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Functionality and Usability Assessment of the Complement Generation Tool (CGT)

A preliminary review

Wenbi Wang

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Abstract

The Complement Generation Tool (CGT) is a crew modelling software that was developed by QinetiQ for the Defence Procurement Agency of the United Kingdom's Ministry of Defence. A review of the CGT was conducted that focused on the functionality and usability of the tool. The results confirmed the usefulness and usability of the CGT for creating manpower and personnel requirements during the early stage of a naval platform's design. The tool does not have functionalities to address certain types of crewing issues, such as complement validation and operator scheduling. A list of questions is suggested to address whether the CGT is suitable for resolving Canadian Navy project needs.

Résumé

L'outil de génération de compléments (Complement Generation tool – CGT) est un logiciel de modélisation d'équipes développé par QinetiQ pour le compte de l'Agence d'acquisition de matériel de défense du ministère de la Défense du Royaume-Uni. Le CGT a été soumis à un examen afin d'évaluer sa fonctionnalité et sa convivialité. Les résultats obtenus ont confirmé l'utilité et la convivialité du CGT en ce qui concerne la détermination des besoins de main-d'œuvre au cours de la phase initiale de la conception d'une plateforme navale. Cependant, l'outil ne possède pas les fonctions nécessaires pour résoudre certains types de problèmes liés au recrutement, par exemple la validation de complément et l'établissement de l'horaire du personnel. On suggère une série de questions afin de déterminer si le CGT convient aux besoins de la Marine canadienne.

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Executive summary

Functionality and Usability Assessment of the Complement Generation Tool (CGT): A preliminary review

Wenbi Wang; DRDC Toronto TM 2011-057; Defence R&D Canada – Toronto; April 2011.

Introduction or background: Modelling and simulation has been recognized as an effective approach to examine complement solutions for future naval platforms. This technical memorandum reviewed a modelling tool, the Complement Generation Tool (CGT), developed by QinetiQ for the Defence Procurement Agency of the United Kingdom's Ministry of Defence. The review focused on the functionality and usability of the tool.

Results: Based on a top-down modelling solution that relies heavily on a functional decomposition analysis, the CGT achieves its designed goals well. The assessment confirmed the usefulness of a CGT model for generating manpower and personnel requirements during the early stage of a ship's design. One advantage of the tool is its support to create innovative crewing concepts. However, the assessment also revealed several functional gaps that were considered beyond the capability scope of the CGT. Specifically, it is not a tool for complement validation and it does not have the functionality to create detailed operator scheduling. Minor issues were identified on three of the evaluation criteria while the CGT performed well on the rest.

Significance: Crewing is one of the common challenges faced by a number of on-going Canadian Navy acquisition projects. An understanding of the capabilities and limitations of the CGT enables the Navy to decide whether or not the tool is suitable for resolving the challenge and what kind of modelling capabilities yet need to be developed.

Future plans: Based on the feedback from the Navy clients, the Defence Research and Development Canada (DRDC) 14dj project will develop a tailored crew modelling capability to better serve the needs of the Department of National Defence's on-going acquisition projects.

Sommaire

Évaluation de la fonctionnalité et de la convivialité de l'outil de génération de compléments (CGT) - Examen préliminaire

Wenbi Wang; RDDC Toronto TM 2011-057; R & D pour la défense Canada – Toronto; Avril 2011.

Introduction ou contexte : La modélisation et la simulation sont reconnues comme des méthodes efficaces pour évaluer des solutions de compléments pour de futures plateformes navales. Dans le présent document technique, on présente l'évaluation d'un outil de modélisation, soit l'outil de génération de compléments (CGT), développé par QinetiQ pour le compte de l'Agence d'acquisition de matériel de défense du ministère de la Défense du Royaume-Uni. Le travail consistait à évaluer la fonctionnalité et la convivialité de l'outil.

Résultats : Grâce à une technique de modélisation descendante qui repose grandement sur une analyse de décomposition fonctionnelle, le CGT remplit bien les fonctions pour lesquelles il a été conçu. L'évaluation a confirmé l'utilité du CGT en ce qui concerne la détermination des besoins de main-d'œuvre au cours de la phase initiale de la conception d'un navire. L'un des avantages de cet outil est sa capacité de créer des concepts de recrutement novateurs. Cependant, l'évaluation a aussi révélé plusieurs lacunes fonctionnelles considérées au-delà des capacités du CGT. Par exemple, l'outil ne permet pas la validation de compléments et n'est pas en mesure de créer un horaire détaillé. Dans l'ensemble, le CGT fonctionnait bien, sauf pour quelques problèmes mineurs concernant trois critères d'évaluation.

Portée : Le recrutement d'équipage est un problème que l'on rencontre fréquemment dans les projets d'acquisition de la Marine canadienne. Le fait de connaître les capacités et les limites du CGT permettra à la Marine de décider si cet outil convient pour résoudre ce problème et de déterminer quels types d'outils de modélisation il resterait à mettre au point.

Perspectives : À partir des commentaires des clients de la Marine, Recherche et développement pour la défense Canada (RDDC) mettra au point, dans le cadre du projet 14dj, un outil de modélisation d'équipage taillé sur mesure afin de mieux répondre aux besoins des projets d'acquisition du ministère de la Défense nationale en cours.

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Acknowledgements

The author thanks Colin Corbridge for providing the CGT and its documentation.

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1 Introduction

The Complement Generation Tool (CGT) is a software program developed by QinetiQ's Centre for Human Sciences for the Defence Procurement Agency of the Ministry of Defence, United Kingdom (UK). The tool was created to address crewing issues encountered in the design of future naval platforms [2].

