CHAPTER 11

RELIABILITY TRIAL DESIGN, IMPLEMENTATION AND DECISION MAKING – A THINK PIECE

CONTENTS

1. Purpose

1.1 There are numerous standards, guides and text books on Reliability trials, the majority of which assume the reader understands the subject and needs assistance with implementation of some aspect of the trial. This paper aims to give an overview of how trials link into the main engineering and programming effort.

2. Introduction

2.1 Reliability trials are a well proven method for gaining knowledge on the reliability characteristics of products. Trials fall into two broad categories:

- Growth trials – which are intended to rapidly identify weaknesses allowing fixes to be applied, and hence the reliability of the product increased
- Measurement trials – which are intended to assess the actual reliability of a product

2.2 In the purest sense these trials are clearly different as one involves improving the reliability while the other is about assessing the reliability. In practice these is some overlap as a reliability growth trial will allow an assessment of the reliability, while a trial to assess the reliability may identify weakness which can subsequently be eliminated.

2.3 The relationship between trials and the product programme is shown in Figure 1, this is further described later

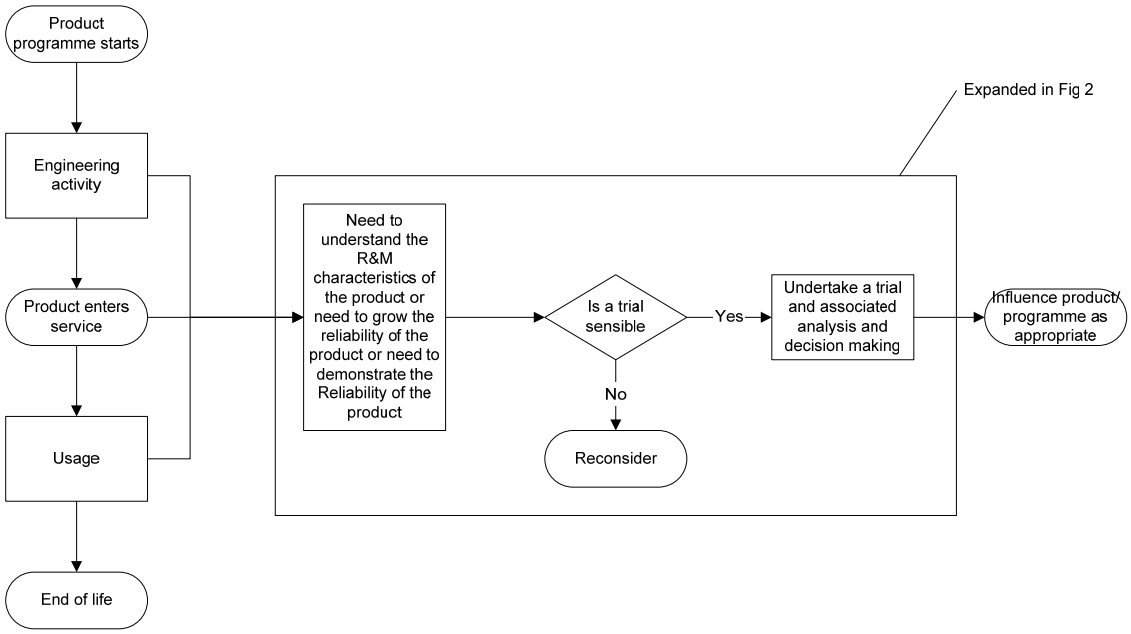

Figure 1 – How trials relate to engineering and usage activities

2.4 The considerations around a trial are shown in Figure 2 and again these are expanded later

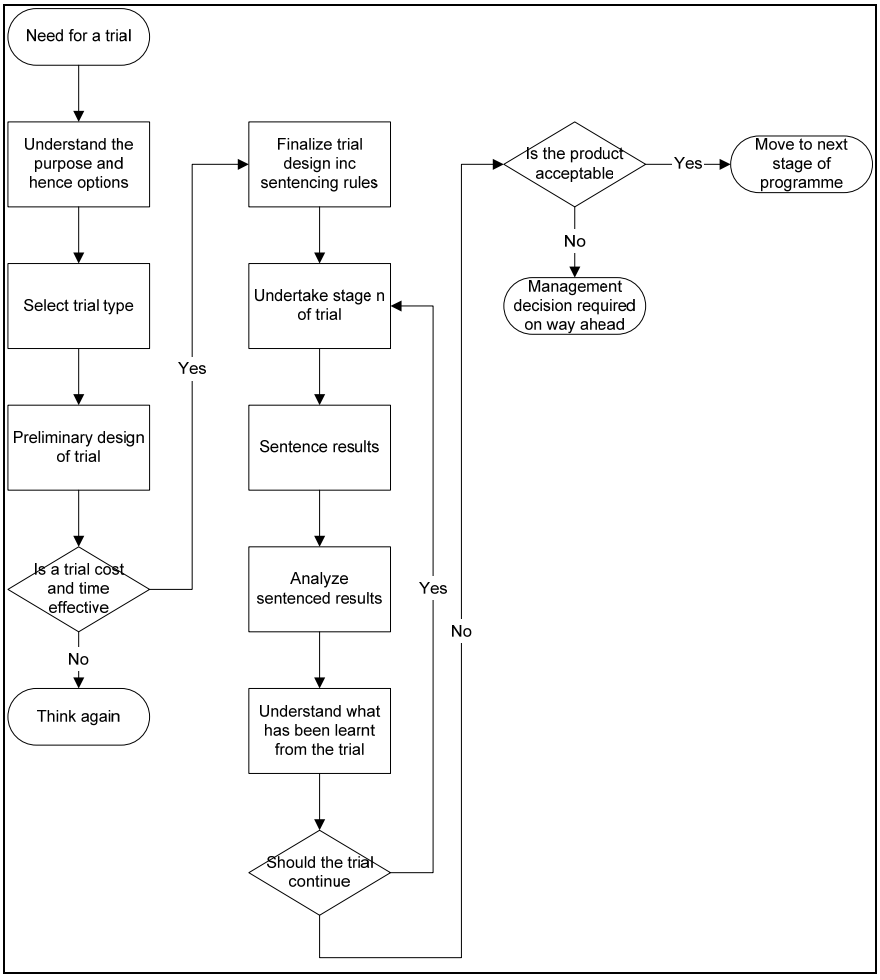

Figure 2 – an overview of the totality of a trial

2.5 At some point in the product life there maybe a need to:

- Assess the reliability characteristics
  - To gain confidence/demonstrate that it is fit for purpose
  - To baseline the characteristics
  - To understand weaknesses/potential
- Do activity to improve the activity (noting that trialling is not the only way of improving the reliability[1]

[1]For a detailed discussion on the subject of reliability growth inc non testing approaches see IEC/IEEE standard 61015 – Programmes for Reliability Growth

2.6 The various standard tests are described at annex A, while references giving specific details on trials related subjects are given at annex B

2.7 Understanding the purpose of a trial is vitally important as the selection of the wrong approach will result in considerable time and effort being expended without achieving the desired goals (if the aim is to understand the reliability of the final product in a hot and dusty environment over a mission length measured in days a trial which consists of a prototype with a different engine, many systems missing being driven in the UK for a few kilometres is unlikely to prove very much)

2.8 Having understood the trial purpose it is possible to select an appropriate type of trial, subsequently using the appropriate standard it is then possible to design a trial. For most trial types there are internationally recognised standards which standardise the calculations associated with the trial, although there is still a need to agree various parameters.

