CHAPTER 1

POTENTIAL SCENARIO ANALYSIS

CONTENT

1 INTRODUCTION

1.1 A Potential Scenario Analysis is the means by which the Operational Requirements, expressed as one or more missions and/or series of functions, the environmental conditions under which the missions will be undertaken and the possible engineering solutions, will be brought together, examined and modelled to provide initial R&M targets. By their very nature, realistic R&M targets cannot be derived except as a result of considering practical engineering solutions to the Requirement. It is possible that later concept or early design studies will arrive at solutions that differ to a greater or lesser degree from the initial studies. If these later studies offer a solution with similar or improved R&M capability, the Potential Scenario Analysis and its associated models may be amended to include it. If the results of later studies do not meet the initial targets it must be seriously questioned why they are being considered.

1.2 The analysis is undertaken under the auspices of the R&M Concept Panel and is used both as an aid to decisions on the capabilities and numbers of systems required to meet a particular operational requirement and to generate targets for inclusion in specifications. It should also be re-visited as a means of examining and assessing the impact of later modifications, whether during development or the course of in-service use.

1.3 This chapter examines:

a) the inter-relationships between R&M and other operational aspects of importance during consideration of possible solutions to an operational requirement;

b) the background to a Potential Scenario Analysis;

c) the difference between specific wartime and other, longer term scenarios and the reasons for examining both;

d) the use of an availability model or models as an aid to the analysis.

2 INTER-RELATIONSHIPS

2.1 R&M derives directly from the engineering solution to an operational requirement and inter-relates with:

a) <u>Functionality</u> - The range of features of which a platform, system or weapon is required to be capable in order to provide the solution to the operational requirement;

b) <u>Performance</u> - The limiting boundaries of capability of the platform, system or weapon;

e.g. maximum forward or reverse speed;

maximum rate of turn;

minimum number of available communications channels;

minimum distance over which it is possible to detect and locate a threat.

c) Cost - the initial cost of acquiring the capability and the through life cost of operating and maintaining it;

d) Safety - of people manufacturing, operating, maintaining and disposing of the solution, of the general public and of the environment in general;

e) Support - the totality of resources required to maintain the capability, throughout its life, in a state to meet the operational requirement;

f) Environment - the range of physical environments in which of the platform, system or weapon will be required to operate in order to meet the operational requirement.

2.2 The first item to consider in analysing an operational requirement is the range of functions needed to successfully meet it. This is the subject of an Operational Needs Analysis (PCCh1). In deciding the means of achieving the functionality in engineering terms, both R&M and performance warrant equal weight. In the first instance a wide range of possible solutions may be considered; alternatively, a limited replacement of an existing system with one utilising more up to date technology to provide increased capability, possibly at a lower cost, may be appropriate. Whichever approach is taken, the capability, in terms of performance of proposed solutions, R&M and cost should be examined together at high level. Although safety and support clearly derive from the solution(s) being considered, any analysis will follow on from concept studies into the potential solutions that emerge from the first stage. The question of the environment in which the solution will operate is important at this stage, particularly if alternative solutions operate in different environments. In this case there may be significant effects on relative costs and support arrangements. For example, a threat from tanks may be countered by mines, ground mobile guns or missiles, a helicopter gun-ship, or fixed wing ground attack aircraft.

3 BACKGROUND

3.1 Prior to generating even the earliest specification for a system or equipment it is necessary to examine closely a number of factors:

a) use or uses to which it will be put.

b) time periods over which it will be required to function.

c) physical environment under which it will operate.

d) arrangements in hand or required to support it.

3.2 In considering the broad design requirements for any equipment, the operational conditions (environment, duration(s) of use and support arrangements) under which it will be handled, stored and utilised should receive as much attention as the actual performance demanded of it. During initial concept studies, it is the R&M specialist, working with his colleagues on the R&M Concept Panel, who has the training, skills and motivation to undertake the work of analysing the scenarios and potential solutions. From these, informed decisions on the potential engineering solutions to be carried forward are made and the Integrated Project Team (IPT) Leader and Capability Manager may incorporate the availability data in the User Requirement Document (URD) and Systems Requirement Document (SRD).

3.3 Frequently, only the service operational analysts (Customer 1) have a working knowledge of the most likely future scenarios in which the equipment will be used. However, the actual operators of current equipment (Customer 2) used for similar purposes will be in the best position to advise on how it will most probably be used in any particular scenario.

