A Methodological Approach to the Design of Advanced Maritime Command & Control Concepts

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Abstract

Life-cycle costs have become an increasingly important design constraint for command and control concepts. To a large degree, life-cycle costs are determined by personnel and exploitation costs. Application of the rapidly developing information technology has until now not yet resulted in a substantial reduction of the number of operators in the Command Information Centre (CIC), although CIC staffing and automation varies significantly over different navies.

This paper starts with an elaboration of the trends in designing new command and control concepts. TNO has addressed the issue of CIC staffing by starting a step by step research programme on Reduced Manning Concepts for future maritime command and control organisations. The goal of this programme is to provide a concept that can be implemented in the year 2010. The first stage was of this programme was directed towards the postulation of an initial identification of the technological feasibility of a reduced manning concept. This stage lasted one year and was carried out in 1998. In this paper, we focus on the different phases of the design methodology used to formulate maritime C2-organisation concepts. Several design considerations that were used to characterise future concepts will be highlighted. We conclude with a short discussion in the hands-on experience with the design methodology.

1 Introduction

Naval Combat Systems range among the most complex of military C3I systems. A modern naval combatant has one of the most powerful aggregations of sensors, communications and offensive and defensive weapons of all military platforms.

Based on the growing need for more sophisticated C3I systems and based on the command & control organisation required by today's and future scenario's, we have identified the following trends that are relevant for the next generation of C2 and C3I systems:

- Life-cycle costs reduction
- Information volume explosion
- Weapon system and threat developments
- Simultaneous execution of warfare tasks

These four trends will be discussed separately within the next sections.

1.1 Reduction of Life-cycle Costs

Current naval command and control concepts are based on an evolutionary continuation of the C2 concepts that have been developed several decades ago. In the last years we have seen that life-cycle costs have become an important design constraint for new command and control concepts. The need to decrease the life-cycle costs will increase in the coming decade. Life-cycle costs are to a large degree determined by personnel and exploitation costs. It is not an exception if the personnel costs amount to almost 40% of the total life-cycle costs. Application of the rapidly developing information technology has until now not yet resulted in a substantial reduction of the number of employees in the Command Information Centre (CIC), although the CIC staffing and automation varies significantly over different navies.

Reduction of the number of CIC staffing however also results in a reduction in human decision making capability which has to be counterbalanced by an increased capability of the supporting information system. This factor especially calls for intelligent systems that incorporate skills, knowledge and experience on naval warfare to substitute for the reduced number of operators.

Some navies have addressed the issue of CIC staffing by starting a research programme on Reduced Manning Concepts for future command and control organisations. Examples of such research programmes are ‘Smart Ship’ and ‘SC-21’. The concept that is developed in the research programme that is carried out by TNO is based on the future (2010) developments and expectations in the information technology.

1.2 Information Volume Explosion

The information availability and demand in future operations will greatly exceed those of current operations. The number of available information sources and their bandwidths will provide much more information than the current C2-systems can handle. Information exchange among C2 systems and their users puts pressure on both the capacity of the communication links as well as on the capability of the users to survey and digest the incoming information.

The more information operators receive, the more time they need to assess the value and relevance of the information in relation to their mission. All this information is converging inside the CIC. Resulting most probably in an information overload for the CIC staffing. The information volume explosion demands significant technological improvements on information management, consisting of information processing, dissemination, filtering and presentation capabilities. The awareness that he who has the most timely, accurate and relevant information has already won half the battle is an old one in military history, but becomes even more important in the information age.

1.3 Threat and Weapon System Developments

Current developments in threats and weapon systems require faster and more reliable C3I systems. Stealth techniques and increased weapon intelligence, manoeuvrability and speed, significantly decrease the self-defence engagement zone around a combatant, and consequently decrease the available reaction time. This becomes even more critical when naval vessels operate in the difficult environments of the littoral. One of the developments to counter these threats is the use of networked surveillance and sensor capabilities, airborne assets and high-acceleration and

agile surface-to-air missiles for anti-ship missile defence. All these solutions demand for sophisticated and highly automated ship-base C3I systems.
Tasks such as programming (smart) missiles currently require a lot of time and attention of the responsible officer. This task must be supported to a high degree by the C2 systems. The operator part of this task has to be simplified to minimise the chance that the officer gets blinkers and is not able to assess and control his complete set of tasks.

1.4 Simultaneous execution of tasks

Future operations are characterised by their high time pressure and complexity. This implies that the command team will have less time for situation awareness and planning. This is especially true in littoral/amphibious operations that require not only control of the three naval warfare areas: Anti Air Warfare (AAW), Anti Submarine Warfare (ASW), and Anti Surface Warfare (ASuW), but also require control of the Land Warfare (LW) area.
Modern warfare demands simultaneous control of all warfare actions conducted against a broad range of objectives distributed over large areas. This will increase the number of possible situations and responses with which the command team must deal. Effective command and control requires control of actions in both time and space, where complex situations must be resolved. Current real-time planning and scheduling tools to support the decision making process are insufficient and restrain the agility, the initiative and the flexibility of operation.