2.9 Using the agreed parameters and the appropriate standard an outline of the trial can be generated, using this, a draft trial plan can then be produced. This has to be reviewed to ensure that it is sensible:

- Is the trial designed iaw the appropriate standard
- Are the various parameters reasonable
- Is the calculation of calendar duration reasonable – the standard calculations will give the length of the trial as in 100 running hours but this could translate in to just over 4 days @24hrs working or around a month working 8 hrs per day/5 days per week starting just before a major holiday period.
- If the trial includes maintenance activity and/or design/manufacture to fix emerging issues then has a reasonable time been allowed for this activity
- Is the expected calendar duration acceptable
- Are appropriate resources available for the trail with clearly defined responsibility for the provision of these resources.
- Is the cost of the trial acceptable

2.10 If the answer to any of these questions is no then it is necessary to think again, and consider:

- Alternative trial type – noting that deferment may result in greater risk and increased costs; in general fixes early in the CADMID cycle are cheaper than fixes at a later date
- Changing parameters – for instance accepting less confidence, but noting the increased risk of an item passing a test which is in fact less reliable than suggested by the test results.
- Consider the impact of not understanding the reliability at this stage

2.11 If a trial is a sensible way ahead, it is necessary to finalise the trial design, this should be agreed in detail as agreement up front reduces the possibility of conflict as the trial progresses. The detail should include:

- clear responsibilities for all aspects of the trial,
- details of the actual trial, i.e. if the trial is based on standardised missions these need to be fully described along with any agreements on how these maybe performed (simply saying a mission is so many miles is unacceptable, there is a need to describe

the percentage of time at a given speed and the types of terrain). For practicality purposes it maybe sensible to break a mission into chunks of similar activity and then repeat a number of these (if a mission consists of 50% of the time operating cross country and 50% of the time on roads, it maybe sensible to do a number of road segments followed by a number of cross country, rather than doing road then cross country then road – especially if different trial facilities are being used).

- Sentencing rules (how different events will be classified) this should include clear failure definitions (at a detailed level – how would failure of various parts impact the availability of the system to operate within the context of the system Reliability requirement) Although previous trials plans can give an indication of sentencing rules, it is not recommended to use previous plans as the starting point as overtime rules become complex as rules are generated to cover "odd circumstances", just because it was convenient to decide one way does not mean that this is the appropriate way.

2.12 The trail is then started, during the trial it is sensible to regularly review the trial and understand where the status of the trial and hence the product, this includes

- Sentence results against the rules decided before hand, it is sensible to do an initial sentencing before any formal meeting so that the meeting time can be spent on the contentious issues.
- Analyze the results, it is not possible to analyze the results of the trial until any events have been sentenced, although as most basic analysis is fairly simple to automate it would be sensible to analyse the results based on the initial sentencing and possible outcomes of the sentencing meeting. This ensures that the meeting can understand the outcome of their sentencing. The desired outcome should not be allowed to drive the sentencing decision
- Understand what has been learnt – this is where the real value of the trial emerges when the results are considered and lessons are learnt about:
    - the robustness of the product, i.e. the power train is strong, but the suspension has issues – this should result in design improvements
    - The accuracy of the initial analysis – things are happen as predicted (or otherwise). This should result in improvements to company techniques
    - The manufacturing capability – the fundamental design is sound but as built the product is weak – this should result in production/detailed design improvements
- Based on the analysis the fundamental question has to be asked, should the trial continue if the product is suffering numerous problems it may be sensible to stop the trial, apply improvements and start again. Conversely the product may be so strong that it is sensible to stop the trial early

2.13 At the end of the trial and after all the information has been sentenced and analysed against the criteria for the trial it is possible to say "Does the product pass or fail?". Although this maybe a black and white decision there is still the need for management decision this can be explained by considering 6 outcomes:

- Clearly passes the test – then it is likely that the product will be considered suitable to move to the next stage of it's development/life cycle – there maybe the need to revisit various analyses and assumptions to update these based on the trial results
- Clearly fails the test – it is likely that the product may not be allowed to proceed to the next stage, as a minimum a substantial get well programme of design/manufacturing improvements will be required along with a major update to the products risk register
- Marginally fails the test – it is possible rather than rejecting the product a get well programme will be introduced, or it maybe considered that the cost of improving out weighs the benefits of achieving better performance in which case it may be considered acceptable to move to the next stage with appropriate changes to requirements and consideration of whole life implications
- Marginally passes the test – although likely to be allowed to pass to the next stage, consideration should be given to the risks of continuing and if there is need for improvements to mitigate against future issues
- Fails the test with most of the problems in one area – it maybe that a concentrated get well programme in this area would deliver a system which meets the needs of the user and this may be more cost effective that rejecting the item
- Passes the test but with unexpected weaknesses – before proceeding the impact of these weaknesses on the user and through life should be considered

2.14 Remember any trial is only an approximation of real life, management input and decision making is required to understand what the trial results mean and how to move forward.

2.15 A trial can be likened to a football match just because a lower division team beats a premier league team in the cup it does not mean that overall the premier league team is the weakest team. Conversely just because on the day the premier league team beats its nearest rival it does not mean that over several seasons it will always win.

Annex A – Types of trials

1.0 Sub-Assembly Testing

1.1 Also referred to as Component Testing, Bench Testing and Proof of Concept Testing at some point the process of practical trialling and testing will commence either through the contractors own efforts or as part of the contractual agreement. Most solutions are developed from bespoke or commercially available assemblies and components integrated together to create the required equipment or systems. Sub-assembly testing is one of the first practical activities to ensure such parts contribute to that requirement.

2.0 Reliability Growth Trial (RGT) (GR77 PtC, Ch 15)

2.1 Probably the most important of all the R&M trials, RGT provides the means by which the R&M qualities of the solution and assurance can be developed. The purpose of the trials, comprising a number of agreed repeatable duty cycles and/ or set piece scenarios, punctuated by periods where repairs and modifications are incorporated, is to identify quality and design shortfalls and weaknesses to enable their rectification through redesign and ongoing development. On completion of these trials it should be possible to demonstrate statistically that R&M compliance is achievable.

Full blown RGT may be preceded by:

Initial Shake-down Trials: to provide confidence in technology demonstrators and prototype equipment and the integration of assemblies;

Initial Reliability Trial: or Informal Growth Trials, to determine the initial maturity of the system and the start point of more formal development. Comprising a nominal series of agreed scenarios (usually fewer than 10) these trials provide valued insight into potential difficulties ahead, and the time that may be required to achieve reliability compliance.

3.0 Reliability Demonstration Trials (RDT) (GR77 PtC, Ch 40)

3.1 Demonstration (or compliance) trials are often used by Contractors to show whether or not prior to R&M Qualification that the R&M characteristics or a property complies with a stated requirement. When witnessed by the Purchaser, with appropriate, pass and fail criteria, these trials (with agreement) may be used to replace R&M Qualification Trials.

4.0 Reliability Qualification Trials (RQT)

4.1 Qualification trials are employed to verify formally to the Purchaser (and Customer) the achievement of R&M contractual conformance. Trial duration should not only be statically sound but representative of the systems through life capability requirement.

5.0 In-Service Reliability & Maintainability Demonstrations (ISR&MD)

5.1 R&M trials conducted post the In-Service Date (ISD) of a system are collectively called ‘In-Service’ trials or demonstrations. Their function is to clone that of the Demonstration and Qualification trials previously described; but are employed where compliance has not been achieved or demonstrated prior to acceptance. This can arise from either shortfalls in the design or from the practicalities of demonstrating compliance as is often the case with maritime systems.

6.0 Production Reliability Assurance Testing (PRAT)

6.1 Comprising one or more short reliability trials of batch sampled systems, PRAT is employed to ensure that the R&M compliance accepted during RDT/RQT is maintained throughout the manufacturing process and delivered into Service. The testing should not be used to demonstrate statistical compliance only that it has been maintained.

