New MMI Concepts for Situation Assessment and Decision Making in Naval Command and Control

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To improve efficiency and effectiveness the Royal Netherlands Navy is aiming to introduce new concepts of organisation, integration, automation and support for future combat management systems. In the exploration and development of these concepts human factors considerations are taken into full account from the outset.

Already manifest in today's command information centres (CIC) the large information flows that have to be processed, integrated, and interpreted, often in a complex and uncertain environment, poses particular problems in the areas of situation awareness and decision making. High levels of cognitive load characterise situation awareness and assessment. And under such conditions commanders and warfare officers are likely to prematurely generate a consistent, plausible story to which they subsequently attach too much weight. Their decisions are subject to biases such as making incorrect inferences and ignoring information that does not fit within the story. It is important that interfaces are developed that organize, visualize, and access the large volume of information, while at the same time minimizing such biases as decision makers are prone to.

TNO Human Factors has developed a novel MMI workstation concept, the *Basic T* , to address these issues. The Basic T consists of four displays, as illustrated in figure 1:

1) *Tactical space*: a 3-dimensional presentation of the tactical environment that can be approached and studied by the user from different perspectives by tilting and turning. A stereo large screen projection is added in order to assess the added value of stereo images.

2) *Assessment support*: graphical and alphanumeric representations of important track parameters, in the form of *track profiles* and *identification support display*. Also, a *side-view display* and a *response manager* are included.

3) *Bird's eye view*: the more traditional presentation of the tactical picture in 2D.

4) *Decision support*: this consists of *tactical evaluation support* and *asset deployment planning*. These have to ensure that decision makers remain aware of alternative options.

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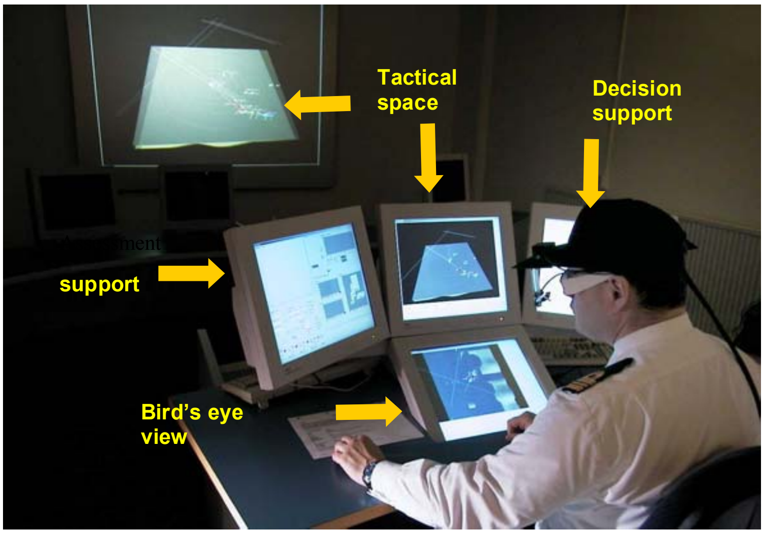

Figure 1: View of a Demonstrator Workstation in the Basic T Configuration, with Four Touchscreen Monitors and a Stereo Large Screen Projection.

At this moment the Basic T concept undergoes extensive user testing and evaluation with domain experts from the Royal Netherlands Navy. Information on the set-up of this evaluation and some first results will be presented in this paper after a more detailed introduction of display and support concepts applied.

TACTICAL SPACE

Probably one of the more prominent features in the Basic T concept is the incorporation of the 3D tactical space in addition to the more traditional 2D presentation of the tactical picture. The idea itself is not a new one. Already from the early 90's examples are known of studies and experiments with 3D perspective displays for application in the command and control domain. A representative example is shown in figure 2.