2 C2-organisation concept design methodology

2.1 Overview of the C2-organisation concept design methodology

The TNO research programme is carried out by the TNO - Physics and Electronics Laboratory (TNO-FEL), and the TNO - Human Factors Institute (TNO-TM). Within this research programme, the results of several international studies such as the MO-2015 and the 'Future Reduced Cost Combatant' studies are incorporated. The Physics and Electronics Laboratory focuses on the technological aspects of the C2-organisation concepts while the Human Factors institute focuses on the human factors aspects of the C2-organisation concepts. The co-operation of the two institutes will ensure a balanced C2-organisation concept.
The research programme consists of three stages and started in January 1998. The first stage lasted one year and was directed towards the postulation of an initial identification of a theoretical C2-organisation concept and a determination of the technological feasibility of this concept. The feasibility of the concept is specified in terms of an identification of the required technological level, an enumeration of the critical technological factors, the impact of the technology on the C2 concept and an initial identification of the tasks and functions for the personnel organisation.
The command and control tasks contain several so-called critical elements. A critical element is defined as a situation wherein an essential process must be executed, while the requirements to this process are stretched to their limits (e.g. complexity, information volume, and time-constraints). In the second stage, these critical elements are analysed in more detail. Various technological and human factors solutions will be analysed on their capabilities to decrease the (negative) influence of these critical elements on the C2 process. These solutions will be put into practise in a laboratory set-up for testing and evaluation.

In the third stage, the findings of the first two stages will be used to adapt the initial C2 concept and to refine the description of the concept by a specification of the human organisation, a specification of the software organisation, an information communication model, and a description of the human-computer interface concept. The human organisation consists of a specification of the functions and the tasks of the operators, and their required knowledge, skills, training and education. The software organisation consists of a specification of the computer functions, and their required performance, required knowledge, technological feasibility, and applicable techniques. The information communication model consists of a specification of the information flows among the operators, the computer functions, and the functionaries and software functions.

The C2 concept design methodology has been subdivided into five phases:

- Functional Decomposition.
- Functional Analysis
- Trade-off Analysis
- C2 concept Definition
- Testing and Evaluation

The technology assessment and the analysis of the ship's mission and the expected scenarios support the functional decomposition, functional analysis. Each of the five phases and their interactions are analysed and discussed in the next five sections. The relation among the five phases is shown in Figure 1.

2.2 Functional Decomposition

The C2-organisation concept design methodology starts with a generic decomposition of the command and control functions. It provides us with a detailed insight into the command and control functions, and provides us with a first insight in the complexity of each function. The results of the functional decomposition are the starting point for an in-depth functional analysis. The functional decomposition process uses the functional decompositions made within the MO 2015 research programme and the Ship System Automation programme as a starting point.

At the highest level of the functional decomposition, four main C2 functions are discerned:

- Observation
- Orientation
- Decision making
- Act

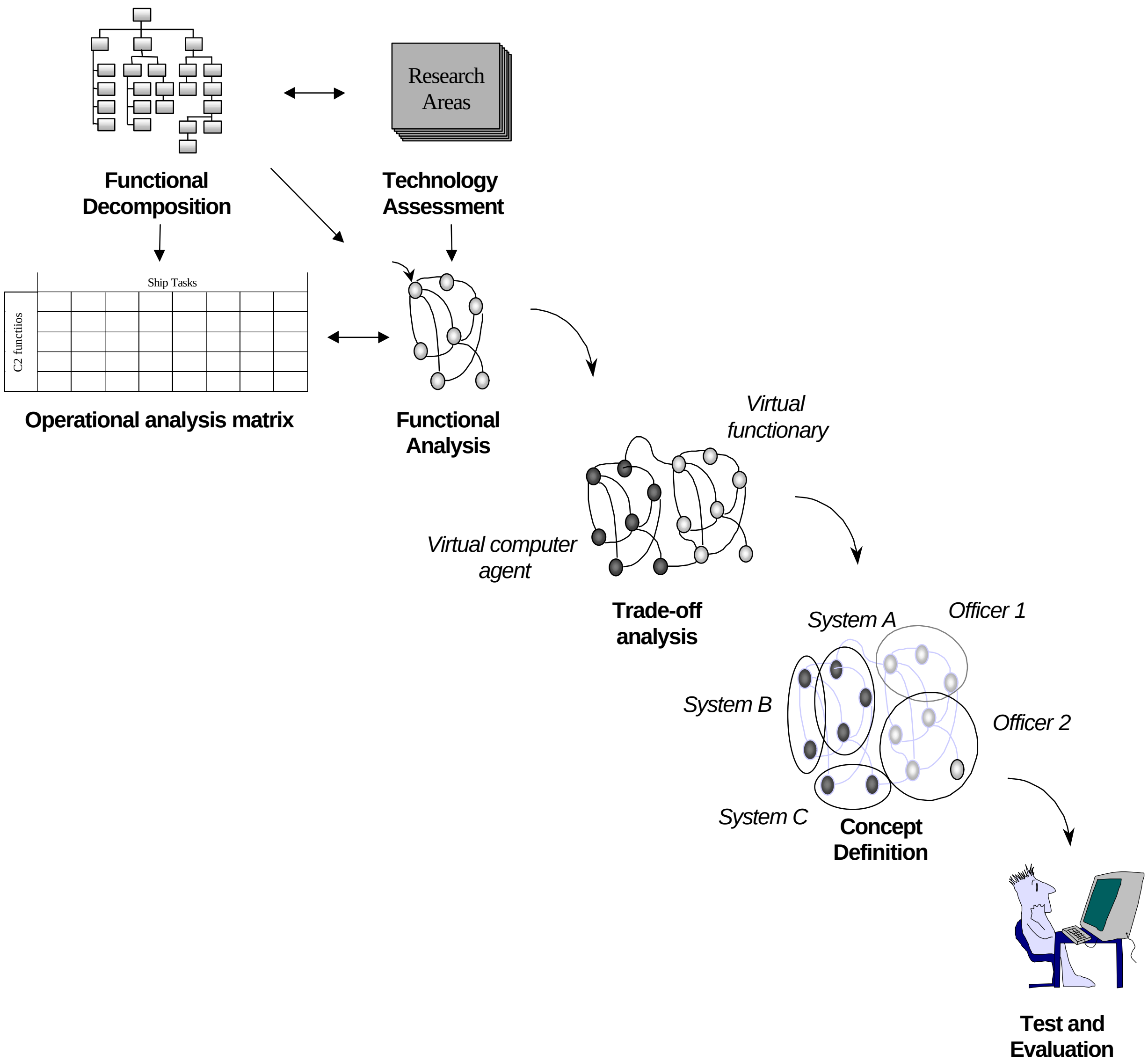

Figure 1. Overview of the C2 concept design methodology

Each of the four main C2 functions is decomposed in 2 till 4 levels to describe the lower levels of these functions with enough detail. This phase interacts with and is supported by the technology assessment, which provides insight in the technological capabilities of, and opportunities and limitations to automate the main C2 functions. It also describes the expected capabilities of the weapons, sensor, and communication systems and the requirements that they pose to the C2 functions. The resulting description of the decomposed functions will be the starting point for a detailed functional analysis on the technological limitations and possibilities.

The following rules are used as stop criteria for the decomposition process, to prevent too much detail, which would decrease the surveyability of the functional decomposition:

- Stop when a clear sight on the possibilities and limitations of the technological and the human factor aspects, that define the organisation concept for that function, can be determined.
- Stop when the new (lower) level function would no longer be a generic function.

2.3 Functional analysis

The functional analysis consists of a technical analysis of the functions derived from the functional decomposition and an operational analysis of the ship and warfare tasks. The combined results of these two analyses provide the starting point for the trade-off analysis.

Part of the operational analysis work is to set-up a matrix in which the C2-functions (observe, orient, decide and act) are correlated with functions within the four warfare areas (AAW, ASW, ASuW and LW) and where each matrix cell is analysed with respect to certain attributes (see below). A second task in the operational analysis is the identification of which ships resources (sensor, weapon and communication systems) are required for specific functions in the warfare areas.

The operational analysis continuous by providing values of several aspects related to the operational and command functions. The Royal Netherlands Navy (RNlN) has analysed four of these attributes:

- Relevance: Not all command and operational functions have the same relevance. For each function, the level of relevance is indicated. The lowest relevance level indicates that the performance of the total command and control concept only deteriorates slightly if the function is not carried out.
- Time: The time aspect expresses the duration of the refreshment cycle of a command function. The time aspect is described using five refreshment cycle levels, varying from reflexive actions (up to 5 seconds) to situations where information needs to be formalised and logged in order to be retained (longer than one day).
- Data and information volume: The data and information volume expresses the amount of data and information, that must be processed simultaneously.
- Complexity: The complexity expresses the difficulty to perform a specific command and control process, with respect to human factors. Low complexity means that the process can be performed by an operator or can be implemented by a machine in a straightforward way. A process is qualified as a complex process if the required information can be characterised as uncertain, ambiguous or incomplete.

In the elaboration on the technology assessment, the technological feasibility to automate each leave of the functional decomposition tree is determined. The technological feasibility is not based on the present state of the level, but is based on the level of automation that is expected to be reached using the technological developments that are expected to be implemented and applied by 2010. Using a bottom-up approach, the functions are aggregated to the highest level at which the technological feasibility, for this highest level and all its sub-functions, can be indicated.

The following classes were used to indicate the feasibility of automation:

- Surely possible to automate: The process can be automated with the current level of technology.
- Likely possible to automate: The process can not be automated with the current level of technology, but it is expected that the process can be automated with the level of technology in 2010.
- Likely not possible to automate: The process can not be automated, unless a technology breakthrough is reached before 2010.
- Surely not possible to automate: It is not expected that a technology breakthrough will be reached before 2010.

