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VTS Simulator SAR Module for Rescue Operation Planning

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Abstract
This article presents the capabilities of a SAR module during rescue operation planning and control. The Navi-Harbour SAR module was used during an exercise, which enabled an operator to plan and monitor the rescue operations of selected water areas. To present the basic capabilities of this module, we prepared a case for the SAR action for a man overboard in the Baltic Sea using actual available SAR resources in this area. For the basic assumptions of the scenario, a research plan was developed that included an assessment of the most probable position of a threatened unit, taking into account the weather conditions in this area.

Introduction

VTS systems are mainly developed to improve safety in areas that are difficult to navigate, especially those with high ship traffic volumes. A VTS system is ‘a service provided by a competent authority to improve the safety and efficiency of vessel traffic and the environment. The service should be able to interact with traffic and respond to situations developing in the VTS area’ (IMO Resolution A.857 (20)). Managing traffic along maritime routes is difficult due to its technical aspects, which means that there is a high demand for specialised services in this field. A VTS service aims to manage maritime traffic by proposing the best routes for a ship and to ensure that no dangerous situations occur along congested routes, thereby ensuring the safety of ships as they ply their trade. One of the most important roles of VTS services is to locate ships. The information collected, stored, and reproduced by various sensors helps to monitor vessel traffic, and is available at all times and can be used in the case of danger. A VTS service often works with SAR services through traffic management, data collection and analysis, and emergency maritime safety monitoring.

This is the case when an emergency occurs and the cooperation of both services is required (e.g., determining the location, obtaining information on the vessel in distress, etc.). The VTS service can help monitor and analyse data related to maritime traffic safety, predict and respond during maritime disasters or environmental threats, and directly coordinate actions in emergencies. Shipping safety is affected by many factors, which in turn affect the chances of survival and retrieval of property during an emergency. When undesirable situations at sea occur – such as those requiring search and rescue operations, or the elimination of pollution in a marine environment – the forces and resources of the Maritime Search and Rescue Service (SAR) are used.

The legal basis for the operation of SAR is the “International Convention for the Safety of Life at Sea SOLAS” (International Convention for the Safety of Life at Sea), signed on 1 November 1974 in London, and the International Convention on Maritime Search and Rescue International Convention on Maritime Search and Rescue, enacted in Hamburg on 27 April 1979. Both documents regulate the search and rescue of humans and the fight against hazards and pollution at sea and require the parties to the convention to maintain the forces and resources for searching for survivors and the establishment of appropriate rescue services. Each state ratifying these conventions has also created legal instruments to regulate the organisation principles of the SAR service.

The activities of the SAR service primarily consist of searching for and rescuing survivors who are in danger on the water. SAR actions are carried out using available means – including sea rescue units and helicopters – that can perform their tasks regardless of weather conditions or time of day (Krystosik-Gromadzińska, 2016).

The basic tasks of SAR services include (SAR, 2019):
- Maintaining constant readiness to receive and analyse notifications for life-threatening and polluting events at sea.
- Planning, conducting, and coordinating search and rescue operations and combating hazards and pollution.
- Maintaining means to save lives and combat hazards and pollution at sea.
- Cooperating with other units in search and rescue operations and in combating hazards and pollution.
- Cooperating with the relevant services of other countries for carrying out statutory tasks.

SAR operation control

The Transas Navi-Harbour 5000 is a VTS system that meets the IMO A.857(20) system requirements and enables operators to perform VTS functions by (NH User Manual, 2012):
- receiving information on navigation situations,
- providing data about tracked objects (in tabular or graphic form),
- monitoring ship traffic in an area with the possibility to plan their traffic,
- generating appropriate alarms according to criteria set by the operator,
- digitally recording data and entire navigation situations, making it possible to subsequently play back and analyse a situation (which is particularly important in the event of failure or violation of the legal regulations near ships using the system).

The system also has a very useful function in the SAR Module by allowing users to plan and monitor a SAR operation and taking into account the weather conditions and the availability of rescue equipment.

The capacity of a SAR module meets the requirements of the IMO issued by the ICAO-IAMSAR Manual Volume II. This module allows an operator to plan and monitor SAR operations based on current weather conditions and the availability of safety equipment, which makes it possible to control search actions and calculate the probability of a successful search.