Figure 2: Example of a 3D Perspective Display *(Adapted from Denehy, John Hopkins APL).*

The strongest motive to go three-dimensional is the inability to combine the two dimensional 'bird's-eye view' with a graphical presentation of altitude and depth information. As a consequence, in all current systems altitude and depth information is presented as numerical read-outs. According to Dennehy et al. [1] representations lacking integrated altitude and attitude information complicate situation assessment in two ways. Data that are difficult to acquire, are more difficult to use in making a decision. Also, without immediately evident altitude information, a decision maker may substitute arbitrary or situation-biased altitudes, that may be difficult to supplant even when the actual data are presented. With more realistic images of the environment and tracks in a 3D perspective, they argue, the interface becomes more natural and less effort is required to comprehend the current situation. It eliminates the burden of integrating and interpreting of multiple representations, abstract symbols, and textual read-outs. Some earlier experimental results with perspective displays confirm these expectations. In a direct comparison between a conventional and a perspective display Bemis et al. [2] evaluated operator performance for two different types of tasks: detect threats and select the closest interceptor for each detected threat. The experiment revealed a significant reduction in errors of detection and interception with the use of a perspective display. Also response time for selecting interceptors was greatly reduced.

Indicating the potential to improve performance, 3D perspective or stereoscopic displays, however, can also have their drawbacks. Inherent to the perspective view, objects are presented larger or smaller as a function of the operators viewing distance, location and angle. Objects close to the operator will be shown with much more resolution than objects at larger viewing distances. In many cases these differences will not necessarily reflect differences in tactical relevance and meaning. In their aspiration to design more realistic or natural representations of the environment researchers and software engineers also prefer to apply the principle of immersion to create the feeling of being part of that environment. Becoming embedded in the situation, however, can have some serious disadvantages. What you see becomes dependent of your own orientation. You have to look around not only to see what is happening miles away in front of you but also what's happening directly behind your back. More realistic does not necessarily mean more functional.

Our approach was a little bit different: let the environment become a 3D object in itself, as in our case a transparent cube, that can be viewed from the outside and easily manipulated to see the environment from different perspectives and in different scales. In figure 3 two pictures are shown that give an impression of this concept of a 3D tactical space. Simple geometric 2D and 3D symbols, comparable to the familiar NTDS-symbology, are used to represent tracks. With your own ship in the centre of the tactical space as default the operator has independent controls for horizontal and vertical zoom-in and zoom-out, to change the range or ceiling for which contacts are displayed. Size of symbols and track labels is held constant, irrespective of the zooming factor. With an off-centre function other tracks than the own ship can be selected to be presented in the centre of the tactical space. By turning around and tilting the cube the environment can be viewed from almost every perspective, let it be air, surface or even subsurface, under water. Independent of the selected perspective all symbols and track labels remain in a steady orientation towards the user to guarantee good legibility. With a time-offset function the user can both playback or consult preceding moments in the situation and extrapolate the situation towards a future point in time. And dependent of platform type and armament critical points in sensor and weapon coverage can be shown.

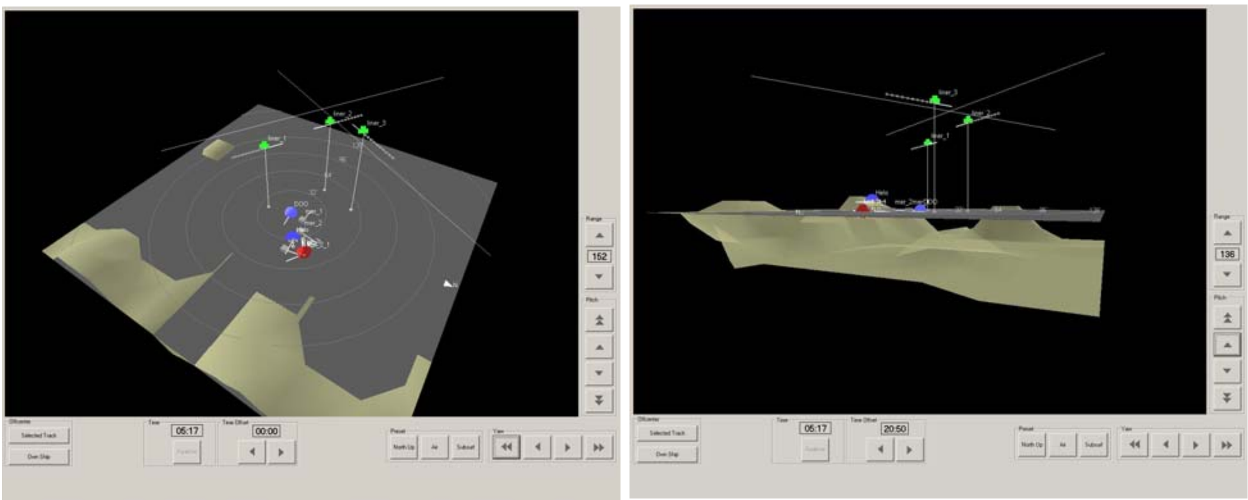

Figure 3: Examples of the Different Perspectives from which the Tactical Space Can be Viewed.