For each of the C2 processes, a detailed description of the following attributes is provided:

- Qualification: A process can be qualified as an event-driven or a continuous process. A process is qualified as event-driven if it is only activated by one or more specific events in the environment. A process is qualified as a continuous if it continually processes the available information.
- Required knowledge: This item indicates the required knowledge in global terms.
- Response time: This item indicates the response time that can be reached with the expected technology level.
- Human involvement: This item indicates the minimally required human involvement to complete a process. It specifically identifies those parts of the processes that can not be automated.

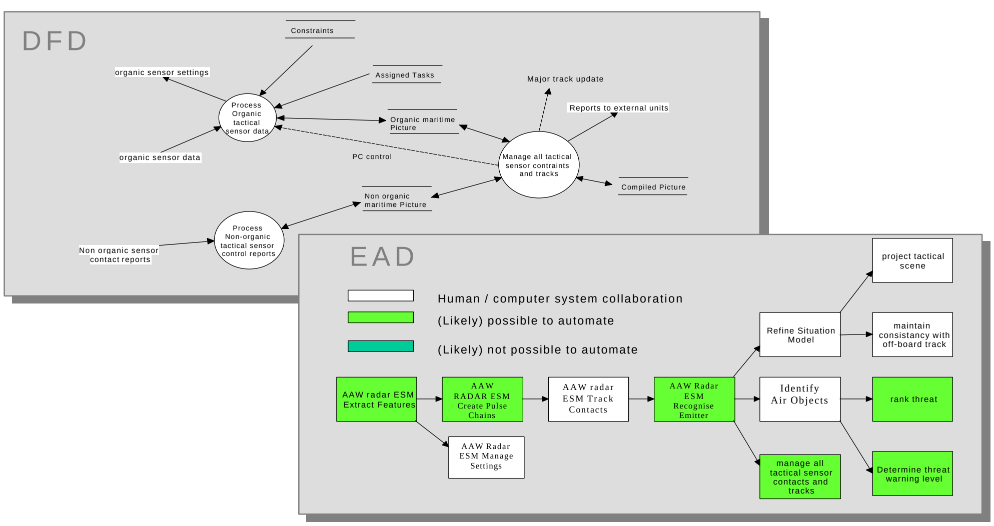

Figure 2. Data flow diagrams and event action diagrams are used to express the connectivity among the different processes.

The Data Flow Diagrams (see Figure 2) provide the process descriptions and also describe the information flows among the processes. The information flows are characterised by their structure (cognitive hierarchy level, type of information, etc.), character (amount, complexity, uncertainty), and their criticality and necessity for the process to which the flow is an input. The event action diagrams are used to indicate the interdependency and the order of activation of the processes. It is also used to determine the ‘critical’ path in the information flows. Both diagrams are used in the trade-off analysis phase. The ‘critical’ paths are also important in the test and validation phase, to determine the processes that must be included in a simulation.

2.4 Trade-off analysis

The results of the functional analysis provide a large amount of detail information of the different functions and processes. A trade-off analysis is introduced to abstract and cluster this information to a higher level to make the information more manageable for the C2-organisation concept definition phase. However, we have to take into account that the relation among the processes that can be automated and the processes that can not be automated might be lost if we do not take special measures. This problem is solved by the introduction of local system arrangement concepts.

The system arrangement concept consists of a description of the role and the involvement of the computer system and of the operators for each function. The system arrangement concept is introduced at a level of the functional decomposition that provides a relatively high-level overview, and contains as much relevant aspects of the lowest level as possible. Five different system arrangement concepts were used [Chalmers, 1998] (see Figure 3):

- Silent/Manual: In silent/manual mode, the operator has total authority. Moreover, the system is completely passive and provides no support whatsoever to the operator.
- Informative: In operative mode, the system only provides the operator with support information, some of which may be a consequence of a request from the operator; however, authority again rests totally at the operator. The operator is able to influence characteristics of the provided support.
- Co-operative: The system and the operator work together in co-operative mode. Authority may be divided or shared by the two parties. However, the operator has the ultimate authority to override the computer system.
- Automatic: In automatic mode, the computer system has total authority, but the operator can influence its behaviour and request information.
- Independent: The operator is completely excluded from the process. This means that the computer system has full authority. It processes information and acts autonomously without any possible involvement of the operator.