The user can quickly select search action parameters from a set of previously entered data. Based on these data, it automatically assesses the effectiveness of the planned action and generates a text file containing basic information about the rescue operations. The operator must enter basic data, such as the incident time, its geographical coordinates, and the weather conditions, and the program automatically calculates the search parameters and determines the search pattern on an electronic map. The system allows SAR operations to be archived in a VTS server.

Rescue planning involves developing a search plan, which includes the following steps (NH User Manual, 2012):
1. Defining the search area and weather conditions by:
   - determining the most probable position/area of a unit in distress and/or survivors,
   - determining the size of the search area.
   - taking into account weather conditions (the drift effect)
2. Deploying the SAR equipment:
   - resource management (number of available units).
3. Setting a route search:
   - choosing a search pattern,
   - planning and coordinating at the scene of action.

There are many automatic search planning solutions for international emergency services. Most of these computer programs support marine rescue operations using probability theories and simulations. There are many programs used worldwide to support SAR action planning, such as SAROPS (Search and Rescue Optimal Planning System for the US Coast Guard), JAWS (Joint Automated WorkSheets), and CASP (Computer-Aided Search and Rescue Planning). Most of these programs use Monte Carlo simulations, which assume a random scattering of the values of a given variable within set limits (Abramowicz-Gerigk & Burciu, 2015). A typical SAR action is the use of the SAR module simulator Transas VTS to plan an exploration campaign. A simulated rescue operation involving 2 SAR units and 2 helicopters (Swedish and German) was used for a man overboard search.

Basic assumptions for a planned incident

At 14/05/2016 6:00 the VTS operator received a mayday message from a ferry whose captain reported a man overboard incident. At this time, the ship was located at 54°16.10'N 014°27.59'E, 19 nautical miles (Nm) north of Świnoujście and 3 Nm inside the German SAR responsibility zone. It was assumed that the following units would participate in the search: m/s "Pasat" – SAR 3000, rescue vessel SAR 1500, and two rescue helicopters (Swedish and German).

The weather conditions in the area were as follows:

- visibility – 5 Nm,
- wind – 210° T/35 kn,
- sunrise – 05:00,
- sunset – 18:00,
- wind field – 194°/32 kn,
- observed drift – 57°/1.86 kn,
- drift speed error (ASW) – 0.3 kn,
- possible observation error (TWCe) – 0.42 kn.

Table 1 lists the information on the wind field simulation parameters.

Table 1. Simulated wind field parameters

Date	Time	deg/kn
14 May	00.00	175/32
	06.00	190/30
	12.00	210/35
	18.00	205/37
15 May	00.00	200/32
	06.00	195/30

Table 2 contains information about the characteristics of the units used for SAR planning.

Table 2. Characteristics of the units used for SAR planning

Type of plane	Speed	Time in air	Level of crew fatigue
EC-145	240 km/h	3 hrs 35 min	normal
BK-117	250 km/h	4 h	normal
Type of vessel	Speed	Time at sea	Level of crew fatigue
SAR-3000	24 kn	12 h	normal
SAR-1500	30 kn	10 h	normal

Defined search area

To begin planning a new rescue operation, the *Option > SAR > Manage Operation* must be selected from the main menu (Figure 1). The dialog window *SAR management* will open, enabling the creation of a SAR operation scheme.