To explore the added value of stereo images a full stereo large screen projection, with polarisation filters for separate left and right eye images, has been added to the Basic T concept. Given the rapid development of autostereoscopic displays that permit full stereo vision without the handicap of having to wear shutter or polarisation glasses, it can be expected that within two or three years the technology will be mature enough for large-scale application.

To our opinion probably the most important function of the tactical space is to have an environment that integrates information from different sources such as intel, traffic management, sensor and geographic information in a tactical meaningful way to support full situational awareness and assessment, especially when situations become less predictable or more complex as for example in the littoral. The concept of the tactical space however does not mean that all other ways of information display become superfluous, as confirmed in research done for the US Navy [3]. There is no single display that can offer all information needed in an optimal way. The secret to good information presentation often lies in the diversity of multiple views on a situation and different graphical formats. With the tactical space well suited for the higher level tactical assessment the 2D bird's eye view for instance, with its fixed orientation, more readily suites the fast localisation of a track. To support the concept of diversity in information presentation the Basic T offers both displays. Other views incorporated are a side-view display for a perspective independent presentation of altitude/range or altitude/bearing information and track profiles for the presentation of altitude and speed information as a function of time. An example of the side-view display is shown in figure 4.

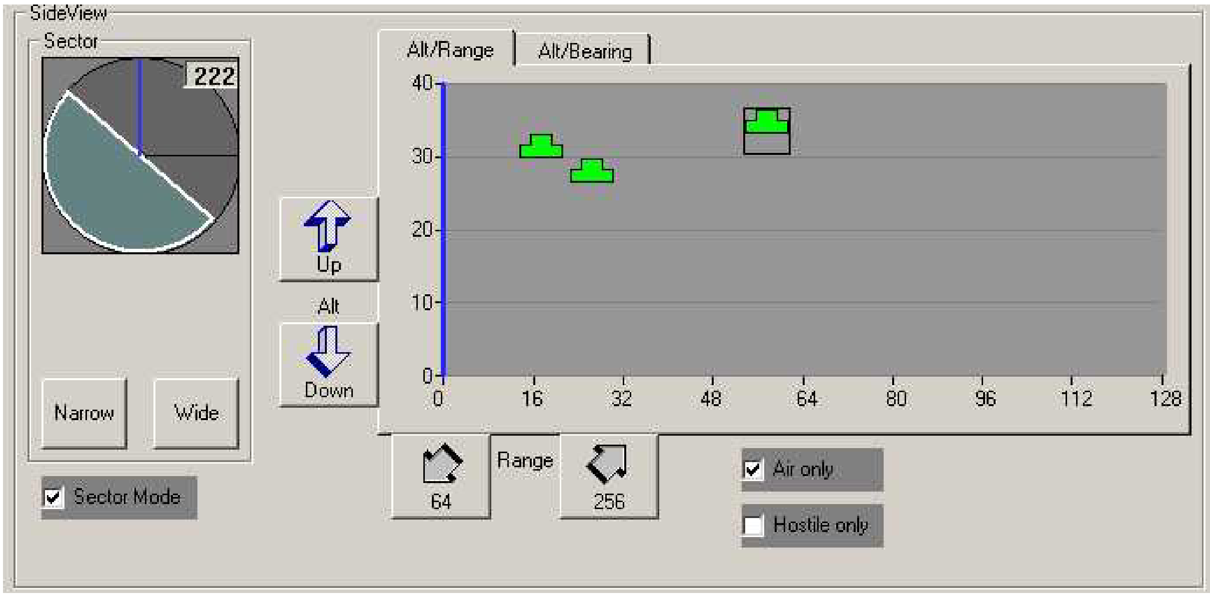

Figure 4: Presentation of Track Information in an Altitude/Range or Altitude/Bearing Orientation. A Sector Mode Can be Selected to Tune the Information to a Certain Threat Direction.

