Requirements for VICTORIA Class Fire Control System

Contact Management Function

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Abstract

The VICTORIA Class Submarines (VCS) are subject to a continuing program of technical upgrades. One such program is replacing the Fire Control System (FCS) displays and re-hosting the system on linux-based servers. As part of this technical refresh, Defence Research and Development Canada – Atlantic has been asked to provide input in the form of requirements that might be satisfied by the addition of content to an anticipated 10% extra screen area. It is expected that these requirements would be used to assist in the evaluation of proposed design/system solutions. To derive these requirements a cognitive work analysis was carried out on the basis of two interview sessions with a total of nine subject matter experts. A variety of different methods were used to identify requirements at a level that do not impose a particular design solution. A total of 30 requirements were generated covering a variety of different potential design directions.

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Executive summary

Requirements for VICTORIA Class Fire Control System: Contact Management Function

Tab Lamoureux; Heather Colbert; July 2014.

Introduction: The VICTORIA Class Submarines (VCS) are subject to a continuing program of technical upgrades. One such program is replacing the Fire Control System (FCS) consoles, which have become un-maintainable. The new multi-function consoles have been specified to provide commonality with other boat consoles and are expected to have approximately 10% more screen area. DGMEPM(SM) is expecting the contractor will propose a number of options on how this screen area could be used, and requested DRDC Atlantic to look at developing operator-task derived requirements that might be used to help assess the options. Since solution independent requirements were desired it was decided that the use of cognitive work analysis (CWA) would be appropriate. Since DGMEPM(SM) has not used this technique before it was decided to do an initial trial on a limited set of FCS functions in FY 12-13.

Results: Under contract to DRDC Atlantic a cognitive work analysis (CWA) was carried out on the Sensor Analysis Console (SAC) which is one of the three consoles that make up the Fire Control System. Data was collected on SAC operation in two interview sessions with a total of nine subject matter experts. Data from the first session was used to develop an initial CWA model. This model was then presented to the second session for verification and extension. A variety of different methods were used to extract console requirements from the analysis techniques. A total of 30 requirements were generated covering a variety of different potential design directions.

Significance: The developed requirements provide a solution-independent set of criteria which may be used both to assess proposed solutions, but also to drive potential solutions to improve operator workload and efficiency. The requirements in this study are fairly high-level and are biased toward the cognitive tasks of current operators and work-flow. The results also are based upon the study of only one of the three consoles in the system. However, even from this limited study a number of requirements were found, that, if met, could significantly improve operator efficiency.

Future plans: As resources permit, the other two consoles in the system will be added to the CWA models and assessed for additional requirements. In addition, the whole system will be assessed to determine a set of system level requirements.

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1 Introduction

This section describes the background, objectives and scope of work for this project.

1.1 Background

In 1998 Canada purchased the VICTORIA Class of submarines (VCS) from the Royal Navy to replace the OBERON Class. The first of the VICTORIA Class (HMCS Victoria) was commissioned in 2000, followed by HMCS Windsor and Corner Brook in 2003, and HMCS Chicoutimi in 2004. As part of the purchase, the training systems associated with the VICTORIA Class were also provided by the Royal Navy.

Contact management (also known as track management) is currently conducted on the Fire Control System (FCS) consoles using software developed for the Canadian Forces under a modernization program for the OBERON submarine. The Royal Canadian Navy (RCN) is currently upgrading the fire control system, which will include moving the software to new modular consoles which have screens with approximately 10% more screen real-estate.

The fire control system Life Cycle Maintenance Manager (LCMM) is interested in investigating options for the use of this additional space. Since the original system was not specifically designed for the VCS, specification of the contact management task within the VCS is required to provide a baseline for options analysis.

In previous work DRDC Atlantic has, under contract, developed cognitive work analysis elements for the VCS command team including an abstraction layer decomposition, and hierarchal goal analysis (HGA). In addition, some work has been conducted to characterize periscope operations. While some elements of this work touch on the contact management task they were not directed specifically at that task.

1.2 Objective

The objective of the current work is the development of engineering specifications for the task and information requirements to conduct contact management in VCS operations.

1.3 Scope

This work is intended to describe the VCS contact management functions, independent of the current system implementation, in order to provide a baseline against which options (amongst which is the status quo system) can be evaluated.

The analysis focuses on the development of contact management requirements that are compatible with end-user needs and FCS activities. These requirements not only focus on the information to be displayed and the tasks to be supported, but also the criteria that must be met so that the Directorate of Maritime Engineering Program Management - Submarines (DMEPM(SM)) can evaluate alternative design and screen options.

The contact management function, as performed by the Sensor Analysis Coordinator (SAC; also referred to as the Command Display Console (CDC) Operator), has been selected as a focus for this work. Weapon control and management functions are not addressed in this work except where they touch on the contact management functions.

2 Method

This work was completed using a Cognitive Work Analysis (CWA) approach. The following sections describe the data collection sessions, the CWA software tool used, and the overall CWA approach.

2.1 Data Collection Sessions

Two sets of Subject Matter Expert (SME) interviews were completed in March 2013. Initial Interviews were conducted with four SMEs (1 Combat Systems Engineer, 1 Maritime Surface and Subsurface (MARS) officer, 1 United States Navy officer, and 1 Naval Combat Information Operator (NCIOP) and the Program Manager in Gatineau, Quebec on March 4, 2013. The data from these initial interviews was then validated and expanded upon during a follow-up session with four SMEs (2 NCIOPs, 1 Naval Communicator (NAVCOMM), and 1 MARS officer) at the Submarine School in Halifax, Nova Scotia on March 14, 2013.

2.2 Tools

A CWA software tool called The CWA Tool, version 1.0.2.0 [1] was used to organize and document this analysis. The CWA Tool was developed by the United Kingdom's Defence Technology Centre. This software has been specifically designed to support the development of new systems that support the cognition of the operator. In particular, the software supports the integration of potentially separate functions into a single, coherent system design.

2.3 Approach

This section describes the CWA approach, as well as the approach to requirements derivation.

2.3.1 Cognitive Work Analysis

During the SME interview sessions, a seven-step decompositional approach to the CWA was taken.

The first five steps involved the creation of an Abstraction Hierarchy (AH) diagram using The CWA Tool. The purpose of an AH is to describe the system in which tasks take place, without focusing specifically on any goal or activity. The AH created as a result of this work is described in Section 3.1. The AH diagram itself, as well as tables indicating the links between nodes at each level of the AH, are included in Annex A.

Table 1 explains the CWA step, the information gathered, how the information was gathered in the SME interview sessions, the purpose for gathering this information and how the information is represented using The CWA Tool.