A copy of the CGT was recently obtained by the Defence Research and Development Canada (DRDC) through The Technical Cooperation Program (TTCP), Human Resources and Performance (HUM) Group, Technical Panel 9, in order to support an Applied Research Project (ARP) 14dj entitled *Risk mitigation in capital acquisition: Modelling and simulation approaches.* This technical memorandum summarises a preliminary review of the tool and is intended to inform the decision-makers in the on-going Canadian naval platform acquisition projects, including the Canadian Surface Combatant project (CSC), the Joint Support Ship project (JSS), the Arctic/Offshore Patrol Ship project (AOPS), as well as other maritime stakeholders, e.g., Directorate Maritime Personnel.

The report focuses on modelling issues associated with the tool, that is, the modelling methodology, model construction processes, and software functionality and usability. The goal is to help the project clients reach informed decisions on (1) whether or not the CGT is a suitable tool for addressing complement issues in the on-going Department of National Defence (DND) projects; and (2) whether or not there are capability gaps in the CGT that can be resolved by the 14dj ARP.

1.1 Crew modelling

Personnel cost associated with operation, maintenance and support represents a significant component in the life cycle cost of operating a naval platform [3]. Under the current budgetary climate, there is substantial pressure to optimize the crewing level for future naval platforms. While a reduction in the crew number is often the objective, such optimization should ensure that the platform's effectiveness, reflected by both its operational capability and operator performance, is not compromised.

To achieve this objective, it is important to start developing a complement solution during the early stage of a ship's design, since such a solution can be used to select and justify equipment and technology (e.g., automation) choices. However, this is a difficult task. The evidence from many previous projects showed that the complement obtained in the early conceptual design underestimated the work demand and an increase of crew size was observed after the delivery of a lead platform [4].

Modelling and simulation (M&S) has been suggested as a viable solution to address this challenge [5-6]. The CGT represents one of a dozen modelling tools developed by the allied navies to study manpower and personnel requirements in naval ship design.

1.2 Basic facts about the CGT

As its name implies, the CGT was developed for generating a complement solution for a ship. In particular, the tool was designed to aggregate the manpower and personnel demands for various platform functions across different operational states. The primary output of a CGT model is a manning list that describes a complete set of personnel that is required to operate a ship. The central question that a CGT model intends to address is: “How many people are required to operate this future platform?” Note this objective differs from those crewing tools that aim at resolving issues associated with complement validation, i.e., whether or not a particular complement will satisfy the manpower requirement of a ship under a range of operational scenarios.

The difference between complement generation and complement validation is significant, since it has implications on how a model can be integrated into the acquisition process. For the CGT, its model is designed for use early in the acquisition process, e.g., during the concept design and early assessment phases. In contrast, tools that support complement validation are often introduced at a later stage when substantial details of the platform design (e.g., equipment choices) become available.

Broadly speaking, there exist two modelling approaches for generating a complement solution. The first is a top-down approach (as adopted by the CGT) based on the rationale that the manpower and personnel requirements can be estimated by an iterative analysis of the platform’s missions, functions, and tasks. This approach involves first a hierarchical decomposition of a platform’s mission objectives into a number of functional areas. Each functional area is then fragmented into a set of supporting tasks. Depending on a task allocation scheme, in which a task can be assigned to a human operator or machine equipment, manpower and personnel requirements can be generated.

Alternatively, there is a bottom-up approach that predicts the manpower and personnel demand based on a modification of crewing solutions obtained from existing platforms. While such an approach is also widely adopted, it is sometimes criticized for its difficulty in introducing innovative crewing concepts and the complement solutions it produces are often considered as evolutionary.

Although the conceptual model of a top-down approach is not difficult to understand, it is important to note that a complement solution directly obtained from a functional decomposition analysis is typically not optimized. Given that task demands fluctuate over time and individual staff can play multiple roles, significant optimization on the complement solution is necessary. The strength of the CGT is its ability to balance the manpower and personnel demands across different states of ship operations.

The CGT requires that users have domain expertise in naval platform operations, understand the complexity of the warship’s socio-technical organization and the different demands imposed on the complement by the operational context.

The evaluation presented in this report is based on the CGT version 3.1.0 build 0. The hardware requirement for running the tool is modest. The current evaluation was conducted on a Microsoft Windows XP computer with a 600 MHz processor. A dual screen was set up to enhance the usability by presenting the model and the complement output simultaneously on separate screens. The Microsoft Office suite of software was used to view the output files.

2 How does the CGT work?

The CGT incorporates a five-stage process to create a complement solution, as illustrated in *Figure 1*. The following description was adapted from its user guide.

Stage 1 involves developing a whole platform functional decomposition of all activities that must be undertaken on the platform including management functions. An outline of whole-platform functional decomposition is contained in the CGT. The user populates the functional decomposition with information concerning the personnel demands associated with the performance of each platform function. Personnel demands are specified in terms of the number of personnel and their “type”, where “type” includes attributes of rate, rank and skills.

Stage 2 involves calculating initial estimates of the personnel required to operate the platform in each of the three watch states (cruising, defence and action). These estimates are based on watchkeeping demands for each department and the demands imposed by maintenance, plus other non-equipment related functions.