ASSESSMENT AND DECISION SUPPORT

Assessment of the situation in general, the early recognition of potential threats, and the decision making on actions to be taken are the core-business of every commander and warfare officer. Here they can excel their knowledge, experience and competence. With every situation regarded as new, unique or different from other situations, they have to cope with unknown elements, unpredictable behaviour, and incomplete or even misleading information. In these situations no commander will rely on systems in which important aspects of assessment and decision making are controlled by computers, no matter how intelligent they may be. On the other hand we also know how human decision making can be coloured by misconceptions and other biases. Decision makers are likely to prematurely generate a consistent, plausible story to which they subsequently attach too much weight. Incorrect inferences are made and information that does not fit is ignored. So, if computers are needed to support assessment and decision making the main objective should be not to surpass the commander or warfare officer, but to stimulate critical thinking, to keep an open mind, and to verify that all information is checked and all options are considered. Two instances can be given of computer support implemented in the Basic T concept. The first example is the realisation of an identification support tool and its interface as shown in figure 5.

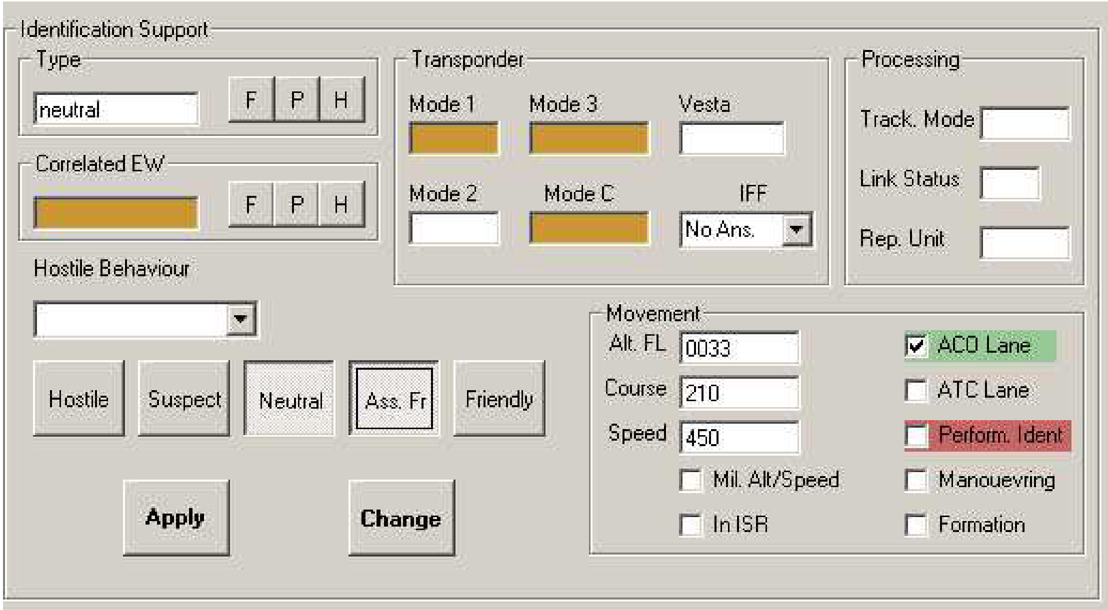

Figure 5: Example of the Interface with the Identification Support Tool. Highlighted information in green, red and orange indicates how well the information fits with the identity that is checked.

Part of the combat management task is to identify air and surface tracks as neutral, (assumed) friendly, suspect and hostile, based on identification rules or identification criteria. A study by Velema [4] revealed that the percentage of correctly identified tracks, given the set of rules or criteria applied, can be as low as 50%. And this result was obtained for very experienced operators. Some of the 'errors' made could be traced as incorrect interpretation of data, careless application of rules, and typical human biases, where computers can do a better job. Other deviations however reflected situations in which human operators perform better by relating the identification of a track to their perception or appraisal of the situation as a whole, in a way it cannot be caught in a limited set of rules as applied by computers. The identification tool as shown in figure 5 was designed to support both. In this window the system shows for each track the identity that fits the data. Not by merely indicating the identity itself but also by highlighting in green color the information that supports the advised identity. This feedback is important to keep the process of identification as transparent as possible and to guarantee full control by the operator. If the operator directly agrees with the advice he has to press the accept button and the system will update or upgrade track information to the indicated identity. However in case of doubt the support tool also offers the opportunity to check the validity of alternative identities. By pressing one of the other identity buttons the operator gets feedback with information highlighted in green, red or orange where according to the system the available information suites the alternative identity considerations made by the operator, creates conflicts in identity or is incomplete. We expect that this checking facilities can prevent errors in the overlooking of information or careless application of rules. It can also cue the operator in the search for more information needed for a correct identification. But at the same time it also gives the operator the opportunity to choose another identity in full awareness of potential conflict with the system advice, if the operator prefers not to stick to the preprogrammed rules in relation to his own appraisal of the situation.