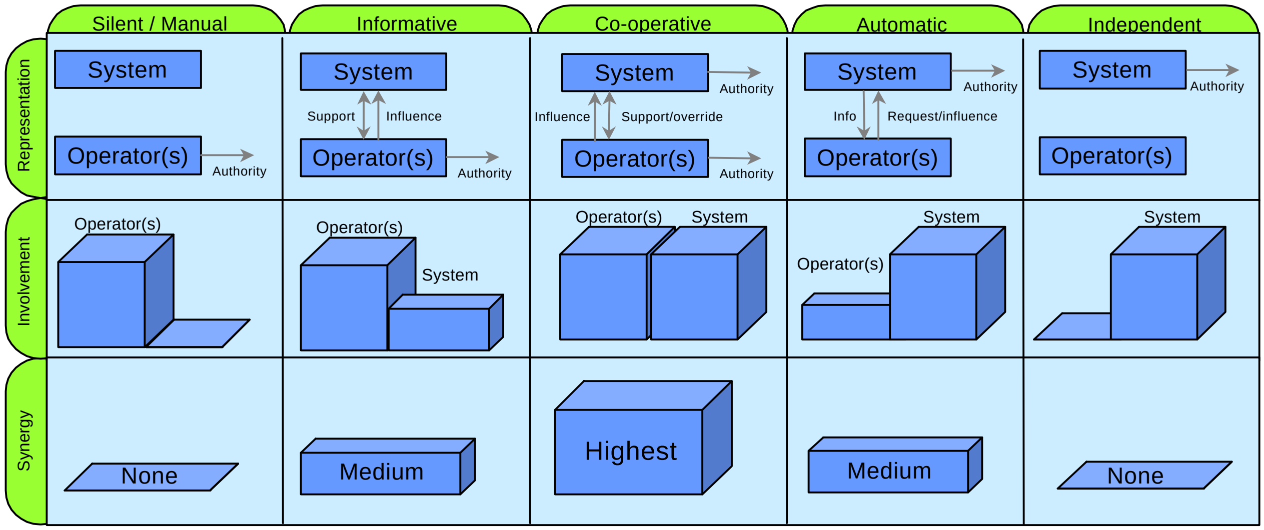

Figure 3. System arrangement concepts

We have taken the following two criteria into account to define a system arrangement concept for each function:

- Maturity of the technology: A process will be assigned initially to the computer system if it surely or likely possible that the process can be automated, otherwise the process will be assigned initially to the human organisation.
- Cohesion and Coupling: The processes that are likely possible to automate will be allocated to the human organisation if these processes have a strong cohesion and coupling with the remaining processes which are already assigned to the human organisation. The processes that are likely not possible to automate will be allocated to the software organisation if these processes have a strong cohesion and coupling with the remaining processes which are already assigned to the software organisation. However, this implies that a technology breakthrough is required to automate these processes. This fact will be indicated when applicable.

2.5 C2-organisation Concept definition

The trade-off analysis provides high-level information about the distribution of the functions between the software and the human organisation. It doesn't provide detailed information about the distribution of functions and processes among the human organisation and the sub-systems within the software organisation. Guidelines for modelling and specifying both the personnel organisation and the software organisation are discussed in this section.

The specification of the human and software organisation starts with a detailed analysis on the cohesion and coupling among the various functions and processes. We identified the following guidelines for this analysis:

- Information flows: The coupling and cohesion for information flows are mainly determined by the objective to decrease and optimise the information flows within the personnel and among the various sub-systems of software organisation. The following parameters are used:

- ✓ Amount of information: The goal is to minimise the amount of information that flows among the sub-systems and the operators. The amount of information does not only exert pressure on the bandwidth of both the operators and communication links, but also requires extra time and capacity of the operators to formulate and interpret the messages.
- ✓ Update rate and period of validity: The goal is to minimise the number of messages that have a high update rate and/or have a short period of validity. Messages with a high update rate might pollute communication queues because they lose their value when an update of the message arrives at the same queue. Information with a short period of validity reduces the time that is available for the decision making process.
- ✓ Cognitive hierarchy: Information flows consists of data, information, and/or knowledge. It is recommended to communicate at the level of information and not at the level of data, or knowledge. Communicating a message at the data level generally requires a large bandwidth compared to communicating a message at the information level. Transferring knowledge is a very difficult process and requires a lot of attention and time of the operators.

- ♦ Human Computer Interface: The simultaneous use of interfering interface concepts by a single operator should be limited to a minimum.
- ♦ Human knowledge and experience: Let the operator be involved as much as possible with processes that require similar knowledge and experience.
- ♦ Workload: Realise an equal and acceptable static and dynamic workload (depending on the capabilities of operators and the performance of the computer system) for each realistic combination of operational tasks.

2.6 Testing and evaluation

The previous C2-organisation concept design phases are more or less based on theoretical views. Technical, budgetary and time constraints did not allow for hands-on experience with the complete proposed command and control concept in the first phase of the research programme. However, to achieve a validated C2-organisation model validation and are needed. We defined the following combination of procedures that will allow us to test and evaluate parts of the concept, and that will provide results for the complete concept:

- ♦ Analysing current C2-organisation concepts
  - ✓ Critical aspects: An inventory will be made of the critical aspects within current command and control concept(s). These aspects will be compared with the aspects of the proposed command and control concept by considering both current and future scenario's.
  - ✓ Workload and processing time: Rough indications on both workload and processing time parameters will be derived for the four main C2 functions. This will be done by scaling the parameters of current C2 concepts with respect to the level of automation.
- ♦ Event-based tactical simulations: Tactical simulations will be made to test and evaluate the throughput and quality of the command and control concept for diverse scenario's. This simulation environment will be event driven and contains simplified models of both

the human organisation and the software organisation. Each operator is simulated by a software agent. Such an agent contains a rule base for decision making (including a distribution of probabilities for specific decisions), a knowledge base that contains knowledge about the workload, distributions of the workload, and the processing time that is needed to make decisions. The simulation results will provide the minimum time that is required to accomplish the command and control tasks, and a rough indication of the changes in workload as a function of time and events. Critical workload situations can be analysed and corrected manually. These corrections are necessary because of the difficulty to determine and calculate the workload and processing time of processes that are carried out simultaneously by each operator.

