

# Complement Modelling for the MHPC Naval Project

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The UK Mine-countermeasures, Hydrographic and Patrol Capability (MHPC) project is in its initial phase and is assessing concepts in which a host vessel deploys off-board systems to conduct data collection and mine disposal.

Human Factors Integration is responsible for ensuring the human component of capability is considered and assessed throughout the project. One aspect is the work-up of personnel numbers and this is being done using complement/workload modelling tools. This encourages an objective, top-down approach to the question and seeks to avoid simply recycling legacy processes that may be inefficient or inappropriate given new concepts and technology.

The Complement Generation Tool (CGT) has been used to generate the core complement using a simple weekly time cycle. Micro Saint is being employed to analyse the crew required to operate the off-board systems and to understand the impact of drivers such as scenario duration, number of systems and level of autonomy.

MHPC is the first RN project to use these tools and therefore provides a case study for similar programmes to experience from.

## Keywords

Complement, personnel, resource modelling.

## INTRODUCTION

This paper presents a case study of how the personnel component of a new naval capability is being modelled in the early phases of the design. It draws on recent experience of the UK Mine Countermeasures, Hydrographic and Patrol Capability (MHPC) project that will provide a series of systems to conduct sea-mine countermeasures (MCM), patrol and hydrographic survey. The resulting capability will enter service with the Royal Navy to replace the classes of RN ship that currently fulfil these functions such as Hunt, Sandown, Echo and Enterprise.

The project is in its earliest design phase during which a number of different concepts are being developed. For each option various aspects of capability are assessed including equipment, information management, doctrine, personnel, training and logistics. The human factors team is

employing a modelling approach to objectively analyse the implication of design options upon the personnel numbers and skill-sets required. This provides information for the naval architects with respect to accommodation requirements and an early indication to Navy manpower planners

Given the early stage of the project this paper comes with the caveat that the proposals discussed are just that and do not necessarily represent the endorsed solution.

## Mission Packs

An interesting aspect of the project is the opportunity to increase commonality in a baseline design rather than developing separate solutions to meet the similar yet different MCM, hydrographic and patrol requirements. The design team is exploring the extent to which commonality may be practical and the benefit that this may bring. For several of the concepts the proposal is to have a single hull-form and then a number of mission packs that can be interchanged onto the ship to meet the requirements of the mission. In support of this project direction the concept of a core complement plus mission pack crews has been worked-up. In this approach the core will belong with the ship and will fulfil the move, sustain, maintain, protect and command and control functions. These personnel will then be supplemented by mission pack crews who will be specialists in the operation of mission pack equipment and the processing of the data gathered.

Developing the personnel solution is an ongoing process involving many stakeholders; part of this process is the use of modelling to predict the numbers of personnel required. The MHPC human factors method is to model the core complement using the Complement Generation Tool (CGT) and to analyse the mission pack crews using the Micro Saint tool. CGT has proven suitable for providing an overview of personnel numbers against functions and equipments but does not have the power to model against a dynamic timeline/scenario. Micro Saint has therefore been employed to make a more detailed analysis of the mission pack crews as it is well suited to sequential time-driven processes; the two tools therefore complement (!) each other well.

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## CORE COMPLEMENT

The Complement Generation Tool (CGT) is a tool specifically developed to work-up a ship's complement in the early stages of a project. It works from the principle of first specifying the functions that must be met and then assigning personnel and equipment to these. In this sense it is a top-down approach which brings the benefit of encouraging integration with wider systems engineering processes and promoting objectivity. In practice bottom-up knowledge is also important as the ship will be operated as part of a wider fleet and consideration of naval organisation, watchkeeping and constraints must be made.

## DATA INPUT

To begin a functional hierarchy was developed outside of the tool and in collaboration with the project systems engineers. The baseline ship's equipment fit (both ship systems and mission systems) was sourced and data on Royal Navy personnel structures and specialisations collated.

Human tasks were then defined and classified as one of the following task types:

- Equipment watchkeeping,
- Non-equipment watchkeeping,
- Manpower (routine tasks such as boat launch)
- Maintenance
- Evolutions (focussed periods of activity to meet a specific objective, e.g. replenishment at sea).

Constraints were also defined including those associated with ship readiness state, location, working hours and required rate/rank and skills.

Having collated the source data it was then input into the model which uses the functional hierarchy displayed in a tree view as its core. Equipment and tasks are assigned to functions which are shown as leaf nodes; links between personnel types and tasks equipment are also defined (Figures 1&2).