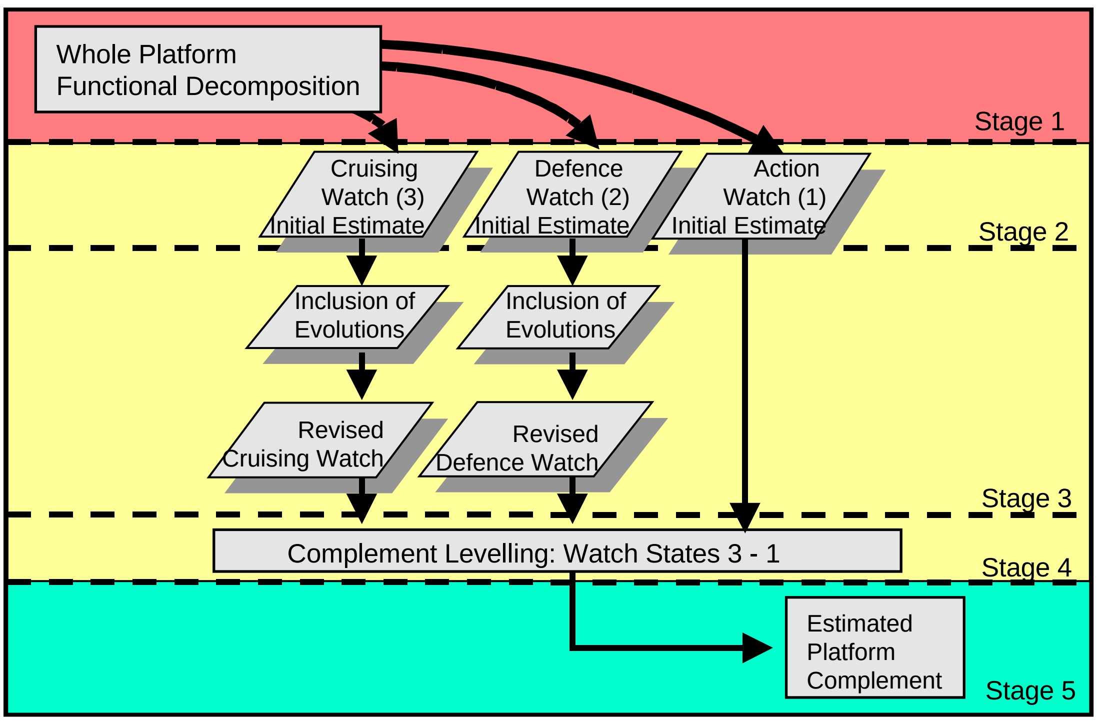

Figure 1: The CGT’s five-stage process for complement generation, adapted from [1].

Stage 3 involves adding in the personnel requirements of “evolutions” that the platform is required to perform in the two lower readiness states: cruising and defence. Evolutions are typically functions that are performed intermittently by the platform and need to be accommodated during the day-to-day operation of the platform, e.g., Replenishment At Sea (RAS). Revised complement estimates are then produced for the cruising and defence watch states.

In Stage 4 of the process the user examines the complement required for each watch state and adjusts the demands placed on the platform in each state to level the complement. This is a complex process requiring trade-offs in terms of both complement number and skills.

The display and storage of the resulting complement estimate is the final stage (Stage 5) of the process.

The five-stage modelling process is supported by three software components:

(1) A functional decomposition module that allows the user to structure the data collection activity concerning the personnel demands associated with the platform functions (i.e., Stage 1).

(2) A complement calculation module that computes the demand for personnel based on the input obtained in the functional decomposition and optimizes the complement by levelling crew demand for each watch state. More specifically, the complement calculator computes how many watch keepers and additional personnel (e.g., involved in specified evolutions) are required for each watch state. The personnel demand is specified by both the crew number and the rank/rate and skills for each individual. The analysis is conducted on a weekly cycle, in other words, the demand for personnel is assessed on a weekly basis for each watch state.

(3) An output module that displays the resulting complement estimate, i.e., the details of the platform functions, their associated personnel demands and the generated complement.

2.1 Functional decomposition module

The functional decomposition module is a stand-alone program and it is where the output from the functional decomposition analysis is collected. *Figure 2* shows a sample screenshot of its main interface.

The analysis considers three platform watch states: cruising, defence and action, each reflecting a specific level of operational readiness. The required tasks, and, consequently, manpower and personnel requirements, are different across the three states. The CGT first calculates the manpower requirements for each of the three states independently and then generates a complement solution by balancing the requirements across the three states.

The manpower requirement in a CGT model is determined by five different types of operator tasks:

(1) Watch keeping tasks associated with a piece of equipment, e.g., the wheel in the bridge or certain radars.

(2) Non-equipment watch keeping tasks, e.g., firefighting or damage control.

(3) Evolutions, that is, functions or activities that are performed intermittently by the platform, involve a number of people and happen every so often. The CGT considers approximately a dozen types of evolutions that a ship is expected to carry out, including replenishment at sea, berthing at buoy, boarding parties and going to anchor.

(4) Manpower tasks that involve manual tasks carried out by one or more people, like clean the deck or administrative work.

(5) Maintenance tasks associated with each piece of equipment.