3.4 Operators will also have a good idea of the effectiveness of support arrangements for current equipment.

3.5 It is, therefore, very important that the Chairman of the R&M Concept Panel (Panel A) involves representatives from these groups in discussions with project staff and R&M Advisors as early as the first or second meeting.

4 ANALYSIS

4.1 For some equipment the operational conditions will be straightforward: for example, ground benign environment, operational availability required 24 hours per day, 365 days per annum, subject to pre-determined downtime, or reduced availability for defined support.

4.2 For much defence equipment, particularly, but not exclusively, platforms (ships, fighting vehicles and aircraft) and weapons, the operational conditions vary widely. It is generally only by close analysis of the engineering options for the equipment and the possible scenarios in which it will be used and supported, that realistic early targets for operational availability may be set. A key element of the Concept Phase, therefore, is to establish as precisely as possible, the profile and requirements of all possible operational missions in which the equipment may be used and the performance and functionality needed of the equipment to meet the requirements. This is undertaken as an Operational Needs Analysis (Pt3Ch1).

4.3 Following this, examination of the inter-relationships between performance, functionality, availability, cost, safety and the support environment may lead to trade-offs. However, an important first step is to establish high-level availability models for the various system/equipment configurations in order that informed decisions may be made on the content of the URD and SRD.

5 MODELS

5.1 Because the equipment is being designed to meet the stresses and demands of combat level operations, including peace keeping and general war, the first model will be of the operational availability in the wartime role and the specific missions considered will be those derived from wartime operational scenarios. The initial specific functionality targets and the URL will reflect this.

5.2 Although defence materiel is designed to withstand the rigours of combat, except in the case of a long-term conflict the combat support environment is uncharacteristic of its normal service life. Because the support environment during peacetime activities, particularly for the Royal Navy but also to a large degree for the other Services, it will also be necessary to establish a long-term availability model. A long-term model will cover a lengthy fixed time period of at least one year, but probably 3, 5 or even 8 years and will include recovery, deep servicing, modification and update periods. It is generated in collaboration with the IPT ILS staff and it is this model that they will draw on to initiate their own work.

5.3 There are a number of factors that have to be considered in setting up an availability model:

a) individual wartime missions or combination of missions;

b) period of operation for the equipment as a whole during the various missions;

c) number and scope of the functions which the equipment is required to perform;

d) criticality of the function(s) to the success of the mission or the safety of the operators and the period or periods over which the functionality is needed. This information is vital to derivation of the system failure definitions;

e) relationship of the functions to the performance required, for example - over what phases and for how long is a platform required to loiter or to operate at cruise or maximum speed;

f) for each function, consideration of which sub-system or sub-systems are required to provide or contribute to the provision of the function;

g) data on systems or sub-systems for inclusion in the model.

Factors (a) to (e) are obtained from the Operational Needs Analysis, while (f) and (g) derive from consideration of possible engineering approaches to achieving the functionality required.

5.4 Unless novel or unconventional technology is being considered right from the start, the top-level systems and sub-systems should be based on appropriate (preferably in-service) conventional equipment for which data is available. Even in the case of novel technology it is sensible to analyse the R&M capability of conventional equipment in the same role to provide a baseline reference figure.

5.5 Data may be obtained from a variety of sources. In order of preference they are:

a) The same or similar equipment, used by the same Service in the same operational, physical and support environment;

b) The same or similar equipment used by commercial operators in a similar physical environment, for example, aircraft or marine engines. In this case it is unlikely that the operational and support environments will be the same and appropriate allowances may have to be made before the data is used;

c) Data derived from a detailed physical and engineering analysis of the short and long-term behaviour of the system or equipment proposed across the range of environmental conditions in which it will be used. This is particularly applicable to novel solutions and for electronic equipment the "Physics of Failure" approach is perhaps the best known. However, the physics of failure (the long term effects of the mechanical, thermal, chemical and other stresses on the component parts and assembly) may be applied to equipment at any scale [*new technology permanent magnet electric motor for warships*] and should form a fundamental part of the Assessment and Demonstration Phases for all novel equipment;

d) Generic data.