Table 1: Cognitive Work Analysis Steps One through Five

Step	**Information Gathered**	**How information was gathered during SME session**	**Purpose**	**Representation in The CWA Tool**
1. Identify Functional Purposes	This step identifies the fundamental purposes of the system, or the reason it exists.	The functional purpose was identified with SMEs	Noting this information helps to ensure that any changes to the system continue to allow the system to meet the functional purpose.	Top level of the AH diagram
2. Identify values and priority measures.	This step identifies criteria that can be used to evaluate how well as system achieves its purpose.	SMES were asked to identify how effective contact management performance is characterized and how performance can be measured.	This step helps to identify performance goals that need to be met or exceeded with any changes to the system.	2^{nd} level of the AH diagram
3. Identify Physical Objects	This step identifies physical system components, as well as information components.	SMEs were asked to identify all the physical and information components that are implicated or involved in the current contact management task.	Characterizing the physical components of the system helps to identify how changes to those components, or related processes impact the system.	5^{th} level of the AH diagram
4. Identify Object-Related Processes	This step identifies the processes related to the physical and information components of the system.	SMEs were asked to identify physical system functions that are performed using the physical and information system components.	Characterizing the physical functions of the system helps to identify how changes to those functions, or related components may impact the system.	4^{th} level of the AH diagram

Step	Information Gathered	How information was gathered during SME session	Purpose	Representation in The CWA Tool
5. Identify Generalized Purpose-related functions	This step identifies the functions required to achieve the purposes of the systems.	SMEs will be asked to identify general functions that describe the purpose-related functions of the system.	Characterizing the purpose-related functions in a general sense, helps to identify general areas impacted by changes to the system.	3rd level of the AH diagram

Steps 6 and 7 in the process expanded on the AH to identify specific situations and strategies of interest for system improvement. Table 2 explains the CWA step, the information gathered, how the information was gathered in the SME interview sessions, and the purpose for gathering this information.

Table 2: Cognitive Work Analysis Steps Six and Seven

Step	Information Gathered	How information was gathered during SME session	Purpose	Representation in The CWA Tool
6. Identify Situations	In this step possible situations that need to be addressed by the system were identified.	SMEs were asked to identify potential situations that arise in using the system and the different functions that come into play for each situation. They were also asked to identify different information sources needed to make decisions according to the situation.	Different situations may require different functions from the system. Some functions are applicable to a range of situations and have significant impact on system performance. These functions may be an appropriate focus for improvement when updating a system because they support many different anticipated situations.	Contextual Activity Template (CAT)

Step	Information Gathered	How information was gathered during SME session	Purpose	Representation in The CWA Tool
7. Identify Strategies	In this step the variety of techniques system operators may use to approach a situation were identified	For specific situations, SMEs were asked to identify alternate strategies which could be used to address the situation within the system. They were also asked to identify different information sources needed to make decisions according to the strategy used.	Operators may use a variety of strategies to approach similar situations within a system. Different strategies may reveal different needs. Any changes to a system must support operators.	Strategies Analysis

2.3.2 Requirements Derivation

The CWA outputs were used to derive requirements for the FCS. Requirements were derived in several ways:

- Direct requests from SMEs for functionality or enhancements were noted as requirements. Where possible, these were mapped to the CWA AH, CAT and/or the Strategies Analysis;
- The number of links entering the object-related process level from the physical objects level below were counted. Those object-related processes with the most links were potential nexus of physical objects, and requirements to address them might be opportunities to integrate physical and informational entities that affect the contact management task;
- The number of links entering the purpose-related function level from the values and priority measures level above were counted. The purpose-related functions with the most links were potential nexus of key aspects of performance, and requirements to address them might directly affect overall system performance at the contact management task by addressing the key performance elements;
- Values and priority measures were directly addressed through requirements for the system design options;
- Object-related processes that map across the most situations listed in the CAT were also considered as nexus for contact management activity. Requirements were developed for those object-related processes that mapped to the most situations, and;

- Requirements that suggested themselves from the different strategies adopted by SMEs to achieve the object-related processes investigated in the strategies analysis were also included.

All requirements derived from a particular part of the CWA were validated against other CWA components to ensure that there was some convergent validation. Some requirements were also validated with SMEs at the Submarine School in Halifax on March 14, 2013.

3 Results

This section presents the results of the CWA including the AH, CAT and Strategies Analysis. Requirements derived as a result of the CWA are also presented.

3.1 Abstraction Hierarchy

The AH diagram created as a result of this work, as well as tables indicating the links between nodes at each level of the AH, are provided in Annex A. The following tables describe each node of the AH according to the five AH levels.

Table 3: Abstraction Hierarchy Nodes, Level 1—Functional Purpose

Node	Description
Information Management	Distributing, receiving, organizing, reformatting or otherwise manipulating or working with information.
Sensor Coordination	Activities relating to coordinating the tasks of sensor personnel, and the use of sensor equipment.
Submarine Safety	Activities relating to avoiding enemy, preventing collisions, or otherwise maintaining the wellbeing of the ship and crew.
Mission Achievement	The objectives of the mission are achieved, including objectives regarding stealth and safety.

Table 4: Abstraction Hierarchy Nodes, Level 2—Values and Priority Measures

Node	Description
Maintain appropriate data update rate for contacts	Data is updated at an appropriate rate to allow contacts to be identified and processed and tracked in support of submarine safety and mission achievement
Enter all required information	No information (track or other) required to achieve the functional purposes is omitted or overlooked.
Contribute to prioritization of contacts	Contacts are prioritized quickly and easily according to appropriate parameters (e.g. threat level, proximity).
Maintain situation awareness	Awareness of the situation is maintained including tracks, ownship and environmental parameters. This involves detecting all contacts in the area of interest, knowing what the contacts are, and knowing what they will do in the near future.
Use sensors appropriately	Sensors are employed in a way that provides the greatest amplification of contact identification and intent.
Communicate effectively	Information is transmitted in a timely, accurate, economical and understandable way.
Do not contravene critical safety parameters	The system must assist the operator not to overlook, omit or otherwise contravene critical safety parameters take place.

Table 5: Abstraction Hierarchy Nodes, Level 3—Purpose-Related Functions

Node	Description
Distribute Information	Ensure that information is provided and available when needed to the people that need it.
Maintain Effective Display	Maintain a display that is clear and accurate, with no redundant or secondary contact information.
Coordinate Activities of Sensor Team	Prioritize and direct the activities of the various sensor teams in order to maximize the understanding of the tactical situation, as appropriate to the current activities.
Coordinate with FCS Team	Prioritize and direct the activities of the FCS team, including Target Motion Analysis (TMA), in order to maximize the understanding of the tactical situation, as appropriate to the current activities.
Prioritize Contacts	Prioritize contact with respect to the danger they represent to the submarine, likely hostile intent, suspicion, etc.