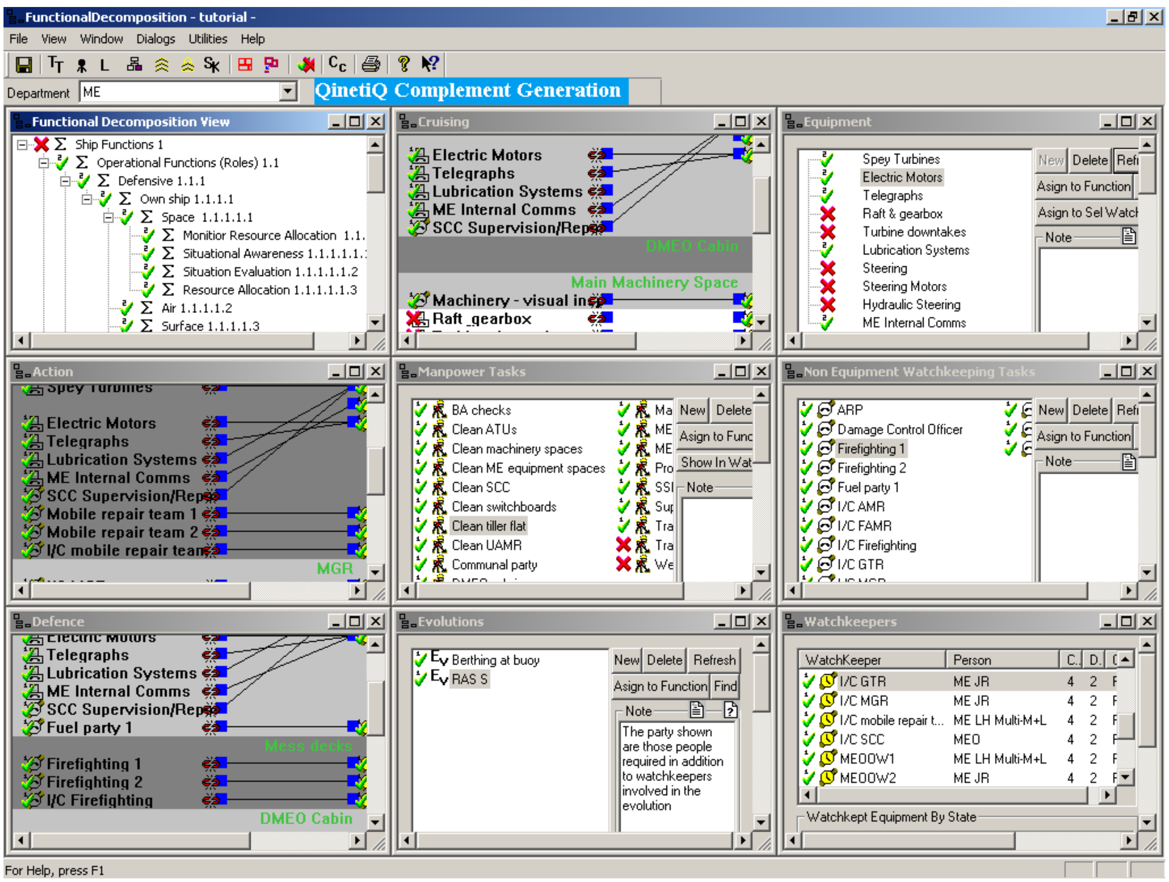

Figure 2: A screenshot of the functional decomposition program in the CGT.

While task demands are commonly defined in terms of who (person type), where (location and department) and when (number of hours), there are significant differences across the tasks that have implications for their manpower requirements. Specifically, watch keepers (regardless whether or not equipment is associated) are allocated a rotation shift. They can not be assigned to certain types of tasks like Standing Sea and Emergency Party (SSEP) where a rapid response is expected to an emergency incident. Evolutions are commonly scheduled events and are only considered in the two lower readiness levels of watch states (i.e., cruising and defence). They typically require additional personnel above normal departmental watchkeeping, and may require that individuals with specific skills interrupt on-going maintenance, or other tasks, to support the conduct of the evolution. Different from evolutions, manpower tasks can be handled asynchronously. For example, a manpower task can be completed by either five people in two hours or one person in ten hours. Lastly, the maintenance tasks are each associated with particular equipment.

Individual staff members are modelled in the CGT in terms of their rank, skills, department and maximal working hours. A cost parameter is also included based on the rank.

The output of the functional decomposition is a hierarchical breakdown of the ship's functions into these five types of tasks. The result is graphically presented, as shown in *Figure 3*. In essence, the data describe the types of tasks to be performed and the types of people required to do them. The data are stored in a relational database and further processed by the complement calculator (the second CGT module) to generate complement solutions.

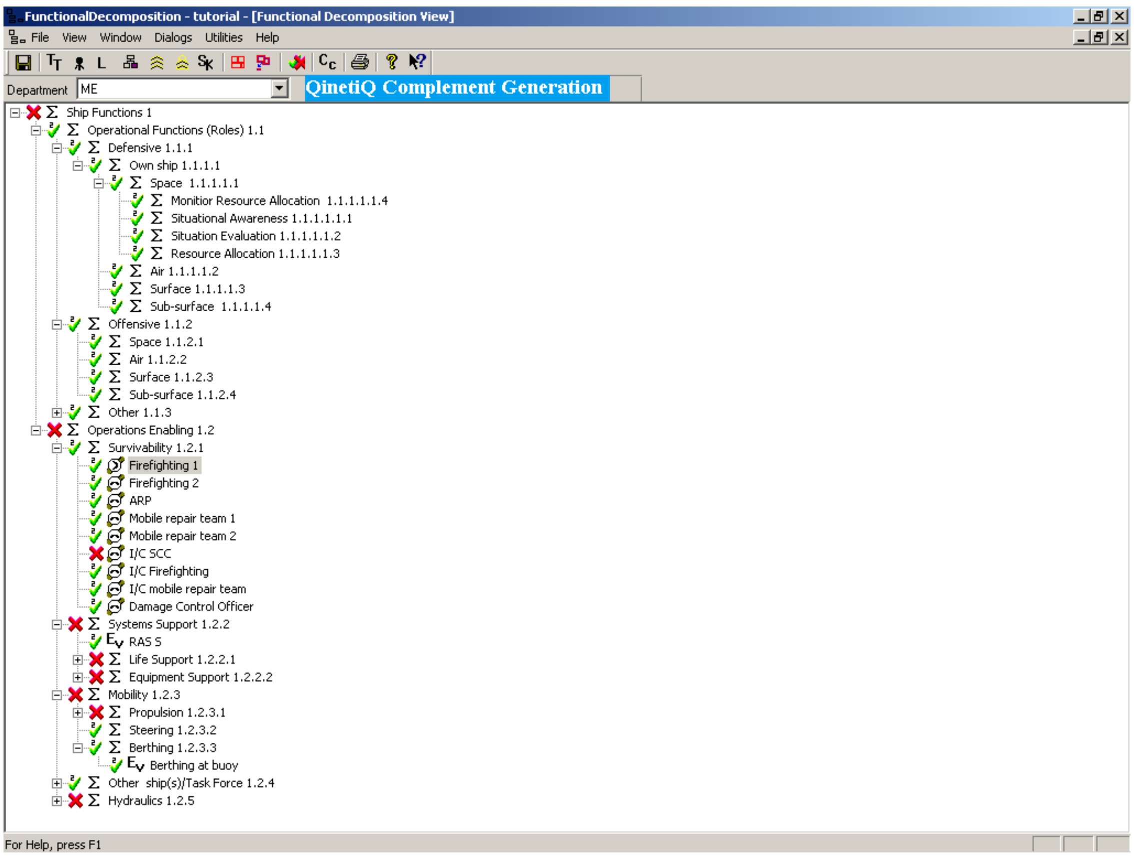

Figure 3: A screenshot of the functional decomposition output.

