CHAPTER 5

R&M ALLOCATION AND APPORTIONMENT

CONTENT

1. INTRODUCTION

1.1 This section describes methods of apportioning, sometimes called allocating, of system reliability and maintainability to the sub-system and assembly levels in order to establish realistic R&M design requirements at these levels.

1.2 The analyst assigns numerical R&M requirements to the various items comprising the system. The apportioned reliabilities should be expressed as either probabilities of survival or as failure rates, depending on the nature of the items. The apportioned maintainability should be expressed as an arithmetic Mean Active Repair Time (MART), where active repair time is the time taken for defect diagnosis, rectification, and retest; assuming that everything required is immediately available. Maintenance man-hours per operating hour may also be apportioned.

1.3 The apportionment of R&M is necessary because it:

a) Provides the designers and manufacturers of each part of the system with R&M requirements.

b) Provides R&M figures for comparison with assessments made during design and development.

c) Enables trade-offs to be studied at an early stage.

1.4 The R&M apportionments should be used as the basis for producing R&M specifications for the items comprising the system. The individual item specification need not exactly match the apportioned R&M, but should provide spare capacity to allow for shortfalls.

2. APPORTIONMENT SCOPE

This section addresses the following:

a) System apportionment process.

b) Derivation of reliability values.

c) Derivation of maintainability values.

d) Types of apportionment.

e) Apportionment refinement.

f) Presentation and updating of the apportionment.

g) Realism, criticality and risk.

2.1 System Apportionment Process

2.1.1 Items to which R&M requirements are to be assigned should have functionally separate identities so that they can be tested or otherwise evaluated in isolation from the full system, i.e. R&M apportionment should be performed to a level at which they have some practical interpretation.

2.1.2 The factors which influence the apportionments are:

a) The system configuration and whether it consists of series dependent items only or whether redundancies are included.

b) The environments which will be experienced during the duty cycle or operational scenario defined in the Staff Requirements.

c) The relative operating times of the items of the system, especially if these do not all operate continuously throughout the mission.

d) The criticality of the items of the system, and the development risks.

e) Whether the items are repairable during the mission.

f) The size, weight, accessibility of items for repair and the availability of Built-In-Test (BIT).

2.1.3 The first step in the apportionment process is to produce models which relate the R&M of the complete system to those of the individual items comprising the system. The reliability block diagram (RBD) is a good means to achieve this.

2.1.4 The next step is to determine the reliability of each item in the models in terms of a failure rate or probability (see Serial 2.2) and the associated maintainability in terms of a MART.

2.1.5 It may be convenient with some systems to express reliability as the product of two probabilities:

a) The probability that an item is failure free at the start of the mission.

b) The probability that an item survives the mission given that it was failure free at the start.

2.1.6 There are two main types of system operation and the differences influence the manner in which the reliability is calculated for each. These are:

a) Systems which run continuously, during part or all of the mission and, through monitoring, any failures are detected and repair action initiated as they occur or when convenient.

b) Systems which can be considered to operate instantaneously on demand.

2.1.7 In apportioning system R&M, the consequences of system software should be taken into account and allowances should be made for the contribution software may make to system failures. Reliability cannot be apportioned to software in the same way as to hardware because failures due to software do not occur as a direct result of the passage of time. Also, there are no standard methods for the prediction of system reliability due to software faults so comparisons cannot be made with predicted values. It is possible to develop systems containing software in which software faults manifest themselves as failures which have only a minor effect on system availability such that the software effects can be ignored (i.e. there is no repair or replacement involved). However, it should be noted that this is not always the case and recovery from system failures due to software faults may take a significant time and maintenance effort, contributing to system unavailability. Consequently, the R&M aspects of software cannot be ignored in the apportionment process.

2.1.8 The next step in the apportionment process is to calculate the system R&M from the associated models and the apportionments given to the individual items.

2.2 Derivation of Reliability Values

2.2.1 When a system consists of items whose duty cycles are not all the same then this should be taken into account in the apportionment. For example, if a system operates a 10 hour mission, but one item within the system only operates for one hour per mission, then the time value used in calculating its apportioned reliability would be one hour.

2.2.2 Other aspects of utilization, such as power switching cycles for electrical or electronic items, and environmental conditions should also be taken into account, especially when equipments in the system are subject to differing utilization conditions.

2.2.3 When a system or an item within a system operates prior to the time a mission starts, or where multiple missions are involved, it may be necessary to consider the probability of the item being available at the start of each mission.