Table 6: Abstraction Hierarchy Nodes, Level 4—Object-Related Processes

Node	Description
Entering Information from Sound Room	Entering information received from the Sound Room into the tactical display. Typically representing information that amplifies the simple representation of a bearing line.
Entering Information from Warner Take Procedure	Entering Information from Warner Take Procedure into the tactical display. Typically representing information that amplifies the simple representation of a bearing line.
Entering Bathy Information	Entering Bathy Information into the tactical display
Entering Information from LINK/Automatic Identification System (AIS)	Entering Information from LINK/AIS into the tactical display
Entering Information from Periscope procedures	Entering Information from Periscope procedures into the tactical display. Typically representing information that amplifies the simple representation of a bearing line.
Entering Information from RADAR/IFF	Entering Information from RADAR/IFF into the tactical display
Entering Information from Ranging Manoeuvre	Entering Information from Ranging Maneuvers into the tactical display. Typically representing information that amplifies the simple representation of a bearing line.
Entering Information from Stern Arc Clearance Procedure	Entering Information from Stern Arc Clearance Procedure into the tactical display. Typically representing information that amplifies the simple representation of a bearing line.
Entering Information from Basic Intelligence (BINT)	Entering Information from BINT into the tactical display. Typically representing information that amplifies the simple representation of a bearing line.
Entering lat/long	Entering the lat/long position of the ownship into the tactical display

Enter Information from TMA	Entering contact information received from TMA (e.g. speed, course, range etc.)
Declutter Display	Processing of tracks including removing redundant tracks, typically those tracks that are opening (becoming distant) on the submarine.
Correlate Tracks	Comparing and combining tracks as necessary when they represent a single entity. Also called associating tracks.
Reassign Track Numbers	Reassigning numbers as necessary (usually after a ranging maneuver or stern arc clearance procedure)
Communicate	Communication in any form (e.g. verbal, via headset, via shared displays). This activity includes the secretarial function of logging verbal commands, especially during emergency situations, such as damage control
Consider contact in relation to critical safety parameters	Consider range, bearing, speed, intent against emergency go deep envelope, current depth, water under the hull, current activities, etc.

Table 7: Abstraction Hierarchy Nodes, Level 5—Physical Objects

Node	**Description**
Low Frequency SONAR	Sensor within the sound room
Hi Frequency SONAR	Sensor within the sound room
Broadband SONAR	Sensor within the sound room
Narrowband SONAR	Sensor within the sound room
Active Intercept (Watcher)	Sensor within the sound room
Passive Ranging Sonar (PRS)	Sensor within the sound room
Searcher	Sensor within the sound room
Underwater Telephone	Sensor within the sound room
Active SONAR	Sensor within the sound room
ESM	Electronic Support Measures (ESM) Sensor
Bathy Information	Data from the Bathy system
LINK	LINK system. On the submarine this is a basic LINK and is typically passive.
AIS	Automatic Identification System. Can provide a lot of amplifying data. Warships may not provide AIS data.
Attack Periscope	Provide bearing to contact, any other information is based on visual and calculated information.
Search Periscope	Provide bearing to contact, any other information is based on visual and calculated information.
GPS	Global Positioning System Coordinates
RADAR	Provides range, bearing, course and speed of contacts.
IFF	This provides identity information for radar contacts. The submarine has a 'receive only' capability.
NAV data	Information regarding course, speed, depth, etc. of submarine. This is automatically entered into the contact management system.

Keyboard (General)	The keyboard input device
Keyboard (Function Keys)	The function keys on the keyboard
Trackball	The trackball input device
Display (Time and Bearing Plot)	The main display, where track bearings are shown over time. Time (now) is at the top of the display and older entries are further down the display.
Display (Cascading Menus)	The menu structure as displayed on the console
Display (Other Pages)	Pages within the display, other than the time and bearing plot or cascading menus
Display Element—Contact (Line)	When a contact has been tracked by a sensor for a time its plot of readings forms a line of symbols (see below).
Display Element—Contact Symbol	A contact appears on the display coded according to sensor (e.g., a "+" for a contact detected by the broadband SONAR, a triangle for a contact detected by the flank array, a square for a contact detected on narrow band SONAR, and a '#' for ESM)
Display Element—Track Number	Numeric Track Number
Display Element—text box	A text box is placed at a point in time to form a log of activities, data readings, and significant events. It is unclear if think bubbles are stored in a formalized way that allows them to be used for analysis and trending information while aboard the submarine.
Display Element (Zero Bearing Line)	The zero bearing line represents true north. The SAC can click on the bearing axis to re-centre the time and bearing plot on the chosen bearing (typically that of the submarine's course).
Display Element (Waterfall)	This is the type of display, which grows from top to bottom with time.
Display Element (Cursor)	The "+" cursor which is controlled by the trackball
Information Element (Course)	Course of the track.
Information Element (Range)	Distance from ownship to track
Information Element (Type)	The type of track (e.g. merchant vessel, frigate etc.)
Draft of ship	Depth to which the hull of a surface ship intrudes..
Ship Knowledge	Knowledge of different types of ships, how they operate, what speeds the move, typical course lengths, hazards around them, including accompanying aircraft, etc.
Information Element (Track Number)	Number, either autogenerated or entered.
Information Element (Speed)	The speed of a track
Information Element (Bearing Rate—Fast, Slow,	Bearing rate relative to Ownship. Bearing rate is judged by the steepness of the curve on the time and bearing plot. The

FWD, AFT or ZERO)	steepest part of the curve indicates the closest point of approach.
Widget (Bearing/Rate Computer)	A slide rule-like device that enables seaman to quickly determine reciprocal angles, angle on the bow, closing speeds, etc.
Tac Board (Range of the Day)	Physical display within the Ops Room including the manner in which sound is propagating due to water temperature, salinity, etc.
Headsets (Comms System)	The interface with the shipboard communications system.
Checklists	Written or Mental checklists used to assist during standard procedures.
Orders	Verbal or written orders
Priorities	Including contacts of interest, operating envelopes, etc.
Procedures/SOPs	Written documents describing standard operating procedures for specific situations. Also things like shipping and ferry schedules, shipping lanes, etc.
Depth under hull (Keel)	Depth under the submarine to avoid manoeuvring into the bottom.
Emergency go deep envelope	The safety bubble around the submarine at which point the submarine will dive to avoid collision or attack. Must be correlated with water depth under the hull.

3.2 Contextual Activity Template

The Contextual Activity Template (CAT) allows the analyst to map elements from the AH to different situations in which the system may operate. From the initial meeting with SMEs (March 4, 2013) the following 19 situations were identified:

- At Depth;
- At Periscope Depth;
- At Surface;
- BINT;
- Entering/Leaving Harbour;
- River Routine;
- Passage Routine;
- Blind Pilotage;
- Transit Routine;
- Ditching Gash;
- Running Opened Up/Closed Down;
- Blowing Tanks;
- Snorting;

- Mine Laying;
- In Shore Operations;
- Underwater Look;
- Special Operations;
- Search and Rescue (SAR), and;
- Working with helicopters or Maritime Patrol Aircraft (MPA).

To complete the CAT, these situations were analyzed according to the object-related processes (as identified in level 4 the AH) that could occur during that situation. During the second SME session (March 14, 2013) the SMEs verified the situation and the CAT and provided the following amendments:

- When blowing tanks or snorting the environment is too noisy to effectively use any of the sensors in the sound room. Although the SAC position is still manned and critical, the primary sensor in use will be ESM, the periscope, and radar (in poor visibility) supplemented by AIS information when provided from the Electronic Chart Precise Integrated Navigation System (ECPINS) display;
- When entering or leaving harbor the SAC position is not manned. Contact management is performed from the conning tower, visually or using radar (in poor visibility);
- During an underwater look, all information coming to the SAC is visual;
- An incoming torpedo is also a critical situation for the contact management function. During this situation the sound room is constantly passing the torpedo bearing. This information is going straight to TMA for targeting purposes, and;
- When working with helicopters or the MPA, the submarine does not specifically plot aircraft, since their tracks are generally not held for long. Nevertheless, the contact management function continues.