2.2 Complement calculator module

The complement calculator is also a standalone program and can be initiated either independently or from within the functional decomposition program. A screenshot of the calculator is available in *Figure 4*.

The program is used after the functional decomposition analysis is completed. It imports the database produced by the functional decomposition program and creates people of specified types to satisfy the task demands defined in Stage 1.

The generation of a complement is based on a set of built-in rules. These rules dictate the type and number of staff created by the calculator. They reflect both the capabilities and limitations of the tool. Below is a summary of the major rules implemented in the CGT.

(1) The complement calculation involves a number of steps and they are conducted in a fixed order. Across three watch states, a complement is created firstly for the action state, then the defence and finally the cruising state. For each state, personnel are allocated first to the equipment watch keeping tasks, and then followed by the non-equipment watch keeping tasks. Evolutions, manpower and maintenance tasks are then allocated where applicable.

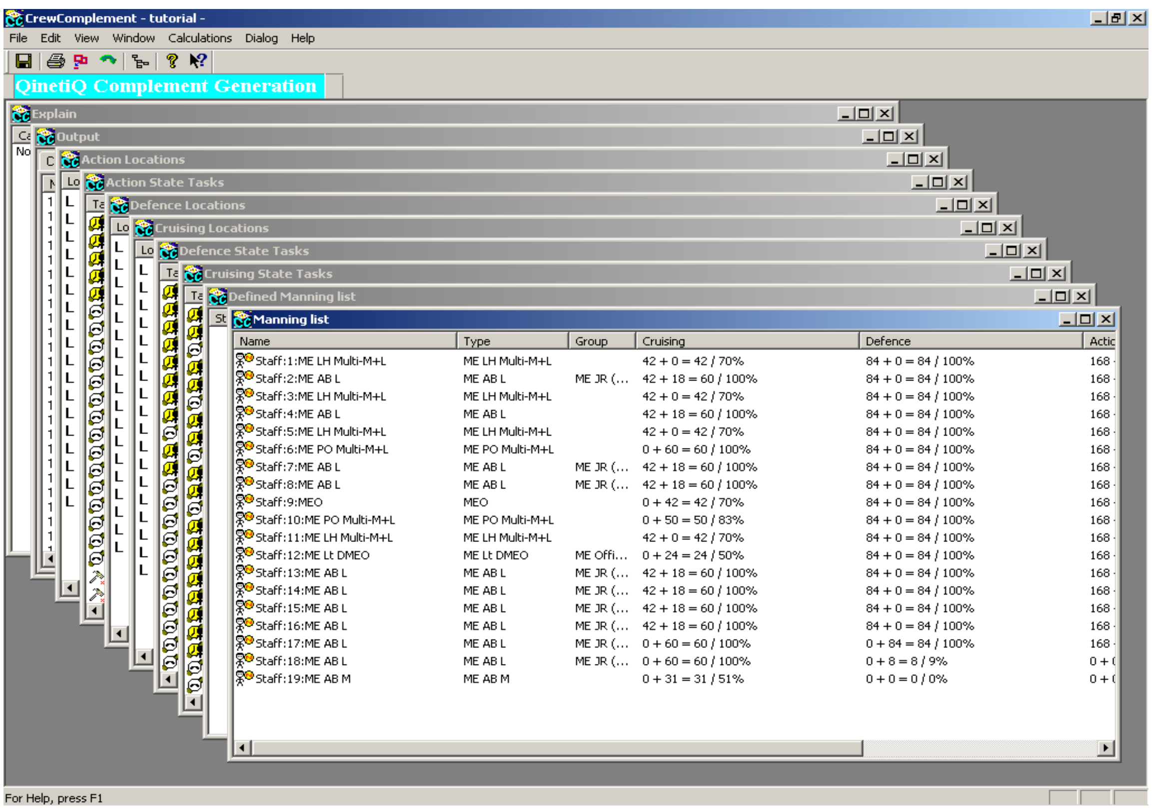

Figure 4: A screenshot of the complement calculator in the CGT.

(2) The evolution, manpower and equipment maintenance tasks are treated in a similar fashion. The calculator first attempts to allocate the task to already-created people (when they have sufficient spare time). If this is not possible, then the calculator will create a new person to handle the task. The number and type of new persons are decided by the cost factor. For example, when a task can be performed by people from a range of ranks, the lowest ranking person (i.e., the least costly) will be created.

These built-in rules also reflect some of the major limitations of the CGT. In particular, the fixed execution sequence adopted by the complement calculator limits the program's ability to create an optimized complement. Specifically, it does not guarantee that the utilization rate of an individual member created by the calculator is maximized. To resolve this issue, manual tweaking of the complement solution is required. To the CGT's credit, the tool does provide a user-friendly interface to examine the complement solution, which facilitates further complement optimization.

A number of "what-if" types of probes are suggested in the CGT user guide to examine the quality of a complement solution. In particular, user adjustment can be made by specifying (1) a list of staff that will always be created; (2) the percentage of certain tasks to be completed in each readiness state; (3) the exclusion or inclusion of non watch keeping tasks in each state. The calculator will incorporate these user-defined conditions in the computation process.

The primary output of the complement calculator is a manning list, which documents the number of staff required to carry out all planned tasks, their skill type, and the utilisation rate (expressed in both hours and percentage) for each watch state.

Additional output formats are also available, including the list of tasks performed in each state, the spatial distribution of personnel (in terms of locations on the ship) in each state, and a summary of the generated complement with its relation to the decomposed functions and sub-functions obtained from Stage 1.