5.6 If data of the quality of (a) or (b) is not available, it is worth establishing whether an in-service data gathering exercise can be set up to provide results during the Concept Phase or early in the Assessment Phase. Data from (c) is unlikely to be available at the outset and generic data needs to be used with great caution and will lower confidence in the modelling results until such time as it can be replaced with better data.

5.7 There are a several methods for undertaking R&M modelling (Pt1Ch8) but for the more complex scenarios it is probable that a computer modelling tool (P4Ch4) will be used. There are a number of MOD sponsored or commercial tools available (Pt1Ch7) and the choice of model will depend on the system and scenarios to be examined. Nevertheless it is essential, for all but the simplest mission profile, that the modelling process examines for each phase or period of the mission in turn, the functionality required, the system configuration providing the functionality and the effects of equipment or sub-system failures on the availability of the function. A number of the tools allow the effects of spares support, logistics delays and repair teams to be factored in. If the tool being used does not have built-in support for a sensitivity analysis it will be necessary to re-run the model sufficiently to establish the sensitivity of the success of the mission(s) to variations in R&M parameters.

5.8 Once one or more missions have been modelled with all the potential engineering solutions at high level, it may be possible to initiate the process of examining possible trade-offs against performance, cost and risk. This is a process which will continue at increasingly deeper levels throughout the detailed design and assessment stages. It is also important to consider, at commencement of the assembly of a model, what its ultimate purpose may be. At its simplest it will do no more than provide initial R&M targets. Conversely several current naval projects, including the CVF aircraft carrier, intend to use the models robustly, not only during the Concept Phase but also throughout Assessment, Demonstration and the vessels' In Service life (see Leaflet B1/1).

6 OUTPUTS

Much of the value of the analysis is generated in the iterative process of considering the functionality required, the engineering systems that could provide it, the performance and availability needed, the costs and the trade-off process that ensues. Nevertheless, the end of this process provides an output that feeds into two specifications; the User Requirements Document and the Systems Requirement Document. It also provides baseline models that may be developed and used for contractual purposes.

LEAFLET B1/1

EXAMPLE OF THE USE OF AVAILABILITY MODELLING DURING A POTENTIAL SCENARIO ANALYSIS AND ITS SUBSEQUENT DEVELOPMENT

1 During concept studies for the future aircraft carrier (CVF) availability models were developed under the authority of R&M Panel A, primarily to derive realistic R&M targets for inclusion in Staff Targets and the COEIA. Once the models had been successfully produced it was decided to embody modelling in the mainstream acquisition activities, by:

a) Issuing to contractors interested in bidding for the Assessment phase, the Concept Phase models and modelling reports together with models populated with wartime and longer term mission profiles but with system logic and data deleted. Prime Contractors selected for the Assessment Phase are required to model their proposed configurations against the standard profiles and provide the results as deliverables. Of necessity, the contractors will be obliged to critically examine the metrics of the designs they propose and because they are not allowed to amend the profiles it will be relatively easy for Assessment Teams to examine and compare the R&M performance of the differing proposals against the same baseline;

b) Ensuring contractually that the models thus generated are used in aid of design studies and decision making at the highest system levels during Assessment;

c) Requiring the Assessment Phase Prime Contractors to develop the models in concert with the evolving design and to issue them as deliverables at the end of Assessment;

d) Requiring the eventual design/build Prime Contractor to make the model the repository of the numeric elements of the R&M Case during Demonstration and Manufacture by populating it with the results of engineering analyses, tests, trials and the DRACAS, as appropriate;

e) Using the model as the prime source of R&M data for the ILS processes;

f) Delivering with the ship, a model which is representative of all the ship systems and may be used to inject a high degree of confidence into operational and support planning through its service life;

2 Having prepared a model which covered a relatively short wartime mission profile, the systems were re-modelled against a 5-year peacetime scenario taking account of scheduled docking, rest periods and peacetime support priorities. The 5-year segment comprised various periods of operation, maintenance and repair, the profile of activities being based on studies of the current Invincible class carriers;

3 Recent work undertaken on the Future Surface Combatant (FSC) and Type 45 destroyer has extended the work on peacetime scenario modelling to cover a series of peacetime and warlike mission profiles interspersed with standard rest and support periods.

This modelling has also examined the effect on subsequent mission effectiveness, of being unable to restore the availability of various systems during the standard recovery period.