The completed CAT is included in 0. In the CAT, the columns represent situations, and the rows represent object-oriented processes (or functions). The likelihood of occurrence of each function during each situation is represented graphically. A function that "can" occur during a situation is indicated by the dotted region, while a function that "typically" occurs is indicated by the box-and-whisker diagram. In the final CAT, the following processes appear to be most generally applicable:

- Entering information from the sound room;
- Correlating/associating tracks (a primarily mental task, see Section 3.3);
- Considering the contact in relation to critical safety parameters; and,
- Communicating, especially the secretarial function of using the keyboard to enter data regarding significant events on the submarine (like a second ship's log).

3.3 Contact Management Strategies

The strategies analysis allows the analyst to capture different cognitive and physical strategies the SME might adopt to achieve a particular function or objective. Following the first SME session in Gatineau (March 4, 2013) the following activities were identified as ones for which SMEs might use different strategies depending upon the context:

- Prioritizing tracks;
- Managing and prioritizing sensors;
- Correlating/associating tracks;
- Reassigning track numbers;
- Decluttering the display;
- Entering sensor data;
- Communication; and,
- Consider contact in relation to critical safety parameters.

No specific information regarding these strategies was collected during the first SME session. During the second SME session the participants represented two different trades: NCIOPs and NAVCOMM. The NCIOPs learn the picture compilation task from the very beginning and have extensive and broad knowledge about the tasks, the sensors involved, and the system vagaries. The NAVCOMMs come to the contact management task abruptly when assigned to a submarine and rely more on external support tools in the control room than knowledge of theory and practice. Thus, NCIOPs tended to carry out tasks mentally, where NAVCOMMs used other information displays within the control room.

The strategy information collected during the second SME session is provided in the following sections.

3.3.1 Prioritizing tracks

Generally, SAC operators apply the following schema when prioritizing tracks:

- Highest priority: Torpedo because it actively seeks to destroy the submarine;
- Next highest priority: fishing vessel because it is hazardous due to its nets, because it drifts and a bearing cannot be taken (Peace Time);
- Next highest priority: another submarine because it may be tracking ownship, thus jeopardizing mission achievement;
- Next highest priority: aircraft because they can see the submarine;
- Next highest priority: warships;
- Lowest priorities: merchant ships and ferries, because they are predictable and rarely exhibit dangerous (i.e., threatening or erratic) behavior.

With the exception of the fishing vessel, anything that is weapons capable is prioritized. Within this prioritization schema, the SAC operator will also prioritize based on speed of the contact and range to the contact. The faster the contact and the closer it is, the higher priority it will be made.

If the mission requires that attention be paid to specific contacts or vessels of interest, these will also be made a high priority, as will enemies in a warfare situation.

3.3.2 Interpreting the Time and Bearing Plot

During the second SME session, personnel stated that the Closest Point of Approach (CPA) for a contact was indicated on the time and bearing plot by the area of the contact curve with the highest bearing rate change (i.e. the most horizontal segment of a contact's line on the screen). When asked to elaborate on how to extract information from the time and bearing plot, they replied that understanding and experience contributed to expertise in interpreting the plot. One SME (NAVCOMM) indicated that he relied heavily on the Tactical Plan Display (TPD).

The time and bearing plot has a key marker: the 0° line representing true North. Contact bearings are plotted in relation to true North, as is the submarine's course. The SAC can re-centre the time and bearing plot to make the submarine's course (or any bearing at all) the centre of the display. The centred bearing then has the remaining 360° laid out to the right and left (in 180° halves). This makes it easier for the SAC to determine bearings relative to each other, including relative to the ownship.

The time available and the preparations made for this SME session meant that we were unable to explore strategies for interpretation further. An investigation into interpretation would probably need to involve scenario-based structured interview approaches to systematically identify the subtle cues and associated meanings applied by SMEs to interpretation of time and bearing plots.

3.3.3 Managing and Prioritizing Sensors

In most situations, the sensors that are controlled by the sound room are the priority sensors. Of these, the broadband sonar is the main sensor. If at periscope depth, however, the visual 'ground truth' picture provided by the periscope is prioritized. If visibility is poor, but the submarine is at periscope depth, then electronic sensors are prioritized. Given the 'passive' listening aspect to ESM, this is more likely to be used in tactical situations (with 'listening' sonar), whereas radar will be used in safety situations. With respect to detection ranges, if used, ESM would likely detect a contact first, followed by the sound room, then the periscope (again, if used). Depending on the contact, the periscope may detect a contact before the sound room (for instance, in the case of aircraft or drifting/quiet entities).

3.3.4 Correlating/Associating Tracks

Correlation and association of tracks is a proactive process on the part of the SAC. When a track is created it is assigned a sensor track number. The SAC will allocate a master track number. Once a track is created by a sensor the SAC coordinates further cuts against that track, and will direct the sensor as to what number to make that track. In the specific instance of the broadband sonar, the SAC will give the track a master track number and will direct the sonar operator to track that contact on a particular channel number. This approach provides a verification mechanism to ensure discussion of tracks is referring to the correct track. The master track number is also used by the TMA operator, to further assist the clarity of communications on the submarine.

When a different sensor picks up a track, the SAC will consider whether it is coming from the original track, and then will direct the sensor to make that track the required track number. Thus, track correlation/association is done mentally based on the knowledge of the SAC of the relative bearings of contacts, and then prior to the contact management display by the sensor operating assigning a coordinated master track number to the contact.

The most common activity to lead to error in correlating tracks is due to human error. When accepting a visual cut to a hooked track (tracks on the SAC display can be hooked, in which case the visual cut will be associated with the hooked track). The SAC workstation has a manual correlation page on which to correlate or associate tracks that have been passed by sensors without being associated or have been erroneously accepted.

The SAC's decision of what tracks to correlate can also be assisted by referring to the Tactical Plan Display (TPD). This display is a geospatial display showing the submarine's course, as well as the periscope's bearing and symbols for all contacts and normally displayed on an adjacent console.

3.3.5 Reassigning Track Numbers

There is not typically a need to reassign track numbers; however there are occasions when this is necessary. The most common instance of reassigning track numbers is done by the sonar operators in response to the SACs allocation of a master track number. The other situation in which track number may be reassigned is when two contact bearings are going to cross. In this situation the system may get confused when the track cross and assign the track numbers to the wrong contacts. In this situation the SAC must monitor the tracks, assume a contact running straight will continue running straight and pay particular attention to the amplifying verbal information passed from the sound room and, if necessary, swap the track numbers around.

The SAC also needs to ensure that the track numbers have remained the same after a ranging manoeuvre. Knowing the magnitude of the ranging manoeuvre, the sensor operator should correctly reassign the master track number. However, the SAC must verify that the information has been maintained correctly.

