimental method must take into account the precision required and the various pitfalls and problems that may be encountered;
- Systems undergoing differing treatments (in the case of R&M – environment, usage and demand profiles) should be treated in the same way throughout the trial period;
- Random errors of estimation should be consistent with the parameter being measured;
- A proper statistical analysis of the results obtained should be possible without making artificial assumptions.

3.2 Reliability and Maintainability characteristics both provide an indication of the system performance and requirements. However, measuring Reliability and Maintainability characteristics requires two differing needs from the data collected:

- Maintainability can be assessed like many other parameters by taking a random unbiased sample and measuring the mean and variation. Thus, a reliable estimate of the Maintainability characteristic is obtained;
- Reliability is almost unique in that its measurement has to based on, or near as possible, 100% capture of all the events that have taken place. Any loss of data will result in an underestimate of the failure rate and, as a consequence, an overestimate of the Mean Time Between Failure (MTBF).

4 DEFINITION OF THE OBJECTIVES OF THE DATA COLLECTION TRIAL

4.1 It is important to ensure that the objectives for the use of the data align with those set out prior to the data collection. A trial where the objectives have not been clearly stated in the initial requirements may lead to a plentiful supply of data that does not reflect the purpose of the trial and is of little use. This is a significant and costly mistake to make.

4.2 Should a particular sub-system have a high software reliability requirement or have recently undergone a software modification, for example, the trial needs to be tailored in such a way to accommodate any such software incidents. Emphasis on the importance of the software requirement and what will constitute a software incident during the brief for the maintainers is of paramount importance. The maintainers brief should improve the quality of data recorded and provide a clearer indication of how the software under test is performing. Where a modification or upgrade to a particular sub-system is in place, the scope of the trial should also extend to any systems or subsystems that may be affected by the change. This will not only test the modified equipment but will also test how well the change has been integrated.

4.3 Consideration of the system definition, in terms of the level of detail required, needs to be assessed during the definition of the initial requirements. For example, there is little gain in collecting detailed data down to component level when the interest lies only at sub-system level. This approach produces a large amount of data requiring significant processing and time consuming analysis to achieve desired output. Conversely, little is gained by reporting at a system level if the interest is at Line Replaceable Unit (LRU) level. This leads to a trial lacking any detail and lacking in purpose. The key point to note is to ensure that the definitions set out in the initial requirements are consistent with the planned level of reporting for the trial.

4.4 Once the system definition is complete, the length of the trial should be considered. The proposed length of the trial required to achieve the necessary confidence in the results should be included in the trial requirements along with the number of trial vessels and their expected period of involvement. Before any detailed analysis occurs, compare the calculated length of the trial with what is expected of the trial requirements. If the trial is deemed too short then the trial is incomplete. Data produced from a trial that is too short does not provide enough confidence in the results.

5 PRECISION REQUIRED AND PIT-FALLS THAT MAY BE ENCOUNTERED

5.1 When conducting an in-service trial, the circumstances that the maintainers have to endure can lead to difficulties in recording data. There is increased pressure on the maintainer to not only complete their daily tasks but, in addition, complete the Event Record Logs (ERL) of the trial and complete them as accurately as possible. The criteria for reporting events should ensure that a data entry is made upon any change in system or sub-system state. If this criterion is not adhered to then the data returns become effectively unusable for R&M analysis.

5.2 A bad example to follow is the "half-hour rule" whereby a failure need not be formally documented unless it took more than half an hour to restore to a fully operational state. As an example, software reboots may only take minutes but will severely degrade a platform's self defence system, it is therefore essential that these events are recorded. The type of approach, following the half hour rule, produces a trial greatly lacking reliability data in the sense that, the measurement of reliability has to be based on as or near as possible 100% capture of all the events that have taken place.

5.3 Extreme weather conditions may have a detrimental effect on the completion of the ERLs, thus impacting on the data returns from a trial. Consider a system on board a ship that, should a particular subsystem fail, requires a maintenance task on deck. If the weather is severe enough to cause hazardous working conditions, the maintenance task may take longer to complete. If this is the case then a description of the environmental conditions should be added. These extra comments can then be used to add clarity to the data analysing process.