2.3 Output module

The output module is integrated in the complement calculator program. The complement solution generated by the calculator can be exported into a file format based on the UK Royal Navy's standard Quarter Bill for a Type 45 platform. This particular format serves as a template and can be further modified to reflect the needs from future projects.

3 Functionality and usability assessment

An assessment was conducted in this preliminary study that focused on the functionality and usability of the CGT. It is useful to note that the validity of the model output was not evaluated in this study due to the author's lack of sufficient domain knowledge of Canadian naval platform operations. To rectify this, a copy of the CGT was provided to the maritime client for a separate evaluation.

3.1 Functionality assessment

The previous section describes the main functions of the CGT. As a mature application, the tool possesses all the necessary functions to achieve the objectives for which it was designed. The following list reflects three issues identified in this review. All represents additional or alternative functions that are not supported by the CGT.

(1) Task demands are represented in the CGT using the unit of time (e.g., hours). The model does not consider other dimensions of task requirements and consequently can not accommodate other types of analysis such as workload assessment. Although operator multi-tasking is implicitly allowed by the CGT, the effectiveness of task time-sharing can not be validated by the model.

(2) The complement calculator assesses task demand on a weekly basis. An individual is assigned to a task when spare time is available. Detailed scheduling of individuals to non-watch keeping tasks is considered beyond the scope of the CGT. In other words, the tool does not produce a complete timeline of events on the platform.

(3) The CGT is limited in its ability to automatically search for an optimized complement solution. This is largely because of the fixed order adopted by the tool for processing manpower requirements across watch states and tasks. Complement optimization is currently conducted by manual adjustment of the solution through "what-if" analysis. Algorithmic solutions that automate the process would be preferable.

3.2 Usability assessment

The usability assessment was conducted by examining the CGT against Nielsen's ten usability heuristics [1]. Below are the results, presented first with a description of the evaluation criteria, followed by a summary of the findings.

(1) *Visibility of system status: The system should always keep users informed about what is going on, through appropriate feedback within reasonable time*.

CGT: The interconnectedness of the data, particularly those manipulated in the functional decomposition program, requires a prompt update of affected data fields when a piece of datum is modified. Overall, this heuristic is followed quite well in the CGT, except the following two occasions:

(a) A "refresh" button is available in many dialogues and windows in the functional decomposition program to force a data update. However, such a manual update is not always necessary, in fact, the test revealed that the program was able to automatically update the data fields most of the time. A problem emerges during the few exceptions where automatic update was not performed, and the user could get quite confused. An addition of some visual feedback, e.g., grey out the "refresh" button after automatic update is performed, should resolve this issue.

(b) A particular function, "Show in Watch Wind", in the Manpower tasks definition window allows the display of manpower tasks alongside the watchkeeping tasks for each state. However, the information is viewable when the state status window is sufficiently enlarged. When the status window is not expanded, however, there is no visual indicator (e.g., a horizontal scroll bar) to inform the user that additional information is available in the invisible area of the status window, as illustrated in *Figure 5*. This is problematic since the manpower tasks by default are not shown in the watch state window. If these windows are not properly enlarged, after a selection of the "Show in Watch Wind" function, the user will not get any feedback even though the information is correctly presented (in the hidden area of the watch windows).

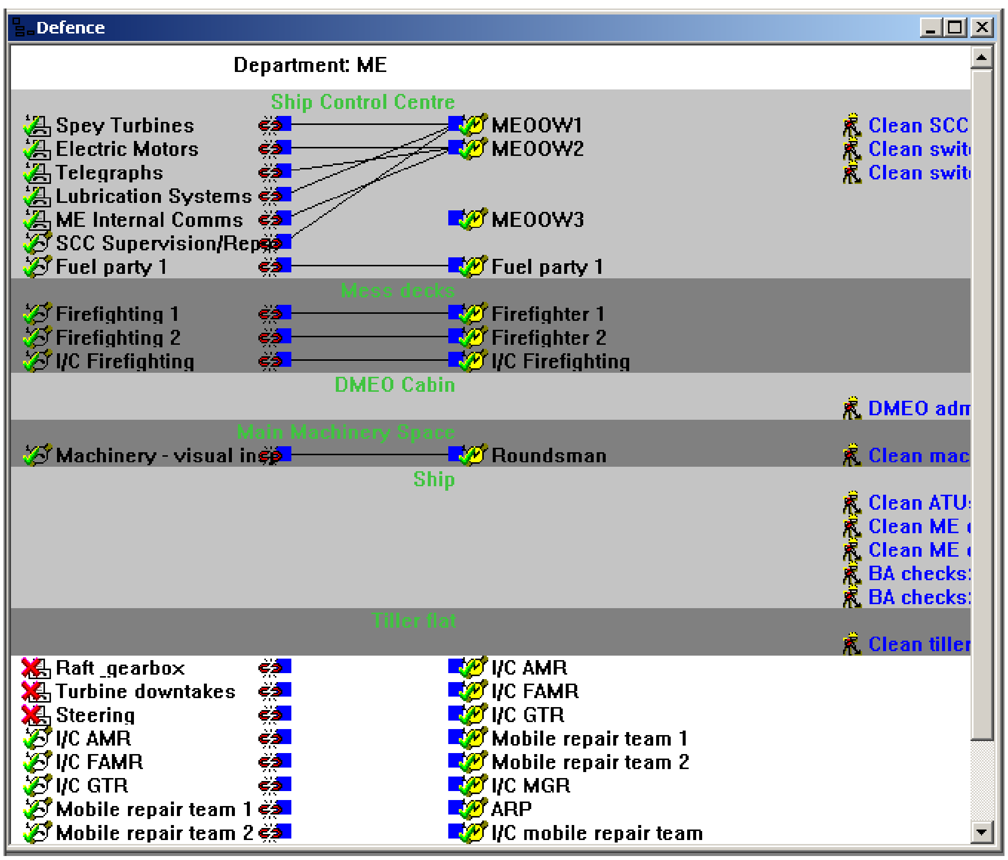

Figure 5: An illustration of the lack of a visual indicator in the status window for a watch state (e.g., Defence). Note the manpower tasks (on the right) are not completely visible, however, the window does not have a horizontal scroll bar to indicate that condition.