3.3.6 Decluttering the Display

Decluttering the display (i.e. clearing the display of information that is of no interest to the operator) is not done except in the case of contacts whose bearing indicates that they are opening on the submarine (i.e. getting further away). In this case, the SAC will request permission to stop tracking that contact, thus decluttering the display.

3.3.7 Entering Sensor Data

This task forms much of the SAC's job. Although the SAC should enter as much detail about contacts and ship's activities as possible, the reality is that SAC typing abilities vary considerably. Some SAC operators have memorized key strokes and sequences to enter data or access menus more quickly. This memorization is made easier because reports are provided from the sensor in a standard format and order, facilitating brevity in communication, but still requiring transcription by the SAC operator to suit the contact management system.

3.3.8 Communication

As noted above, communication is fairly standardized in terms of its format and order, so that the team has expectations regarding communication, thus facilitating the identification of critical information. The radio network is also open to anyone in the Action Information Organization, so anyone can supply amplifying information, such as knowledge of ship capabilities and dimensions, ferry schedules, shipping lanes, etc. Operators also have to contend with transposing alphabetical characters when discussing contacts, to numerical characters on their displays and in their systems. SMEs wrote the 'decode' of letters to numbers in grease pencil on the console, indicating that this is a cognitive overhead that is particularly prone to errors.

Verbal communication is the source of much of the most useful information available on the submarine. From the sound room they receive information that amplifies a contact concerning the number of blades on the propeller, imperfections in the propeller rotation, and other characteristic acoustic signals. The sound room will also pass information regarding transients and biologicals (activity outside the submarine, based on actually listening to the sonar feed), which can be loud or can be weak, but generally do not last long enough to be caught in a sonar cut and thus be passed across to the SAC. Bearing and amplifying information will also be provided over the voice networks by the ESM operator because the system can generate a large number of individual tracks. Therefore, the ESM operator manually/mentally determines the average of the bearings and passes the information verbally to the SAC, who has to enter the bearing manually. The navigator maintaining and monitoring the ECPINS display (onto which is also plotted AIS data) also passes data verbally. SAC operators will often jot down verbal communications onto a piece of paper and enter the information as and when they have the opportunity (according to workload).

3.3.9 Consider Contact in Relation to Critical Safety Parameters

The safety of the submarine is the responsibility of all crew. Anyone in the Action Information Organization can contribute to decision making regarding safety, irrespective of rank. However, practically, much of the situation awareness for safety is held by the Officer of the Watch (OOW), watch officers and Chief of Operations (CHOPS). These crew members know where the submarine is in relation to water depth, coastlines, underwater topographic features, territorial waters, etc. and allow a comparison of the tactical picture with ground truth. Likewise, the maintenance of situation awareness for the Go Deep Envelope is the responsibility of the crew member on the periscope. If a contact suddenly appears close to the submarine unexpectedly the periscope operator will command the submarine to go deep. The SAC will annotate this order.

The SAC will also annotate significant events on the submarine, such a fire, and will listen to the damage control to keep that information updated.

The SAC does maintain a consideration of safety with respect to contacts that could hit or otherwise kill the submarine, and what the submarine could hit. Weapons-capable contacts are mentally highlighted by the SAC, as are contacts with high bearing rates because they are close, visual contacts in the middle of the ocean, and 'abrupt-in' contacts (i.e. contacts that seem to appear from nowhere, typically fishing vessels when they start their engines and other submarines).

It is likely that SMEs set thresholds for different classes of contact. These thresholds trigger alerts when met or exceeded. These may be thresholds set informally by the SAC, or set formally by the Captain of the submarine. One example provided during the second SME session concerned fishing vessels against which the submarine needs to maintain a certain distance for safety against possible nets or lines in the water. As with bearing rate interpretation above, time precluded specific investigation of the different ship specific strategies.

3.4 Requirements

The following requirements are divided into four main sections; these sections correspond to the top level 'functional purpose' of the analysis. They are:

- Information Management Requirements;
- Sensor Coordination Requirements;
- Submarine Safety Requirements; and,
- Mission Achievement Requirements.

Note that the nature of the contact management task is sufficiently integrated and seamless that functional purpose-related requirements could reasonably be categorized into any of the four purposes. We have attempted to categorize requirements according to the purpose on which a requirement would have the clearest impact.

In deriving the requirements, the constraints imposed by both:

- The limited screen area being targeted; and,
- The simple re-hosting of the fire control system, rather than a complete re-implementation of the software;

were respected. All requirements fall within the specific constraints on design options for this technical refresh.

Throughout the lists of requirements 'must' was used. This is not intended to imply that all requirements must be met; rather, if a design solution touches upon an area that makes the requirement relevant, the requirement must be met. Given the scope of the technical refresh of the FCS system, it is also understood that cost-benefit analysis may render some requirements unachievable, even if they are pertinent to the design solution.

Additionally, a set of requirements were derived concerning the impact of any design change on system performance outcomes (with particular emphasis on the human components of system performance).

In the following sections, 'the system' refers solely to the contact management time and bearing plot display, unless otherwise indicated.

3.4.1 Information Management Requirements

- The ability of the SAC to enter information into the contact management system must be improved with respect to items of information entered per minute.
- The reliance on memorization of key sequences must be reduced.
- The need to maintain a temporary, parallel database of information for later input to the system must be eliminated.
- The use of brevity codes must be exploited.
- The standard format of information of different types must be exploited to minimize keyboard entry.
- The information management system must present sensor- and contact-type-specific data entry forms.
- The sensor- and contact-type-specific data entry forms must be arranged to match the format of the standardized verbal reports provided to the SAC.
- The information management system must reduce the breadth and depth of the menu hierarchy required to enter information.
- The system must support both alphabetical and numeric track identifications (up to and including full words). Reasonable limits to the number of characters are acceptable.
- The system must represent ECPINS 'ground truth' data, concerning geographic information and other contextual/situational cues, as well as the representation of the growing pool of errors.
- The system must automatically integrate AIS information with track information at the SAC position.
- The system must allow the operator to 'unpack' a track into its constituent sensor tracks in an integrated fashion across both the time and bearing plot and the tabular sensor tracks display.
- The system must permit the user to control any automatic or manual highlighting, in particular allowing the operator to turn off any highlighting.

3.4.2 Sensor Coordination Requirements

- The system must highlight sensor data that has been entered automatically while the SAC has been fully engaged with entering data from another sensor suite.

3.4.3 Submarine Safety Requirements

- The system must support the entry and automatic comparison of safety and tactical parameters (e.g. alerts for speed, range, course, bearing, bearing rate, assigned to contact types if required) against contact type, range, bearing, course, and speed data, for the purposes of highlighting and alerting.
- Any presentation of safety-related information must be immediately clear to the user with respect to: 1) its presence, 2) its meaning, and 3) its implications for the submarine.
- For intermittent contacts the system must indicate the range of possible locations at time = now, and time = user defined.
- The system must support alerts for specific, operator-selected contacts.

3.4.4 Mission Achievement Requirements

- The system must support user-initiated highlighting of priority contacts.
- Any change to the system must enhance the submarine's ability to achieve the aims of the mission, remain covert, and maintain safety.
- The system should extrapolate to indicate when the CPA of a contact will occur.