As an additional feature the support tool also offers facilities for dynamic task allocation. By changing task settings the operator can change the role of the system in the identification process from an advisory one to full autonomous identification that no longer requires acceptance by the operator. Task settings can be changed for each individual identity type at any moment. Typical situations to run the identification process in an automatic mode are probably those situations in which large numbers of tracks make the task of acceptance and control highly repetitive and demanding, or situations in which time is the most critical factor.

A similar support concept has been worked out for the planning of actions. It is related to the optimal deployment of platform, sensor and weapon systems based on a set of preprogrammed assessment criteria. Applied to the harpoon weapon system as a suited example for demonstration, the system can generate a number of options for deployment and evaluate these options for the criteria as programmed. As shown in figure 6 the operator gets feedback for each option in green or red , indicating whether the option matches the criteria. It gives the operator the support for an instant comparison, and it will help him to prevent a situation in which considerations are made for only one or two options at the cost of ignoring other, possibly more effective options. The selection of criteria to be applied and the order in which criteria are shown do not need to be fixed. Although not implemented, it must be possible to have more sets at one's disposal depending on the kind of operation, threat type and rules of engagement. Probably the most important feature of this concept is that the system does not necessarily prescribe or indicate what the preferred option should be. In a transparent way, overseeing the options and where they match the criteria, the user can give his own weights to the criteria and make his own decision. One restriction has to be mentioned. The concept is less suited for applications that do not allow the definition of a limited set of production rules needed for automatic option generation.

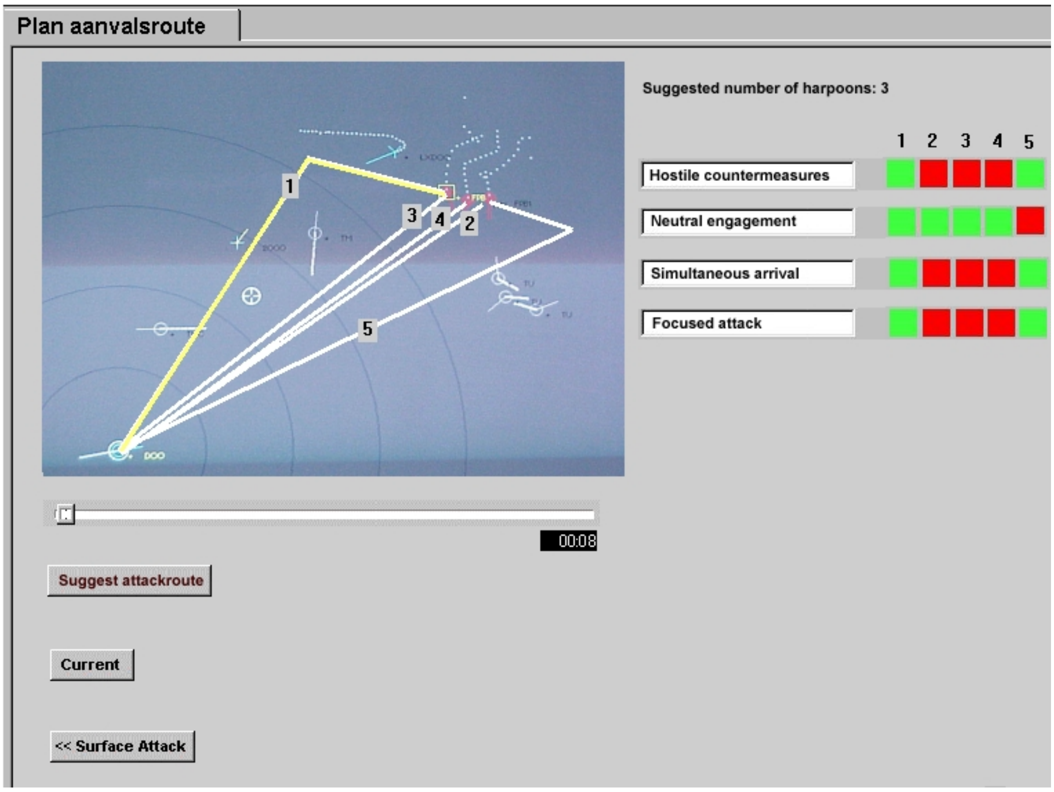

Figure 6: Example of the Assets Deployment Planning Support Window. In green and red information is supplied how well each generated option matches with the relevant criteria.