(2) Match between system and real world: The system should speak the users' language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms. Follow real-word conventions, making information appear in a natural and logical order.

CGT: This heuristic is well followed by the tool. While the format of user-entered data is a matter of user's choice, the labels automatically generated by the tool are presented in an easily readable fashion. The tool's ability to output the complement into a Quarter Bill (i.e., a standard document used by the Royal Navy to describe the positions that need to be filled by personnel to work and fight a warship.) was found to be particularly useful. It enables the presentation of a complement solution in a format that's accessible by the client community.

(3) User control and freedom: Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

CGT: Undo and redo are not supported by the functional decomposition program. Some effort was made to ameliorate this issue. For example, many user functions are context sensitive which means they are disabled (e.g., greyed out) to prevent accidental initiation in the wrong context. However, this lack of action recovery function creates some difficulties in the complement adjustment process. That is, when the user conducts "what-if" experiments with a complement solution, it is cumbersome if an adjustment is found to be undesirable and a return to the previous complement state is needed.

(4) Consistency and standards: Users should not have to wonder whether or not different words, situations, or actions mean the same thing. Follow platform conventions.

CGT: The interface is fine in this regard. Standard labels and interaction styles are followed throughout both programs.

(5) Error prevention: Even better than good error message is a careful design which prevents a problem from occurring in the first place.

CGT: Two useful measures were incorporated in the CGT to prevent user error. The first is the context sensitive activation of user functions. The second is a capability to automatically check input data's integrity. The incomplete data entries (e.g., with missing parameters) are highlighted by salient visual cues in the functional decomposition program.

(6) Recognition rather than recall: Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable wherever appropriate.

CGT: This is an important issue in this tool since a potentially very large set of data is created in a model and the user often has to compare data points across different dialogues and windows. The CGT handles it quite well. In particular, dual screen setup is suggested to run the functional decomposition and complement calculator on separate displays, so that sufficient screen real state is available to support cross-referencing data between these two programs, which otherwise would require an increase of memory load if a single display is used and frequent window-switching are performed. Additionally, in both functional decomposition and complement calculator, built-in functions are created to provide the user with central portals to examine both the entire dataset and individual data points and their relationships. Such functions significantly reduce the user's cognitive demand in data retrieval.

(7) Flexibility and efficiency of use: Accelerators – unseen by the novice user – may often speed up the interaction from the expert user to such an extent that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

CGT: Toolbars with shortcuts to frequently-used functions are provided for experienced users to quickly access these functions.

(8) Aesthetic and minimalist design: Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

CGT: The tool is fine in this regard.

(9) Help users recognise, diagnose and recover from errors: Error messages should be expressed in plain language (no codes), and precisely indicate the problem and constructively suggest a solution.

CGT: The tool is fine in this regard.

(10) Help and documentation: Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

CGT: The tool's user guide is a valuable document. It includes a tutorial which provides a good walk-through of the entire modelling process. But the guide itself is not sufficient to teach the user how to effectively create a model. Other references are needed, such as [7]. A help function is available inside the tool. However, the function is not context sensitive as its reference icons suggest. A click on a help icon will invariably bring up the user guide.

Overall, this preliminary assessment revealed the CGT as a well-polished modelling tool. No software bugs were encountered during the week-long testing. With a few exceptions, the user interface is well designed and easy to use. The software is well documented. A tutorial on a sample modelling exercise provides a good start point to navigate through the tool's functions.

4 Whether the CGT can be directly used to support DND projects?

Although this assessment confirmed the CGT as a highly useful and usable crew modelling tool, a number of issues need to be considered when deciding whether or not it is suitable to support the Canadian Navy's project needs.

First of all, a caveat of the current study should be kept in mind. That is, the current assessment only focused on the functionality and usability of the tool. Further evaluation, particularly regarding the validity of the complement solutions, needs to be considered. This issue is nonetheless not significant since the complement the CGT generates is intended as an initial solution with an expectation that further verification and validation will be conducted in the follow-up acquisition process.

Secondly, it is critical to obtain a clear understanding of the needs from the on-going Canadian Navy's acquisition projects. The following list of questions illustrates the type of issues that can affect the tool choice.

(1) Is the identification of a complement (i.e., size of the crew and the skill requirements) sufficient to satisfy a project's needs?

(2) Is it important to examine the timeline of events and tasks for individual staff members during a maritime operation?

(3) Is it useful to provide a visual representation of the personnel's spatial distribution on a platform?

(4) Is it important to link personnel types used in a model to the Canadian Forces' military occupations?

(5) Whether or not operator mental workload should be considered in task allocation? This issue becomes significant when manpower and personnel demand are balanced against technological solutions (e.g., different levels of automation).

While the CGT is a viable solution to resolve question (1) above, additional modelling capabilities need to be developed if any of the remaining four questions (2 to 5) are to be addressed.

Lastly, the default modelling constructs implemented in the CGT reflect the doctrines as well as the Concept of Operations (CONOPS) followed by the Royal Navy. Customization is needed to tailor the tool to satisfy the requirements for the Canadian Navy.

It is worthwhile to note that the CGT is considered to be one of the better crewing tools from our allies that can be tailored to support DND's needs. The customization effort will be smaller compared with the alternative, bottom-up based, modelling tools like QinetiQ Crew Aggregation Tool (QCAT) that relies extensively on a particular class or type of existing platform.

5 Summary

This preliminary review confirmed the capability of the CGT as a modelling tool to support complement generation during the early stage of naval platform design. Whether or not the tool is suitable for the on-going Canadian Navy's acquisition projects depends on the nature and granularity of the crewing issues to be addressed by the model.