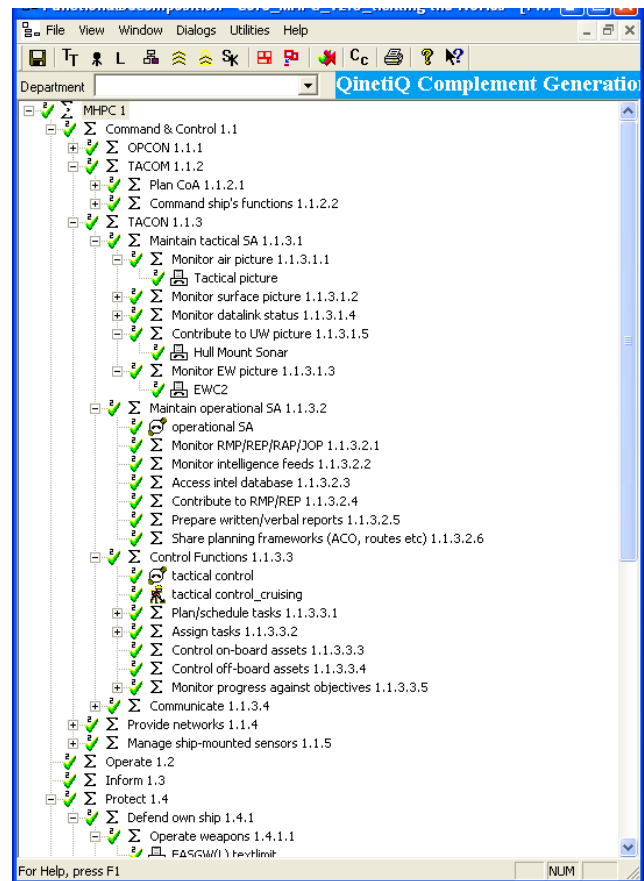


Figure 1 Functions hierarchy in tree format

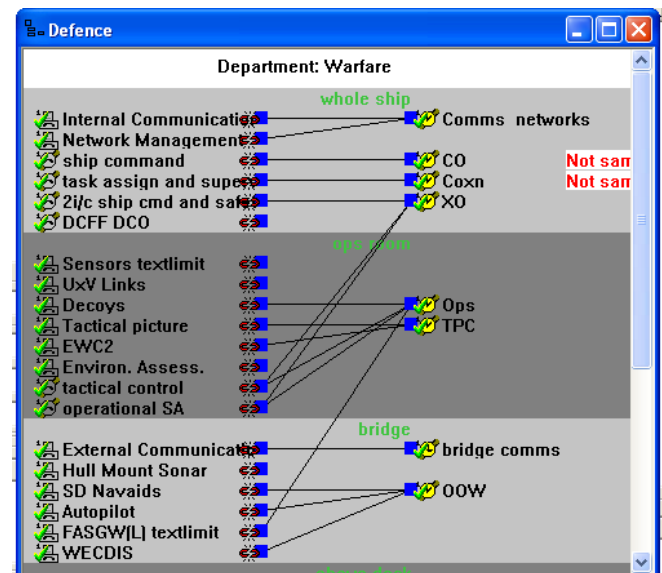


Figure 2 Linking equipment to personnel

## Assumptions

A number of assumptions were made and verified as the modelling progressed. A key assumption was defining the boundary between core and mission pack personnel (which in practice will not be a clear demarcation but for the purpose of the project is required.). It has been assumed that core personnel will not operate or maintain off-board systems

(including software applications) with the exception of assisting with launch and recovery.

## RESULTS

When it is run the tool calculates the complement size and composition by summing up the resource requirement given the constraints on skill-sets, working hours and watch-routines. Watchkeeping tasks are resourced first, followed by evolutions, manpower tasks and then maintenance. In each case the model will, in theory, seek to use personnel that have already been generated rather than assigning tasks to a new person. The output is a non-optimised calculation of the number of personnel required across all watch states and the respective allocation of personnel to tasks.

### Balancing & Validation

Following the initial calculation analyst skill and judgement is necessary to review the output and make adjustments to balance the complement. Balancing is the process of smoothing out the peaks and troughs of resource demand such that the tool doesn't generate new people of low utilisation for a specific task when existing complement members have capacity. Four mechanisms that were used for balancing, these were: 1) changing the overall percentage of a manpower task conducted in each readiness state; 2) moving the effort from one person type to another within a state; 3) moving effort for a specific task from one state to another; 4) making minor adjustments to the maximum hours worked for a given person type.

The balanced complement was then reviewed with Royal Navy personnel with expertise in the areas of warfare and engineering. This real world, bottom-up experience provides an essential reality-check and resulted in some minor amendments being made to the complement, for example in areas where it was judged the manning levels were too low or where the balance between rates wasn't realistic to deliver the required capability.

The figures generated represent the first step in developing the complement solution. As the project moves into assessment phase and beyond these numbers will be worked-up with details of specialism and tasks and RN stakeholders will be engaged to seek endorsement.