2.3 Derivation of Maintainability Values

2.3.1 The maintenance flow diagrams evolved during a maintainability analysis are annotated with the estimated times to perform each activity. There may be insufficient design data at this stage to reach accurate estimates; in such cases values will have to be assigned on the basis of previous experience and/or engineering judgment. When a complete set of times has been assigned it will be possible to:

a) Deduce mean active corrective/preventative maintenance times by making use of the reliability figures allocated to the sub-systems and lower assemblies.

b) Ascertain that the overall system requirements can be met for the depth of maintenance required at each line.

c) Deduce the corresponding sub-system requirements which are consistent with the system requirements.

2.4 Types of Apportionment

This section addresses the following:

a) Equal apportionment.

b) Agreed apportionment.

c) Growth Apportionment.

d) Repairable systems apportionment.

e) Feasibility apportionment.

f) ARINC apportionment.

2.4.1 Equal Apportionment: based on the assumption that each subassembly has an exponential failure distribution, this in one of the most simple of the apportionment methods in that each subassembly is afforded equal apportionment.

2.4.2 AGREE Apportionment: This method of apportionment takes into account the complexity and the significance of each subassembly and assumes that subassemblies are in series and have exponential failure distribution. Developed by Advisory Group on Reliability of Electronic Equipment it is based on the minimum acceptable mean life required for each subassembly to satisfy the minimum acceptable mean life of the whole system.

2.4.3 Growth Apportionment: the principle underpinning this method is to apportion reliability growth to the subassemblies/subsystems in order to achieve the required reliability at least cost. In the early stages frequently it will be employed to support design effort and determine the reliability growth requirement to support the whole system. In the latter stages it will be employed to optimize get well programmes to address system reliability shortfall.

2.4.4 Repairable System Apportionment: assumes that each subassembly has a constant failure rate and are in series with an exponential failure distribution. Each subassembly is allocated a failure rate which allows the host system an achieve its required availability requirement for a repairable system.

2.4.5 Feasibility Apportionment: is base on the reliability (or maintainability) drivers such as environment, operating duration, mission profile, system complexity, etc. which have a direct influence on reliability attainment. It assumes that subassemblies are in series and have an exponential failure distribution and each driver is rated/factored based on previous knowledge and/or judgement to provide weighting and subsequently allocations for each subassembly.

2.4.6 ARINC Apportionment: assumes that each subassembly has an exponential failure distribution and are all in series. Designed by the Advisory Group on Reliability of Electronic Equipment allocations are based upon previous data, experience and weighting factors.

2.5 Apportionment Refinement

2.5.1 The apportionment process described above provides values of R&M which, if met, would mean that the R&M requirements for the system or equipment would be met provided that the assumptions made in their derivations were valid.

2.5.2 In the early stages, the apportionment process should be used, at least partly, to determine the feasibility of a particular design. In cases where designs are very unlikely to achieve apportioned requirements it will be necessary to implement one or more of the following procedures:

a) Review those areas contributing most to unreliability and maintenance load to determine how and where improvement could be obtained;

b) Introduce (further) redundancy.

c) Change the local environment, e.g. anti-vibration mounts, environmental control etc.

d) Change the maintenance concept.

e) Increase quality level of parts.

2.5.3 Since any of the above actions will change the assumptions on which the initial apportionment was based the apportionment will require to be repeated. Apportionment is therefore, in this sense, an iterative process.

2.5.4 Having completed the initial R&M apportionment from system to sub-system and to assembly levels, the achievement of these requirements would mean that the system R&M would be met provided that the assumptions, for example, concerning the environmental factors and the relative failure rates, were valid. However, care should be taken to ensure that the requirements are not taken for granted and the development effort necessary to achieve them is applied.

2.6 Presentation and Updating of the Apportionment

2.6.1 The apportionment should be presented against the R&M models developed in support of the activity. Reliability Block Diagrams (RBD's) are widely used, with each block representing an item for which an apportionment has been made. The blocks should be annotated with the following information:

a) Apportioned R&M values (reliability, failure rate, MTBF, as appropriate, and MART).

b) Assumptions used in the derivation of R&M values and the models.

c) Item utilization relative to system utilization.

d) An indication of the relative criticality of the item and the development risk.

2.6.2 Separate apportionments will be required for each system option being considered.

2.6.3 The apportionment may need to be revised if the purchaser and prime contractor agree to changes in the system requirement.

2.7 Realism, Criticality and Risk

2.7.1 It is essential that apportionments to each item are realistic. For example, it is incorrect to apportion a relatively low reliability to one item simply because its utilization is low. As the design of a system proceeds it may be necessary to reapportion the system R&M to ensure that a realistic balance is achieved between all items in relation to the relative risks involved in achievement of their apportioned R&M.

2.7.2 Apportionments should take account of the criticality of the various elements of the system and of the risks involved in their development; untried technology involves greater risks. The values stated shall be realistic and a high risk item should not be expected to have as high reliability as one of equivalent complexity but which is identical or similar to a mature one.