♦ Empirical analysis of technological assumptions and of assumptions of human cognitive capabilities: Parts of the command and control concept will be implemented using a real-time simulation environment. The simulation environment will be used to identify and to refine the feasibility of the technological and cognitive aspects of the innovative parts of the concept. It will also be used to refine the parameters for the tactical simulator and to corroborate the findings of the tactical simulations. The simulation environment consists of a mock-up of a command and control centre, human computer interfaces, computers and a scenario management system (see Figure 4). The simulation are implemented using a DIS/HLA[1]-based simulation environment.

Figure 4. Mock-up of the Command Information Centre Facility at TNO-FEL

[1] DIS/HLA: Distributed Interactive Simulation / High Level Architecture

3 Design Considerations on Decision Support and Information Management

3.1 Introduction

In the previous chapter, we discussed the overall framework of designing alternative or new command and control concepts. Part of the R&D work in developing and using the methodology dealt with the identification of several design aspects or concepts which we tend to use in the design process of the future command & control organisation and systems.

This paper we will address three of this aspects:
- ♦ The operator support suite concept
- ♦ Organisational and systems adaptability
- ♦ Information management

3.2 The Operator Support Suite Concept

Most of the decision support systems (DSS) in today's C3I systems can be characterised as information gathering and storage systems which allow the operator to get only a pre-defined view of the stored information. Teamwork-based decision support in current C3I systems is in general almost negligible.

This section discusses some of our ideas with respect to advanced individual operator support.
In order to achieve a much higher level of decision support for the individual operator we defined three basic support functions each operator DSS has to provide:
- ♦ provision of relevant, timely and accurate information to support and achieve situation awareness and assessment;
- ♦ provision of understanding in the possible course of actions and the consequences of these actions;
- ♦ provision of support in which tasks have to be performed and at what time by a specific operator in a specific scenario.

This may be called Situation, Analytical and Task support or SAT support.

Most DSS are currently only providing the operator with situation awareness information. Substantial support from DSS based on 'internal systems knowledge and understanding' of what the user role and current scenario is at the best incidentally supported. All situation assessment and operator task execution activities are currently performed by the human mind itself with little or no system support at all.
To achieve the SAT support as described above from the DSS we postulated a conceptual framework which we have named the Operator Support Suite (OSS) upon which the individual operator decision support tools designed in the new C2 concept will be based.

The functional architecture of the OSS concept is given in Figure 5.

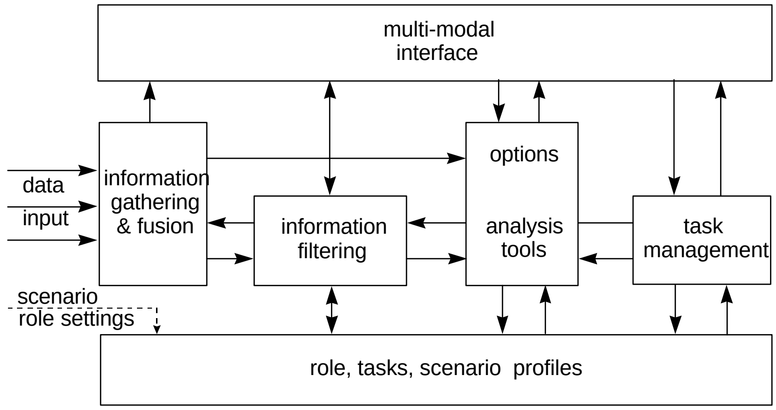

Figure 5. The Operator Support Suite Functional Architecture.

This OSS architecture provides the elementary support functions we believe as fundamental for the individual operator to execute his tasks.

The functional architecture of the OSS concept is depicted in Figure 5. Situation support is provided through the information gathering and information filtering modules. Analysis support is given by the option and analysis module. The operator-task-execution-support is provided through the task management module. The interaction of the operator with the system occurs through a multi-modal interface that should support touch, 2D and 3D vision, voice control and 3D sound.
All these support functions are supported by system-based knowledge about the user role and the scenarios and the actual scenario development. The simulation environment discussed in section 2.6 and shown in Figure 4 supports this OSS-type architecture.
It may be noted that this OSS functional architecture is in concert with the ideas and results originating from the US Navy TADMUS project [Moore *et al.*, 1996].

Apart from filtering, intelligent scheduling, reasoning with uncertainties, adaptability and other functions one of the major differences with today's DSS lies with giving the OSS a kind of 'internal knowledge and understanding' about user roles and tasks, scenarios, situations and threats such that actual system-based support can be given with respect to situation assessment and task management support.