EVALUATION

At this moment the basic T concept, interfaced with new CMS functions for automatic identification and classification as developed by the TNO Physics and Electronics Laboratory, is tested and evaluated with domain experts from the RNLN. Up to seven teams of principal warfare officers (PWO's) and air defence officers (ADO's) are invited to take part. With two teams tested up to now, and the analysis of test data just started, its to early for a complete and correct appreciation of the results. So, the discussion on results in this paper will remain restricted to some first impressions and remarks.

Results will be based on tests with five different scenarios. Two scenarios are typical surface warfare scenarios meant for testing the Basic T concept with the PWO in command. Two other scenarios with an air threat were prepared for testing with the ADO in command. Both for surface warfare and air defence one scenario reflects a basic, easy to handle situation and another scenario a more complex or more busy situation with a high information density. A fifth scenario contains a combined air and surface threat situation and is used to test the concept and new CMS-functionality for situations where a single warfare officer has to cope with both warfare types. This scenario is mentioned to test the limits in performance and workload. The average duration of a scenario is about 20 minutes. During the tests one of the team members plays the role of referee, carefully judging the performance of the PWO or the ADO in their awareness of the situation, their threat evaluation and decision making. All interaction of the PWO and the ADO with the system is logged, and with a combined eye- and headtracker records are made of all eye- and head movements, indicating from moment to moment what information is looked at and what attentional switches are made from one display or information source to the other. Every three minutes the PWO or ADO is triggered by the system to indicate his or her subjective experience of workload. Physiological indicators of effort and activity are recorded with ECG, EOG and EEG measures, reflecting heart, eye and brain activity. Due to the limitations of a small sized set-up for concept testing in a laboratory environment, it was impossible to create realistic internal and external communication. Knowing how communication can contribute to workload and also interfere with on going activities, a Continuous Memory Task (CMT) is used as a kind of simulation in which the PWO or ADO has to listen to series of letters presented on the headset, that have to be remembered and acted upon. Performance on this task can be used to trace the moments were attention to the voice communication channel interferes with other tasks, and as a consequence information is missed or neglected. See figure 7 for an impression of the experimental set-up and the test equipment used.

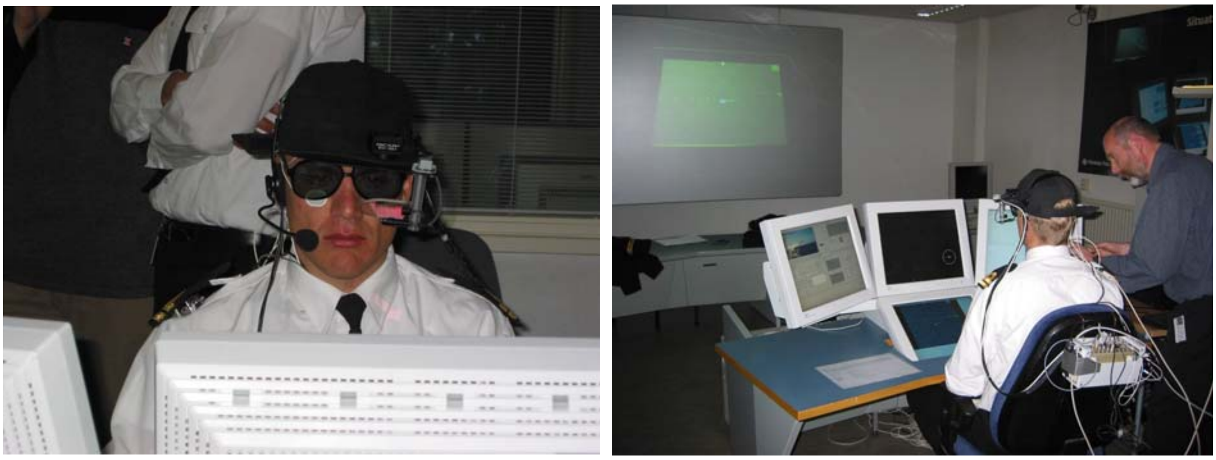

Figure 7: Pictures of an Air Defence Officer during the Tests, Equipped with Mini-Cameras, Sensors and Electrodes. Polarization glasses are used to see the stereo images.