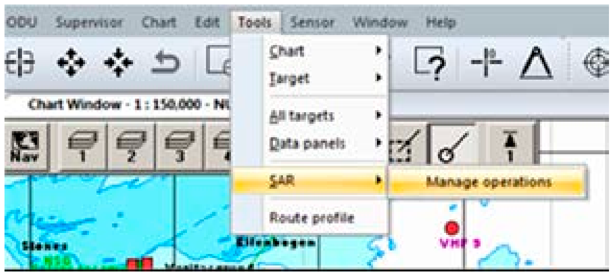

Figure 1. The main window of Navi-Harbour – the start of SAR action planning

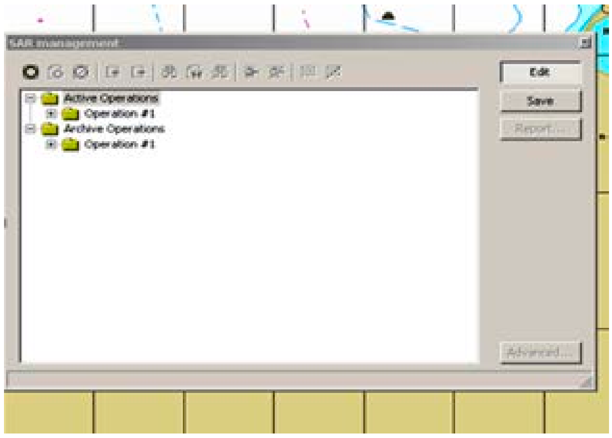

Figure 2. SAR management dialogue box window

The active operation parameters are displayed in the management dialogue box of the SAR operation (SAR Management) (Figure 2).

Determination of the most probable position of the searched unit

The location of the incident was determined from the information associated with the received "man overboard" signal (Figure 3). The first step in creating a SAR action is to introduce the main parameters of a new rescue operation:

- Position – position of reported incident;
- Position Date – the date of the incident;
- Position Time – the time of the incident;
- Search Object – select from the list the type of action (SAR Ship, Survival Craft, or Man Overboard).

There are three ways to define the position of the incident:

- Point incident location – enter the coordinates of the position;
- Line incident location – enter the coordinates of the two points that define the position of the line;
- Area incident location – enter the coordinates of the centre of the area, its width, and length, as the values that define the search area.

In the simulation, the position of the incident is determined using the option positions point of the incident location.

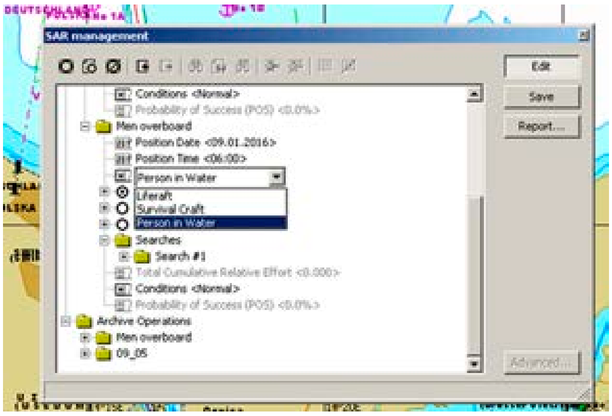

Figure 3. SAR Management window for determining the position of an incident

Search area determination

The basic parameters of the search action must be specified in the branch *Searches*. The detailed parameters *Datum time*, *Average Surface Wind*, E*, and Separation Ratio* were determined based on the IAMSAR Manual Volume II Mission coordination 2008 edition.

Based on the wind and current parameters, the most probable position of the searched-for unit was determined by taking into account the drift from the moment of the incident. The reference point was defined as the geographical point where the searched unit was expected to be located (Figure 4).

R is the radius of the search area, which depends on the current and wind force and direction; *Datum* refers to the location to begin the search.

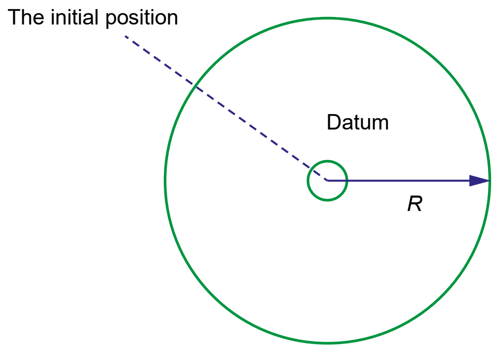

Figure 4. Position of commencing a search

To determine the reference position, the current and wind parameters must be specified. The tab *Surface Wind* is used to calculate the Average Surface Wind (ASW), which requires the introduction of wind parameters (time, speed, direction).

The *Surface Wind* data window is used to calculate and enter the time, wind speed and direction, and the Average Surface Wind (ASW) (Figure 5). The current has more influence on the man overboard incident, and the current data can be specified in the *Tidal Current* (TV) window (Figure 6).