3.3 Organisational and Systems Adaptability

In future C2 organisations, a very high emphasis will be placed on the flexibility or adaptability of both the human and the systems component of the complete command & control system. This is a result of the reduction of the human complement and the consequential increase of the level of automation needed to perform all tasks.

When in a reduced manning C2 organisation the task execution is predominantly individualised the capability to deal with human operator loss is much less compared to a situation where the task execution is much more team-oriented. To create an adaptable organisation a good balance between team and individual work approach is required. This cannot be accidentally achieved but has to be designed into the complete system from the start. This means that we not only need a conceptual decision support framework for the individual operator like the OSS, but also a conceptual framework to support teamwork. This concept of a Teamwork Support Suite (TSS), of which the OSS is an integrated part, is currently being developed within this research project.

The reduced human complement in a C2 organisation requires a much higher level of automation then currently encountered in supporting C3I systems. Many decisions now taken by human operators will be taken by the automated system. The various system arrangement concepts were already discussed in section 2.4 and shown in Figure 3. The concepts and functionalities needed to enable the operator to achieve a timely and sufficient insight in the decisions taken by automated systems requires a deep knowledge of human thinking and decision making capability, not only of the individual operator but also of the team. This demands a substantial involvement of human factors specialists in the design of these systems.
The human interaction with the system will be influenced by factors like the complexity, intensity, uncertainty and familiarity of the scenario, the consequences of actions to be taken and the level of experience and training of the operators themselves. The system should be able to provide the operator with relevant information, on the correct level of abstraction and on the right time to achieve a fast situation awareness and assessment in all situations and to perform decision making. This requires very sophisticated information management capabilities like adaptable information filtering and control functionalities.

Systems adaptability not only involves adaptable information filtering and control but also a flexible level of the systems decision making capability, with will be dependent on the operator workload. The system arrangement mode as discussed in section 2.4 is therefore variable and will depend significantly on the human operator processing capability in the various stages of a scenario. Varying the system arrangement mode however is just one way of adapting to operator workload or overload situations. Tasks can also be re-allocated to other operators or to the team itself. Dynamic task re-allocation and adaptable system arrangements not resulting in uncontrolled system behaviour is however still a rather basic research issue. It is not at all clear in this stage of our research whether these functionalities will become part of the combat management system of the next generation NL frigates.

3.4 Information Management

In C2 systems, decisions must be based on an accurate assessment of the current situation. This accuracy depends on the available intelligence, on the incoming sensor information, on the environment models, etc. Too much information, or information in the wrong form, has a negative influence on the accuracy. This requires the need to have the right information, at the right person, on the right time, and in the right form. An important issue here is the danger of information overload. The probability on an information overload is mainly determined by the organisational conditions, the environment and the nature of the information [Schneider, 1987].

However, only the organisational conditions and the nature of the information can be taken into account during the C2-design phase. The susceptibility of the organisation to information overload is mainly determined by:

- Levels of differentiation and integration: Team and functional boundaries act in most cases as barriers on information flows. The lack of boundaries can cause defective filtering (failure to screen out irrelevant information overloads members on the higher levels). Often, the problem is not in the gathering of information, but in the integration of information.
- Organisation design: Organisation designs affect how information is processed. Functional designs may restrict or distort information flow as it reaches higher levels or can even result in important information not reaching the top. Nowadays, more and more adaptive organisation aspects are introduced in command and control concepts to spread peak load among the human and software organisation. This might cause a lack of clarity of the information needs of each operator.
- Frame of references: Information may not be processed because of the characteristic styles of collecting, analysing and verifying information at a managerial level. In modern Command and Control organisations the frames of references are not only controlled by operators but will also be managed by the computer organisation.
- The nature of the information: The nature of information can be categorised in terms of uncertainty, ambiguity, complexity, intensity and amount.

An improvement of the information exchange between operator and computer system will require the following design considerations:

- Providing only relevant information to the operator: Support is required that allows the operator and systems to pull only the information that is needed. This approach requires that the computer system discern exactly what kind of information must be presented to the operator and what not.
- Avoiding information overload: Support is required that allows the computer system to provide only information to the operator to perform only the most critical tasks. This approach requires that the computer system is able to measure task progress and the symptoms representing the information (over)load of the operator. Tasks will be postponed or broken off if task progress stagnates and/or that the information load exceeds a certain threshold value.

Figure 6 shows a functional architecture that supports these two design considerations.