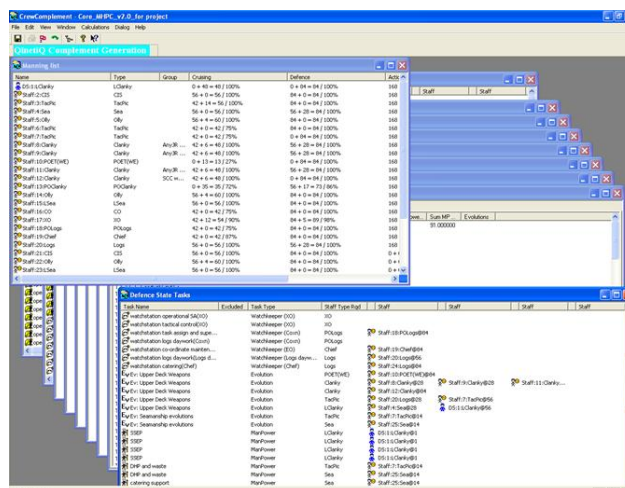


Figure 3 CGT Output Module

### Baseline Variations

A benefit of using CGT is that it is possible to quickly assess the impact upon complement due to scoping functions and equipments in or out of the equation. As a result the model is well geared towards making comparisons between the various MHPC concepts and as the project progresses the model will be used in this way.

For example it is assessed that by *not* supporting the launch and recovery of off-board systems and by *not* fitting the small calibre guns the complement could be reduced by two personnel.

### Tool Observations

The tool has some issues and by using it on this project it has become apparent that some of the logic in generating the output appears flawed. In some cases for example the tool generates “new” personnel for a task when existing personnel are available with the right skill-sets. As a consequence after each run the output must be scrutinised carefully. Errors in the tool have been reported back to the supplier.

### MISSION PACK CREWS

The core complement will be supplemented by mission pack crews that will embark with the mission pack equipment. The concept raises complexities with respect to the division of responsibility and team cohesion however before these are addressed the fundamental task of understanding the crew numbers required must be conducted.

Assessing the effort to operate and maintain the off-board systems is of particular interest and calls for more detailed modelling than the core complement for three primary reasons. The technology is new and evolving rapidly and as a result there is little empirical experience available. Secondly the personnel requirement may vary significantly as it is

strongly correlated with scenario driven parameters such as the performance requirement and number of off-board systems (OBS) employed. Thirdly the human effort required is linked with the level of autonomy, as a result the implication of autonomy level needs to be understood and quantified.

Work is underway to model the mission pack crew numbers using the discrete-event simulation tool, Micro Saint Sharp. Utilised in the HF domain it is well suited to modelling time-based sequential tasks with dependencies upon resource. A network of human tasks is created and the interdependencies between these are programmed including probabilistic and deterministic paths. Tasks are given a duration with a distribution and standard deviation and resource requirements are specified and allocated to tasks.

When executed the model will calculate the number and skill-type of personnel for a given set of parameters such as number of OBS, mission duration and level of autonomy. Alternatively personnel may be used as constraint and the output can indicate areas where there are bottlenecks in the process or a shortage of skills and the impact thereof upon overall process duration.

The most important aspect of developing such a model is sourcing valid input data. In the case of MHPC the plan is to use the timings from the output of the project Performance Model which has recently been developed to look at the impact of mission pack equipment composition/numbers upon performance against a number of scenarios. These timings will provide the top level metric of overall time spent on different mission phases.

As with any model the level of fidelity can be varied depending upon the question being posed and the degree of confidence required. For the first pass of the MHPC MP crew model the personnel are modelled at the whole-person skill level (e.g. sonar analyst). In future phases the work may be taken further to map out specific cognitive and physical demands.

## **CONCLUSION**

This paper has provided a case study of a real-world naval design project where the concept of a core ship complement supplemented by mission pack crews is being explored.

Two points are made in conclusion; firstly when assessing the personnel component of capability it is beneficial to be able to utilise a tool and analyst to model the demand for personnel. This encourages an objective, top-down approach to the question and seeks to avoid simply recycling legacy processes that may be inefficient or inappropriate given new concepts and technology. The output from such studies informs Navy manpower planners and naval architects scoping ship size and design.

Secondly, it is important to maintain flexibility in the analysis approach as the best suited tool/method will be dependent upon the problem/question being posed. In the case of MHPC the relatively well understood functions of the core complement were modelled at a high level using the bespoke Complement Generation Tool. For the more complex and time-driven demands of mission packs crews the Micro Saint tool was selected. The tools work at different levels of detail but are complementary as the output from the mission crew analysis can be summarised in CGT.

As a result the project, which is in its first phase, has a sound model-based assessment of the personnel requirement. As the project matures different concepts and mission pack compositions will be evaluated at the project level. The complement groundwork will enable the impact of such variations upon personnel to be readily assessed.

## **ACKNOWLEDGMENTS**

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