3.4.5 Requirements Concerning the Impact of Design Options on System Performance

- The proposed change must make it easier to maintain the appropriate data update rate for contacts. This can be measured by whether cuts can be taken quicker and whether information can be entered more quickly.
- The proposed change must encourage and facilitate the recording of all the data possible. This will be measured based on the time it takes to enter each item of data, the accuracy of data entry.
- The proposed change must make it easier to relate information over time, develop expectations, and predict the likely moves of the contact. This may be measured during scenario-based investigations (table-top or higher fidelity) based on direct questioning.
- The proposed change must assist the SAC to prioritize the attention paid to different contacts. This will be measured according to the time it takes to prioritize a set of contacts and the adequacy of the prioritization.
- The proposed change must make it easier for the SAC to detect changed data, understand what the data is telling him, and predict what that data means for the future. This will be measured by detection rates, comprehension speed, and prediction accuracy.
- The proposed change must make it easier for the SAC to determine how to employ the different submarine sensors, measured in time to decide and adequacy of the decision.

- The proposed change must make it easier to develop a shared awareness of the current situation and the priorities of the situation through timely and accurate communication. This will be evaluated by comparing knowledge of different sensor operators regarding which sensor is currently the priority, what sensor will be the priority, what they can do to contribute to the maintenance and updating of the contact management information, and what contact is the highest priority.
- The proposed change must make it easier to consider contacts in relation to the critical safety parameters such that those parameters are not contravened. This will be measured by evaluating what safety parameters are contravened how often.
- The proposed change must increase the SACs certainty regarding the picture, in particular knowledge regarding bearing, range, course and speed of contacts.

4 Conclusion

The approach taken to deriving contact management requirements resulted in 30 requirements that do not impose design solutions. Within these requirements there are some clear themes:

- The method by which the SAC inputs information to the system is laborious and sub-optimal. Several requirements concerned the improvement of the data entry process, including making it quicker, enabling the use of alphabetical characters for track identifiers, and developing pre-formatted and standardized data entry forms that match the type of information to be entered.
- Situation awareness for ‘ground truth’ and geographic data is desired by SAC operators. Adding information from ECPINS and other sources as a supplemental verification of one’s understanding would be beneficial.
- The setting of alerts and automatic and manual highlighting of tracks is desirable.
- A tote of priority contacts, whether automatically or manually determined, would assist situation awareness.
- Any design option must be evaluated for its impact on system performance, including but not limited to speed and completeness of information entered into the system, situation awareness of the SAC and the broader Action Information Organization, ability to prioritize contacts, and ability to effectively use sensors.

In carrying out this work, SMEs provided a great deal of design suggestions. However, further work will be required to fully develop design options, whether corresponding to SME suggestions or to address a requirement. With the understanding provided by carrying out this analysis, such design work could be accomplished quickly and easily.

Another finding, incidental to this work, concerns the analysis method employed. The CWA software tool obtained from Jenkins et al (2006) assisted in structuring and guiding the analysis process, as well as facilitating the completion of the analysis in good time. A number of usability issues were identified, and some recommendations for improving the ability of the analysis to support requirements derivation will be shared with the authors (Annex C).

References

[1] Jenkins, D.P., Stanton, N.A., Walker, G.H., Salmon, P.M., Young, M.S. (2006). Applying Cognitive Work Analysis to the design of rapidly reconfigurable interfaces in complex networks. School of Engineering & Design, Brunel University, Uxbridge, Middlesex, UB8 3PH, UK. Retrieved from: http://www.hfidtc.com/cwa/jenkins-2006-human-factors.PDF.

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Annex A Abstraction Hierarchy

This Annex contains the AH diagram, as well as tables indicating the links between nodes at each level of the AH. The AH diagram is shown in **Error! Reference source not found.**. In the CWA Tool, individual nodes can be selected in order to see the links between the nodes, using red lines. In **Error! Reference source not found.**, the "RADAR" node in the physical element level of the AH has been selected.

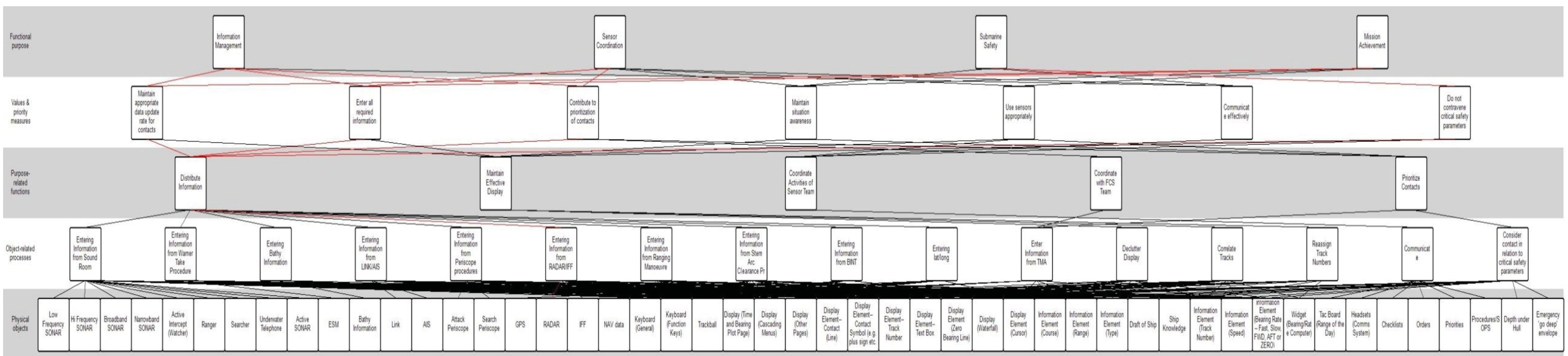

Figure A-1: Abstraction Hierarchy

Table A-1 summarizes the links between AH nodes at the Functional Purpose level and AH nodes at the Values and Priority Measures level.

Table A-1: Functional Purposes to Value and Priority Measures

		Functional Purposes			
		Information Management	**Sensor Coordination**	**Submarine Safety**	**Mission Achievement**
Values & priority measures	**Maintain appropriate data update rate for contacts**	X	X		X
	Enter all required information	X	X		X
	Contribute to prioritization of contacts	X	X		
	Maintain situation awareness		X	X	X
	Use sensors appropriately		X		X
	Communicate effectively	X	X	X	
	Do not contravene critical safety parameters			X	
	TOTALS	4	6	3	4

Table A-2 summarizes the links between AH nodes at the Values and Priority Measures level and AH nodes at the Purpose-Related Function level.