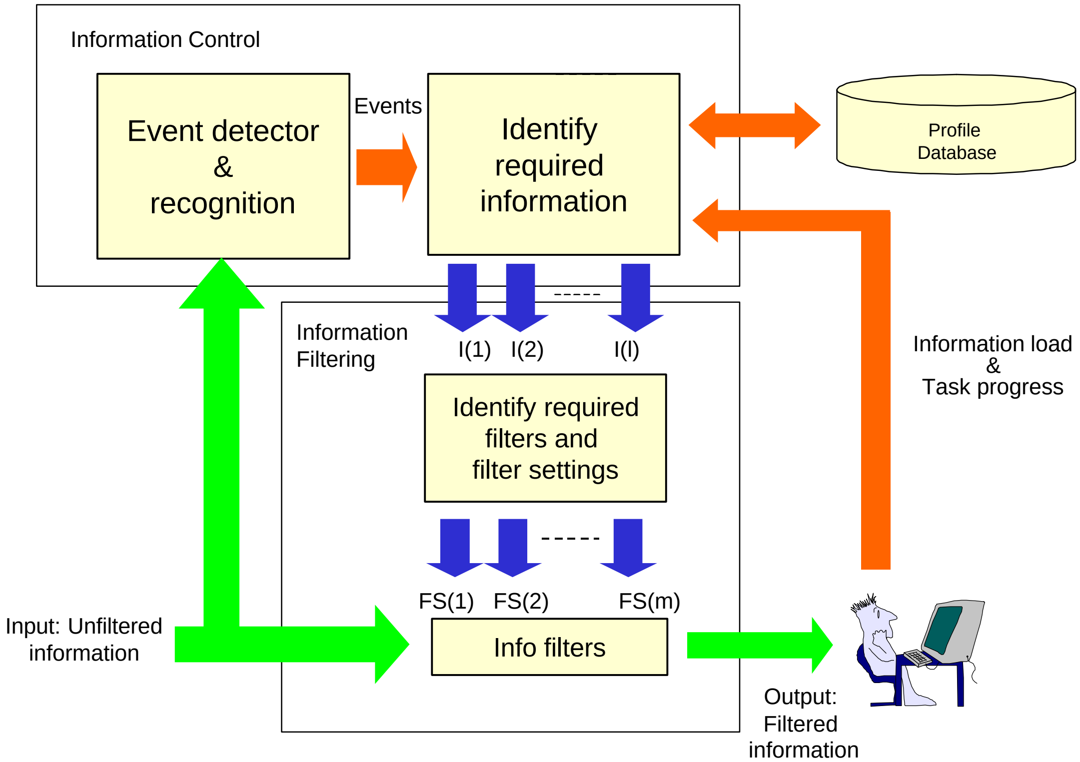

Figure 6. A functional architecture of information filtering and control system

This Information Filtering and Control (IFIC) architecture consists of an information filtering module and an information control module [Maas, 1998]. The information control module is part of the task management module of OSS (See Figure 5).

The information control module consists of two sub-modules ('detect and recognise events' and 'identify required information') and uses a database containing profiles. The module 'identify required information' uses the database profiles to define the required information to start and accomplish a task as a reaction on a detected and recognised event.

The information filtering module interprets the descriptions of the required information to identify the required information filters and determine the information filter settings.
The task manager will detect information overload situations by means of an operator feedback. This feedback contains information on the task progress and/or the information overload level. The task manager will adapt the required information settings to reduce the information overload level. This implies that:

- Information can be presented at another format to increase the level of understanding.
- Tasks can be hand over to other staff members who have the capability and time to accomplish the task.
- Tasks can be hand over (partly) to the computer system. This may implies that the task will be carried out with a lower performance.

Research on information filtering and control is conducted within the framework of the 'IFICS'-project. 'IFICS' is an EUCLID/EUROFINDER project that is carried out by a consortium of industrial companies and research institutes in four European NATO countries: TNO-FEL (NL), TERMA (DK), SIGNAAL (NL), DATAMAT (I), and INTRACOM (GR).

4 Conclusions

The first phase of the research programme is completed in 1998 and the second phase has started. In this first phase the discussed methodology which was followed produced a huge amount of information on the command and control process. Valuable insights were gained in identifying the major research areas for the next phase, some of which are identified and discussed in this article.

During the first phase we learned that substantial navy involvement in the research programme is crucial. Both to identify the shortfalls in current C2 organisations and C3I systems as well as to produce results that are likely to be accepted by the navy itself. A major challenge of achieving a very low-manned C2 organisation is not only 'solving' the technological issues, but also to deal with a (natural) resistance to change, with decreased career possibilities and with a large part of the navy infrastructure itself, like education and training and finding the highly qualified personnel capable and willing to function in these very high tech and high risk environments.

We also believe that this type research which so fundamentally deals with human processes and thinking can only succeed by making use of multi-disciplinary teams where technological, human factors and military experience is brought together. Only this combination of involvement and skills is able to produce the synergy needed to accomplish successfully the task of the design of this new C2 organisation and its supporting C3I systems.

The constraint of reduced manning imposes such a heavy demand on the functionality of the supporting C3I system, like adaptability, systems intelligence to reason with uncertainties, to filter information, improved human-computer interaction and a lot of others. The research effort to succeed in this task is very high indeed. This imposes a need to focus the available research effort in the subsequent phases of the programme to those areas, which contribute most to produce valuable improvements in the current way of executing command and control.
To achieve substantial improvements in a rather limited amount of time we feel that strong (international) collaboration is needed. Needed both from the point of view of the research effort as well as from the point of view of remaining interoperable with navies that have different C2 organisational structures and systems.

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