7.0 Maintainability Testing (GR77 PtC, Ch 41)

7.1 Maintainability versions of Growth, Demonstration and Qualification trials can all be employed as practical options to develop and demonstrate the contractual compliance of the maintainability aspects of equipment and systems. R&M development, trialling and testing will often occur in tandem providing the opportunity to optimise resources and hasten compliance achievement.

8.0 Accelerated Testing (GR77 PtC, Ch 16)

8.1 Condensing testing by using continuous testing techniques, applying higher g-forces, overloading, and testing at extreme environmental conditions; time scales can be truncated and design weaknesses detected and resolved sooner. Statistically correlating failure modes under such conditions with in-service usage while ensuring that equipment is not excessively tested beyond its operational envelope is very difficult hence contracting for accelerated testing or decision making based solely from its achievements should not be made without first obtaining specialist advice

Annex B – Related guidance material

1.0 GR77 (http://www.sars.org.uk/mod-page)

2.0 Part A General

Chapter 8 Practical Demonstration of R&M

Chapter 10 R&M evidence collection

3.0 Part C R&M Related Techniques

Chapter 16 Highly Accelerated Stress Testing

Chapter 17 Ease of Maintenance Assessment

Chapter 14 Step Stress Testing

Chapter 15 Reliability Growth Testing

Chapter 39 Availability Demonstration

Chapter 40 Reliability Demonstration

Chapter 41 Maintainability Demonstration

Chapter 42 Testability Demonstration

Chapter 45 Environmental Stress Screening

4.0 Part D Supporting Theory

Chapter 7 Test Results Analysis, Parameter Estimation, Confidence Intervals & Hypothesis Testing

Chapter 8 Reliability Growth Models

Chapter 9 Availability Demonstration Plans

Chapter 10 Reliability Demonstration Plans

Chapter 11 Maintainability Demonstration Plans

5.0 Part E R&M Management Techniques

Chapter 1 Reliability and Maintainability Panels and Working Groups

6.0 Standards

Standard No	Title
BS 5760-2:1994	Reliability of systems, equipment and components – Guide to the assessment of reliability
BS 5760-8:1998	Reliability of systems, equipment and components – Guide to assessment of reliability of systems containing software
IEC 60300-3-5 Ed. 1.0	Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles
IEC 60410 Ed. 1.0	Sampling plans and procedures for inspection by attributes
IEC 60605-2 Ed. 1.0	Equipment reliability testing – Part 2: Design of test cycles
IEC 60605-4 Ed. 2.0	Equipment reliability testing – Part 4: Statistical procedures for exponential distribution – Point estimates, confidence intervals, prediction intervals and tolerance intervals
IEC 60605-6 Ed. 3.0	Equipment reliability testing – Part 6: Tests for the validity and estimation of the constant failure rate and constant failure intensity
IEC 60706-3 Ed. 2.0	Maintainability of equipment – Part 3: Verification and collection, analysis and presentation of data
IEC 61014 Ed. 2.0	Programmes for reliability growth
IEC 61123 Ed. 1.0	Reliability testing – Compliance test plans for success ratio
IEC 61124 Ed. 2.0	Reliability testing – Compliance tests for constant failure rate and constant failure intensity
IEC 61163-1 Ed. 2.0	Reliability stress screening – Part 1: Repairable assemblies manufactured in lots
IEC 61163-2 Ed. 1.0	Reliability stress screening – Part 2: Electronic components
IEC 61164 Ed. 2.0	Reliability growth – Statistical test and estimation methods
IEC 62429 Ed. 1.0	Reliability growth – Stress testing for early failures in unique complex systems
IEC 62506 Ed. 1.0	Methods for product accelerated testing
00-42 Part 5 Issue 2	Reliability & Maintainability Assurance Activity. Part 5 – In-Service Reliability Demonstrations
00-42 Part 6 Issue 2	Reliability & Maintainability Assurance Activity. Part 6 – Maintainability Demonstration
00-44 Issue 1	Reliability and Maintainability Data Collection and Classification