5.4 Further inaccuracies can occur should the maintainer delay recording an event as a result of simply not being present or available at the time of failure. Maintainers are often responsible for more than one system so could quite easily miss the failure occurring. Again if this situation occurs, the maintainer should add further description in the ERLs. For every event recorded it is essential that there is space for additional comments so that further substance to the data can be added.

5.5 The following table, Table 1, highlights a very poor example of an ERL. The code ‘O’ stands for fully operational and ‘D’ stands for degraded. The recording period should have reflected an entire month of data collection. With only one entry made, no estimation can be made on when the failures occurred, the number of failures occurring, what measures were taken to repair the failing equipment, how long the repairs took to make, etc. The only information that can be gleaned is that there was a problem with Processor 2.

Event Date and Time	System State	Processor 1	Processor 2	Display 1	Display 2	Server	Radar Unit	VDU & Keyboard	Comments
Various Occasions	O	O	D	O	O	O	O	O	Processor 2 Fails

Table 1 A Poor Example of an Event Record Log

5.6 Table 2 shows an example of how an ERL should be filled in. The codes H, M and C stand for hardware failure, awaiting material support and corrective maintenance respectively. The time taken to diagnose the repair was two minutes, to wait for a part took 23 minutes and to fit the part took five minutes. The total time taken from failure of the item to the system being fully operational was 30 minutes. The information shows exactly when and where the failure occurred and how long the failure took to repair. What it also shows is the effect on the overall system. The system, labelled as System State in Table 2, is in a degraded state, coded D, throughout the whole event. When the hardware failure occurred in Table 2, a defect report form called an S2022 was raised. The serial number of the S2022 has been marked in the comments column of the ERL. This form allows the maintainer to provide more detail regarding the failure. Implementing this process throughout the trial increases the traceability of failure.

Event Date and Time	System State	Processor 1	Processor 2	Display 1	Display 2	Server	Radar Unit	VDU & Keyboard	Comments
18/07/00 12:15	D	O	**H**	O	O	O	O	O	Processor 2 fails. S2022 Serial No: A123456
18/07/00 12:17	D	O	**M**	O	O	O	O	O	Waiting for Processor 2 from stores
18/07/00 12:40	D	O	**C**	O	O	O	O	O	
18/07/00 12:45	O	O	**O**	O	O	O	O	O	Back on line

Table 2 A Good Example of an Event Record Log

5.7 Comparison of Table 1 with Table 2 shows that briefing the maintainer on the importance of the trial and the importance of accurate entries in the ERLs are key to the success of any trial. Interim reporting methods are also a useful way of catching this type of problem early. If interim reporting highlights this problem, the maintenance staff can be briefed again so that further reporting errors do not occur in the future.

5.8 If the stores demand data is all that is available then difficulties can arise when trying to perform an analysis. Problems in interpretation can occur because for any data entry it will be unknown whether a replacement part was due to planned or corrective maintenance. In addition, it will not be known how long the repair took. This will inhibit any repair time or Maintainability calculations. In addition, stores data cannot provide failure data where the corrective action does not require a replacement item. A software reset, for example, requires no spares to return a system back on line.

6 DIFFERENCES IN THE TREATMENT EXPERIENCED ON INDIVIDUAL NAVEL VESSELS

6.1 Deciding when an In-Service R&M Trial should begin in order to maximise useful data returns requires some careful considerations. It is important that usage of equipment is representative and consistent with the objectives laid out in the initial requirements. This can lead to too much or too little usage due to varying roles of ships, for example, the use of the Hunt Class as an NI Guard Ship would result in no usage of a Sonar System and produce little useful data. There is also little use in beginning a trial on board a ship if it will be spending significant time alongside.

6.2 Another consideration is the number and location of the trials taking place. The consistency of data obtained can become an issue depending on the perception and judgement of each of the maintainers of the system under investigation. Discrepancies in the recording have been known even when two trials are taking place on board the same ship. The maintainers need to be briefed on how accurate the data recording process is required to be and what is defined as a failure.