After each test with one of the scenarios the PWO and ADO are debriefed in a separate room where they can monitor a recording of their performance on videotape, and they can comment on the recorded events and their own reactions. They are also asked to indicate minute by minute what activities were directly related to situational awareness, to threat assessment, to the planning of measures to be taken and to the execution of actions. After completion of all the tests the team members have to fill an evaluation questionnaire in which they can comment in detail on all advantages and disadvantages they have experienced with the new MMI-concept and supporting CMS functionality. They are also asked to indicate on a five-point scale how important they regard the different interface components and functions for further development and future implementation on board ships.

SOME FIRST RESULTS

According to the experience and judgement of PWO's and ADO's that took part in the tests up to now, the workstation and support concepts will contribute to a situation in which their task requires less effort and can be done under less time pressure. Subjective workload measures recorded during the sessions confirm their opinion. As shown in figure 8 average workloads, measured on a five point scale, remained within acceptable limits. However, especially in the sessions with the combined air and surface multi-threat scenario, most of the PWO's and ADO's experienced moments where individual workload levels became too high to keep full control.

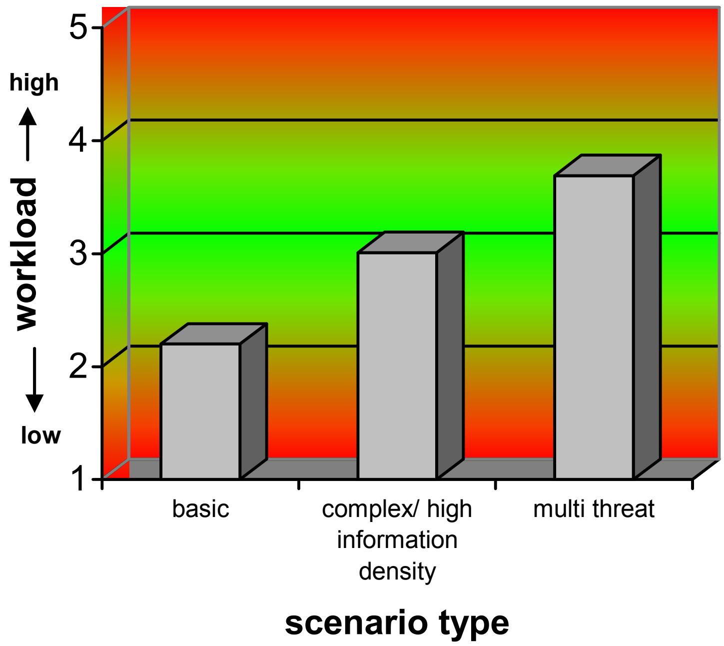

Figure 8: Measured Average Subjective Workload Levels for Three Different Scenario Types.

Given their scores in the questionnaire for each individual interface component, many of the support and information display concepts were judged as more or less important for effective task execution. All the PWO's and ADO's experienced important advantages of working with the tactical space, especially in combination with the 2D top-down view. Results from a pre-test done last year gave an indication that about 40% of the time attention was focused on the tactical space and about 10% of the time on the bird's eye view. No differences were found for air and surface related scenarios. The addition of stereo images was not always regarded as strictly necessary, but very effective in the more complex air defence situations. The fact that they had to wear special glasses and the stereoscopic presentation positioned at a more excentric location was regarded as an extra handicap.

CONCLUDING REMARKS

The increase in complexity of the environment and conditions in which commanders and warfare officers have to do their job pose new challenges to the design of future combat management systems.

New concepts of automation, support and human-system task integration have to be developed to meet the demands for high levels of efficiency and effectiveness.

With the Basic T concept a significant but modest step is taken to explore some of these concepts. In a limited laboratory set-up some of the features certainly look promising. However further development and testing in the real environment will be necessary to prove how effective this concept will be at the end.

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