An important capability gap identified in this review is the lack of more sophisticated measures of system effectiveness and performance. Technological advancement, particularly in the form of automation, is one of the most important enablers for crewing reduction [3, 8]. This has at least two implications on ship complement design. First, automation has a tendency to transform the nature of operator work, often reflected by reducing the physical requirement while at the same time increasing the cognitive demand. Consequently, the use of a time parameter alone (as in the CGT) becomes less than adequate for evaluating operator performance of those automation-assisted tasks. Second, the complexity of a system is increased with the expanded use of automation, the result of which is a potential decrement of overall system reliability (which is the product of the reliabilities from all component elements). For mission critical functions, it is important to evaluate the consequences associated with automation failure, including its impact on manpower and personnel. To effectively handle these implications, more sophisticated modelling solutions with alternative performance measures are required.

One possible way ahead is to adopt a task network-based modelling approach and embrace the concept of simulation. Such an idea is not new, and it can be found in existing crewing tools like the United State's Integrated Manning and Personnel Analysis Computation Tool (IMPACT). DRDC's own modelling tool, the Integrated Performance Modelling Environment (IPME), also presents a mature platform for developing task network models and conduct discrete-event simulation. The IPME can be further developed to include modelling constructs specifically for supporting complement generation and validation.

Given that the complexity of a task network model often exceeds that of a CGT type of model, it is debatable whether or not the creation of a full-ship complement in a task network model is economically desirable. In fact, a hybrid modelling solution, incorporating both a CGT type of complement model and an IPME model, presents a promising solution. While the CGT model provides a coarse representation of a ship's full complement, IPME models can be constructed to investigate specific functional areas where innovative automations are introduced.

This direction is in line with the objectives of the on-going DRDC 14dj ARP. It is the aim of the project to work closely with the Maritime community to identify crew modelling requirements and develop software capabilities accordingly to best serve the needs of the Canadian Navy.

References

[1] Nielsen, J. (1994). Heuristic evaluation. In J. Nielsen & R. L. Mack (Eds.), *Usability inspection methods* (pp. 25-103). New York: Wiley.

[2] Merrett, G., & Bailey, N. (2008). *Complement Generation Tool: User guide v3* (QINETIQ/EMEA/TS/UG0800118/3.0). QinetiQ.

[3] Beevis, D., Vallerand, A., & Greenley, M. (2001). *Technologies for workload and crewing reduction: Phase 1 project report* (DCIEM TR 2001-109). Toronto, Canada: Defence Research and Development Canada.

[4] Tools for optimizing naval platform manning and manpower requirements. (2002). (TR-HUM-1-2002). The Technical Cooperation Program.

[5] Archer, R. D., Lewis, G. W., & Lockett, J. (1996). Human performance modelling of reduced manning concepts for navy ships. In *Proceedings of the Human Factors and Ergonomics Society – 40th Annual Meeting* (pp. 987-991). Santa Monica, CA: Human Factors and Ergonomics Society.

[6] Bost, J. R., Malone, T. B., Baker, C. C., & Williams, C. D. (1996). Human systems integration (HSI) in navy ship manpower reduction. In *Proceedings of the Human Factors and Ergonomics Society – 40th Annual Meeting* (pp. 977-981). Santa Monica, CA: Human Factors and Ergonomics Society

[7] Cook, C. A., Corbridge, C., Older, M. T., Clegg, C. W., & Waterson, P. E. (1996). Function allocation for future systems: Developing an improved methodology. In *Proceedings of the Human Factors and Ergonomics Society – 40th Annual Meeting* (pp. 982-986). Santa Monica, CA: Human Factors and Ergonomics Society

[8] Hiltz, J. A. (2005). *Damage control and crew optimization* (DRDC Atlantic TM 2005-010). Halifax, Canada: Defence Research and Development Canada.

List of symbols/abbreviations/acronyms/initialisms

AOPS	Arctic Offshore Patrol Ship project
ARP	Applied Research Project
CGT	Complement Generation Tool
CONOPS	Concept of Operations
CSC	Canadian Surface Combatant project
DND	Department of National Defence
DRDC	Defence Research & Development Canada
HUM	Human Resources and Performance Group
IMPACT	Integrated Manning and Personnel Analysis Computation Tool
IPME	Integrated Performance Modelling Environment
JSS	Joint Support Ship project
M&S	Modelling and Simulation
QCAT	QinetiQ Crew Aggregation Tool
RAS	Replenishment At Sea
SSEP	Standing Sea and Emergency Party
TTCP	The Technical Cooperation Program
UK	The United Kingdom

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Évaluation de la fonctionnalité et de la convivialité de l'outil de génération de compléments (CGT) − Examen préliminaire (U)

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(U) A review of the Complement Generation Tool (CGT) was conducted that focused on the functionality and usability of the tool. The results confirmed the usefulness and usableness of the tool for creating manpower and personnel requirements during the early stage in a naval platform's design. The tool does not have functionalities to address certain types of crewing issues, such as complement validation and operator scheduling. A list of questions is suggested to decide whether the CGT is suitable for resolving Canadian's Navy's project needs.

(U) L'outil de génération de compléments (Complement Generation tool – CGT) est un logiciel de modélisation d'équipes développé par QinetiQ pour le compte de l'Agence d'acquisition de matériel de défense du ministère de la Défense du Royaume−Uni. Le CGT a été soumis à un examen afin d'évaluer sa fonctionnalité et sa convivialité. Les résultats obtenus ont confirmé l'utilité et la convivialité du CGT en ce qui concerne la détermination des besoins de main−d'œuvre au cours de la phase initiale de la conception d'une plateforme navale. Cependant, l'outil ne possède pas les fonctions nécessaires pour résoudre certains types de problèmes liés au recrutement, par exemple la validation de complément et l'établissement de l'horaire du personnel. On suggère une série de questions afin de déterminer si le CGT convient aux besoins de la Marine canadienne.

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(U) complement generation; crew modelling; naval platform acqusition

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