Table A-2: Value and Priority Measures to Purpose-Related Functions

		Values & Priority Measures						
		Maintain appropriate data update rate for contacts	**Enter all required information**	**Contribute to prioritization of contacts**	**Maintain situation awareness**	**Use sensors appropriately**	**Communicate effectively**	**Do not contravene critical safety parameters**
Purpose-Related Functions	**Distribute Information**	X	X	X			X	
	Maintain Effective Display	X	X		X	X		X
	Coordinate Activities of Sensor Team					X	X	X
	Coordinate with FCS Team			X			X	
	Prioritize Contacts			X	X	X		
	TOTALS	3	3	3	2	3	3	2

Table A-3 summarizes the links between AH nodes at the Purpose-Related Function level and AH nodes at the Object-Related Process level.

Table A-3: Purpose-Related Functions to Object-Related Processes

		Purpose Related Functions				
		Distribute Information	**Maintain Effective Display**	**Coordinate Activities of Sensor Team**	**Coordinate with FCS Team**	**Prioritize Contacts**
Object-related processes	**Entering Information from Sound Room**	X				
	Entering Information from Warner Take Procedure	X				
	Entering Bathy Information	X				
	Entering Information from LINK/AIS	X				
	Entering Information from Periscope procedures	X				
	Entering Information from RADAR/IFF	X				
	Entering Information from Ranging Manoeuvre	X				
	Entering Information from Stern Arc Clearance Procedure	X				
	Entering Information from BINT	X				
	Entering lat/long	X				
	Enter Information from TMA	X				
	Declutter Display		X		X	X
	Correlate Tracks		X			
	Reassign Track Numbers		X			
	Communicate			X	X	
	Consider contact in relation to critical safety parameters					X
	TOTALS	11	3	1	2	2

Table A-4 summarizes the links between AH nodes at the Object-Related Process level and AH nodes at the Physical Object level.

Table A-4: Object-Related Processes to Physical Objects

		Object-Related Processes															
		Entering Information from Sound Room	Entering Information from Warner Take Procedure	Entering Bathy Information	Entering Information from LINK/AIS	Entering Information from Periscope procedures	Entering Information from RADAR/IFF	Entering Information from Ranging Manoeuvre	Entering Information from Stern Arc Clearance Procedure	Entering Information from BINT	Entering lat/long	Enter Information from TMA	Declutter Display	Correlate Tracks	Reassign Track Numbers	Communicate	Consider contact in relation to critical safety parameters
Physical Objects	Low Frequency SONAR	X															
	Hi Frequency SONAR	X															
	Broadband SONAR	X															
	Narrowband SONAR	X															
	Active Intercept (Watcher)	X															
	Passive Ranging Sonar (PRS)	X															
	Searcher	X															
	Underwater Telephone	X															
	Active SONAR	X															
	ESM		X														

		Object-Related Processes															
		Entering Information from Sound Room	Entering Information from Warner Take Procedure	Entering Bathy Information	Entering Information from LINK/AIS	Entering Information from Periscope procedures	Entering Information from RADAR/IFF	Entering Information from Ranging Manoeuvre	Entering Information from Stern Arc Clearance Procedure	Entering Information from BINT	Entering lat/long	Enter Information from TMA	Declutter Display	Correlate Tracks	Reassign Track Numbers	Communicate	Consider contact in relation to critical safety parameters
	Bathy Information			X													
	Link				X												
	AIS				X												
	Attack Periscope					X											
	Search Periscope					X											
	GPS										X						
	RADAR						X										
	IFF						X										
	NAV data										X						
	Keyboard (General)	X	X	X	X	X	X	X	X	X	X	X		X	X	X	
	Keyboard (Function Keys)	X	X	X	X	X	X	X	X	X	X	X		X	X	X	
	Trackball	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Display (Time and Bearing Plot Page)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Display (Cascading Menus)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Display (Other Pages)															X	

	Object-Related Processes															
	Entering Information from Sound Room	**Entering Information from Warner Take Procedure**	**Entering Bathy Information**	**Entering Information from LINK/AIS**	**Entering Information from Periscope procedures**	**Entering Information from RADAR/IFF**	**Entering Information from Ranging Manoeuvre**	**Entering Information from Stern Arc Clearance Procedure**	**Entering Information from BINT**	**Entering lat/long**	**Enter Information from TMA**	**Declutter Display**	**Correlate Tracks**	**Reassign Track Numbers**	**Communicate**	**Consider contact in relation to critical safety parameters**
Display Element--Contact (Line)	X	X	X	X	X	X	X	X			X	X	X	X		X
Display Element--Contact Symbol (e.g. plus sign, etc.)	X	X	X	X	X	X	X	X			X	X	X	X		X
Display Element--Track Number	X	X	X	X	X	X	X	X			X	X	X	X	X	
Display Element--Text Box	X	X	X	X	X	X	X	X			X	X	X	X	X	
Display Element (Zero Bearing Line)												X	X			X
Display (Waterfall)												X	X			X
Display Element (Cursor)	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Information Element (Course)	X	X	X	X	X	X	X	X			X	X	X	X		
Information Element (Range)	X	X	X	X	X	X	X	X			X	X	X	X	X	X
Information Element (Type)	X	X	X	X	X	X	X	X			X	X	X	X	X	X
Draft of Ship	X	X	X	X	X	X	X	X			X	X	X	X	X	X
Ship Knowledge	X	X	X	X	X	X	X	X			X	X	X	X	X	X

		Object-Related Processes															
		Entering Information from Sound Room	Entering Information from Warner Take Procedure	Entering Bathy Information	Entering Information from LINK/AIS	Entering Information from Periscope procedures	Entering Information from RADAR/IFF	Entering Information from Ranging Manoeuvre	Entering Information from Stern Arc Clearance Procedure	Entering Information from BINT	Entering lat/long	Enter Information from TMA	Declutter Display	Correlate Tracks	Reassign Track Numbers	Communicate	Consider contact in relation to critical safety parameters
	Information Element (Track Number)	X	X	X	X	X	X	X	X			X	X	X	X	X	X
	Information Element (Speed)	X	X	X	X	X	X	X	X			X	X	X	X	X	X
	Information Element (Bearing Rate- Fast, Slow, FWD, AFT or ZERO)	X	X	X	X	X	X	X	X			X	X	X	X	X	X
	Widget (Bearing/Rate Computer)													X	X		
	Headsets (Comms System)															X	
	Tac Board (Range of the Day)															X	
	Checklists															X	
	Orders															X	
	Priorities															X	
	Procedures/SOPS															X	
	Depth under Hull																X
	Emergency 'go deep' envelope																X
	TOTALS	27	19	19	20	20	20	18	18	6	8	18	18	21	19	21	14

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Annex B Contextual Activity Template

The Contextual Activity Template is shown in Figure B-1. In the CAT, the columns represent situations, and the rows represent object-oriented processes (or functions). The likelihood of occurrence of each function during each situation is represented graphically. A function that "can" occur during a situation is indicated by the dotted region, while a function that "typically" occurs is indicated by the box-and-whisker diagram.