7 RANDOM ERRORS OF MEASUREMENT

7.1 Analysing results from a trial will usually require a calculation relating to failure of a particular system or subsystem, for example, a failure rate. This failure rate should not only be expressed as a point estimate of a mean but should also be expressed using levels of confidence. Just using the point estimate of a mean is of little use. As an example, data collected for a system may show that the system exhibits a constant failure rate. If several of these systems are in-service, we cannot say with any certainty that any one of the systems will fail after a given time. What we can do after calculation, however, is make a statement regarding the probability of failure. We can go further still and state that, within specified statistical confidence limits, the probability of failure lies between certain values above and below this probability. Using confidence limits provides a more defined level of certainty in the results produced dependant on the level of confidence required.

7.2 The failure rates of repairable items can also vary with time so it is equally important to consider these trends and not only establish the average or mean failure rate. A constant failure rate may result from externally induced failures. A constant failure rate is also typical of complex systems subject to repair and overhaul, where different parts exhibit different patterns of failure with time and parts have differing ages since repair or replacement. Repairable systems can show a decreasing failure rate when reliability is improved by progressive repair, as defective parts which fail relatively early are replaced by good parts. An increasing failure rate occurs in repairable systems when wearout failure modes of parts begin to predominate. Planned maintenance is often a task occurring during a trial period.

7.3 Monitoring this task and the failure rates throughout the duration of the trial may provide an indication of the usefulness of the periods of planned maintenance.

7.4 In reliability engineering, Weibull probability analysis is the most widely used of all the techniques for establishing variable failure rates. This is due to the flexibility of the Weibull distribution in describing a number of failure patterns.

7.5 Quite often during in-service trials unavoidable periods occur where no data has been recorded, for example a period of time where a vessel is alongside. Time truncated data returns need to be taken into account when performing variable failure rate analysis or trend analysis. These periods of time, usually recorded as being switched off, essentially need to be removed from the time-scale of the trial so that the time-scale represents only periods where the system is being operated.

8 AVOIDANCE OF ARTIFICIAL ASSUMPTIONS

8.1 When the time comes to conduct the analysis of data for a trial on a system across several different vessels, it may be apparent that there are significantly fewer failures on some vessels compared with others. An assumption that is often made at this stage is that the number of failures are proportional to the operational time, number of cycles or number of firings accumulated on each of the systems during the trial. Part of the analysis of data should include calculations of these parameters so that MTBF, or other appropriate parameter calculations can be made.

8.2 Throughout the life of many systems, modifications may be required for a variety of reasons all essentially concerned with improvement of the product. If a trial is taking place over a number of different vessels, an important factor to consider is the modification state of each system. By knowing the modification state of the system, part of the analysis of data can involve grouping the data according to the modification state. This is a useful exercise in that one would expect to see fewer failures in a more recently modified system than one having been modified at an earlier date. This may not always be the case as any changes to any system may have unforeseen outcomes which see a deterioration in performance. It is therefore important to find out what version or modification state the equipment is in prior to the trial and not assume that an improvement in reliability is linked to a more recently modified system.

9 SUMMARY

9.1 The obstacles and hurdles to encounter when obtaining and interpreting in-service data, which have been highlighted in this chapter, if not tackled properly can reduce the usefulness of any in-service trial. A number of methods exist to minimise the risk of poor data returns but essentially, if the requirements of the trial have been clearly defined and procedures are in place to effectively monitor every stage of the trial, the risk of obtaining unusable data is greatly reduced. The monitoring process should be in place right from the definition of the trial through to the last batch of data returns.

9.2 The main aim of an in-service trial is to influence design. 100% data capture, or as near to it as possible, coupled with a data recording method that is representative of the system under test are key elements of the reliability data collecting process. These elements facilitate the interpretation of failure data. Each failure should be attributable to a root cause to assist in further investigation and any corrective actions that maybe required.

Remember:

If you are not keeping the score you are only practising – what gets measured gets done!