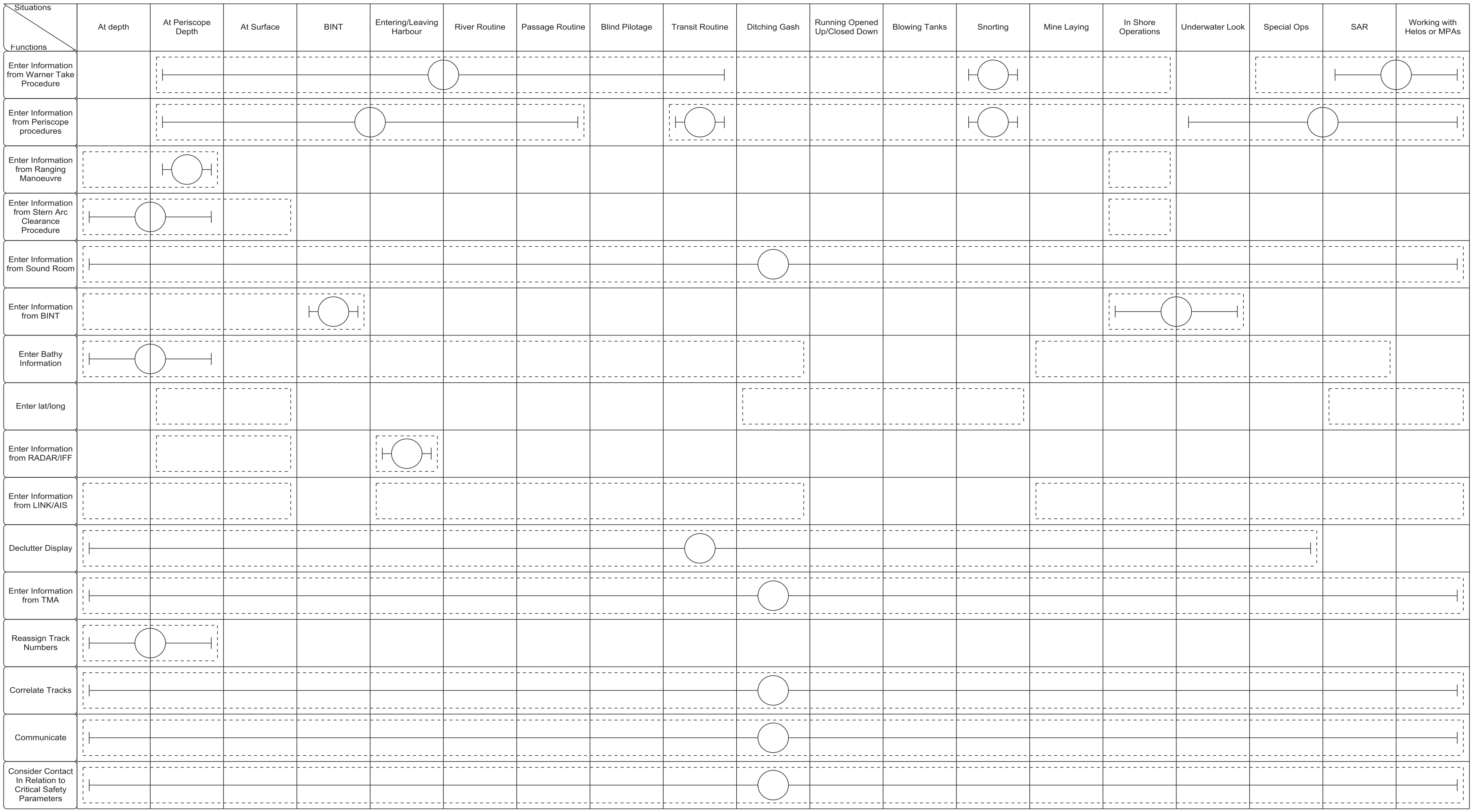

Figure B-1: Contextual Activity Template

Annex C Usability Notes on The CWA Tool

The notes below are offered as observations on using the Human Factors Integration Defence Technology Centre's CWA tool. These observations are made without communication to the creators of the tool and may, in some instances, reflect a lack of understanding of how the tool is intended to be used.

- The Abstraction Hierarchy does not automatically scroll while making links. This means that, before making links, the user needs to either:

  a) Zoom out until all nodes are visible, or

  b) Alter the node row height, node width or node height so all nodes are visible.

- With a large AH, both of these techniques make the node labels too small or too compressed to read while completing the links.

- The Abstraction Decomposition Space doesn't have an effective way to deal with multiple subsystems and components. Specifically, a system will be comprised of several subsystems, but the tool only allows the creation of a single subsystem linked to a system. Likewise, a single sub-system can only be broken down to a single component. There should be a way to create multiple subsystems and multiple components, mapping to single instances at a higher level.

- The CAT is not updated along with the AH. When functions are imported into the CAT, they are not linked to the nodes in the AH. This means that changes to the node name (for Example) would need to be made manually in both places.

- The AH provides a visual overview of the links, but there is no way to get a tabular summary of links from the tool. This would be a useful feature for summarizing data. It is difficult to determine the links from the AH diagram alone, especially in large diagrams with many links.

- Analysis tools would be useful, for instance counting the number of links between nodes in the AH (from nodes that are higher in the AH and nodes that are lower), and counting the number of situations a particular function is typically done or can be done.

- The decision ladders shown in the CAT-DL are too small to be meaningful.

- When exporting the AH diagram to a JPG, the exported file will also show a node selected and red links, even if no node is selected when the export is selected. It is not possible to export an AH with no links highlighted (unless there are no links in the AH).

- Support for annotations would be useful, especially when defining nodes in the AH.

- Support for tracking requirements throughout the entire analysis would also be useful. Many requirements are suggested independently in separate analysis, and it would aid traceability to maintain a master list of requirements that could be linked to discrete points in the analysis.

- Additional online help regarding the intended manner in which the tool should be used would be beneficial. An included complete worked example with suitable accompanying background material would help users understand how the tool's creators expected the user to employ to tool for analysis.

Note that, in spite of these observations, the CWA tool did facilitate the derivation of requirements for system redesign. Further, it facilitated the analysis of both SME sessions and assisted in the identification of particular areas to address during the second SME session. The tool also assisted in the communication of requirements and the justification of these requirements when challenged.

List of symbols/abbreviations/acronyms/initialisms

AH	Abstraction Hierarchy
AIS	Automatic Identification System
BINT	Basic Intelligence
CAT	Contextual Activity Template
CHOPS	Chief of Operations
CPA	Closest Point of Approach
CWA	Cognitive Work Analysis
DMEPM(SM)	Directorate of Maritime Engineering Program Management--Submarines
DND	Department of National Defence
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
ECPINS	Electronic Chart Precise Integrated Navigation System
ESM	Electronic Support Measures
FCS	Fire Control System
GPS	Global Positioning System
HGA	Hierarchical Goal Analysis
LCMM	Life Cycle Maintenance Manager
MARS	Maritime Surface and Subsurface
MPA	Maritime Patrol Aircraft
NAVCOMM	Naval Communicator
NCIOP	Naval Combat Information Operator
R&D	Research & Development
RCN	Royal Canadian Navy
SAC	Sensor Analysis Coordinator; also called Command Display Console (CDC) operator
SAR	Search and Rescue
SME	Subject Matter Expert
TG	Task Group
TMA	Target Motion Analysis
TPD	Tactical Plan Display
VCS	Victoria Class Submarine

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