SAR resources dislocation

Resource management involves designating the units that will participate in the SAR action. The appropriate craft – two rescue helicopters and two SAR vessels – were selected (Figure 7). The unit types were selected in the *Facility Type* section, and then their search parameters were set (i.e., the speed of the search, the time to participate in the search, the hours until sunset, the amount of driving action, as well as a correction factor that accounted for crew fatigue).

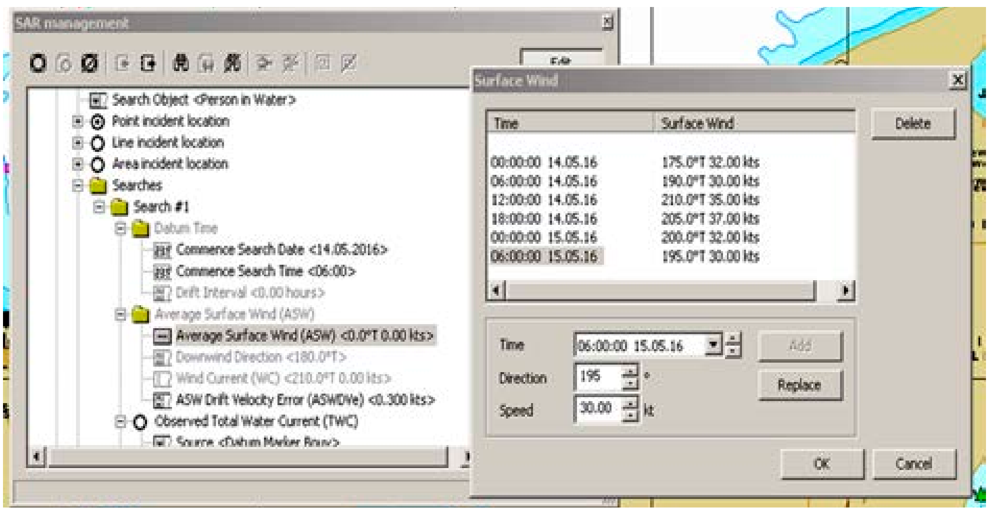

Figure 5. Introduction window of wind parameters and their changes

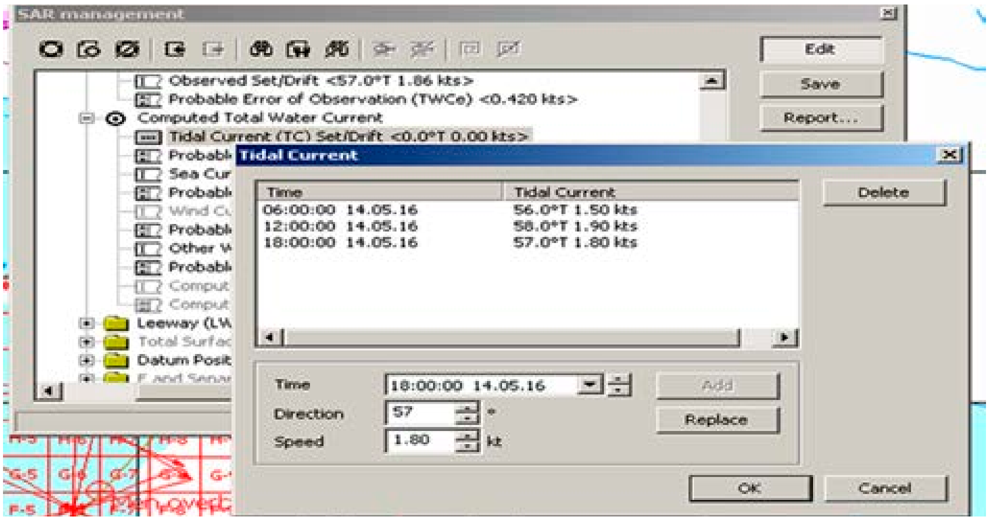

Figure 6. Introduction window of the current parameters and their changes

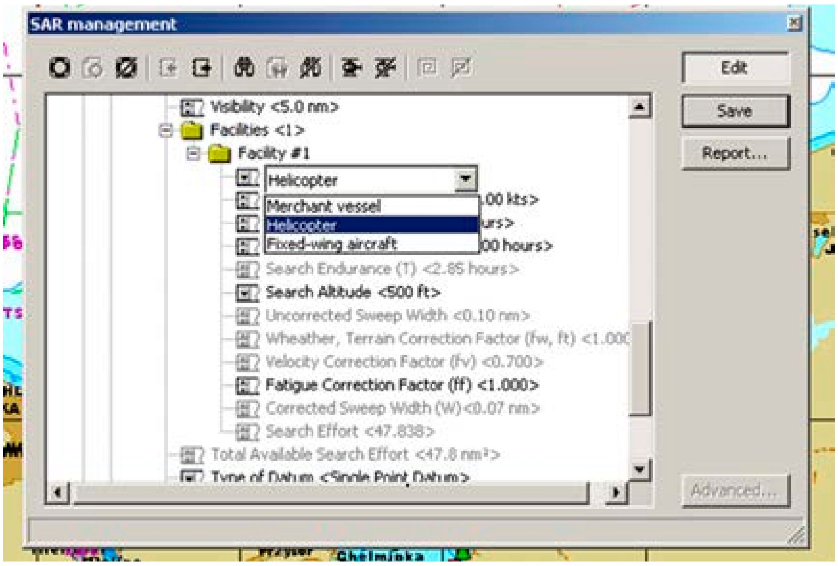

Figure 7. The selection of available rescue facilities

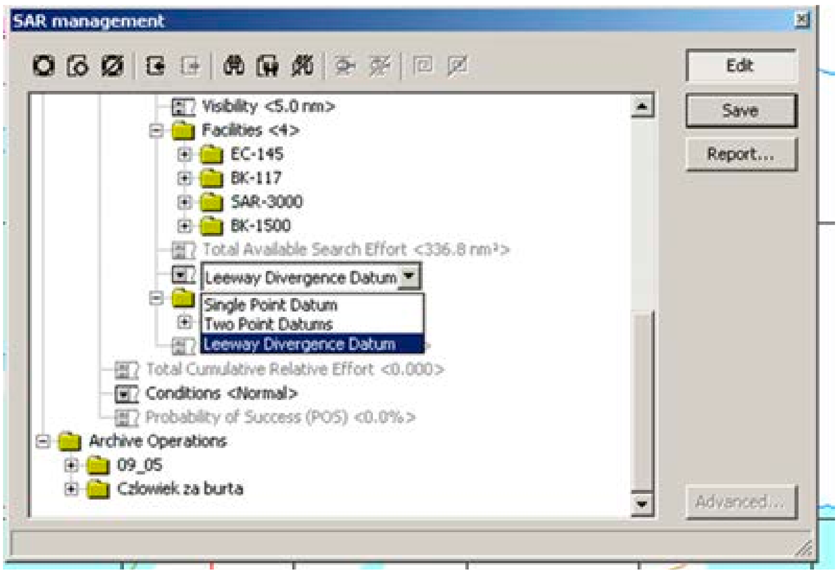

Figure 8. Facilities setup – *Type of Datum*

After entering the above parameters in the *Type Of Datum* tab, one of two possible reference points was selected (Figure 8). After the introduction of the first rescue unit, the next was added in the same way.

Setting the search tracks

After determining the reference position and the number of available rescue teams, the diagram of the search should be selected (separately for each rescue craft). The list of available rescue units should be checked in the *Search Area* tab under *Facilities Chosen*, and the correct search pattern should be chosen for each unit. One of five methods (diagrams) can be chosen to search for an object in distress in the SAR module:

- Sector search method (VS);
- Expanding square method (SS);
- Parallel sweep search (PS);
- Contour search (OS);
- Track line search (TS).

Sector search method (VS)

The sector search method is the most effective in cases in which the location is fairly well-known and soon after it has occurred. The starting point of rescue is always the reference position. This method involves having a position of the reference survival craft headed in the direction of the expected drift of survivors, and after passing a distance *S*, alter the course to right 120 degrees, cover the next *S* miles, and again turn 120 degrees to the right, etc. In the diagram, in the case of routes where no survivor was found, the entire graph must be moved 30 degrees to the right (dashed lines in Figure 9), and further exploration continued. For vessels, the distance *S* can vary from 2 Nm to 5 Nm (United States Coast Guard, 2006; IMO 2019b).

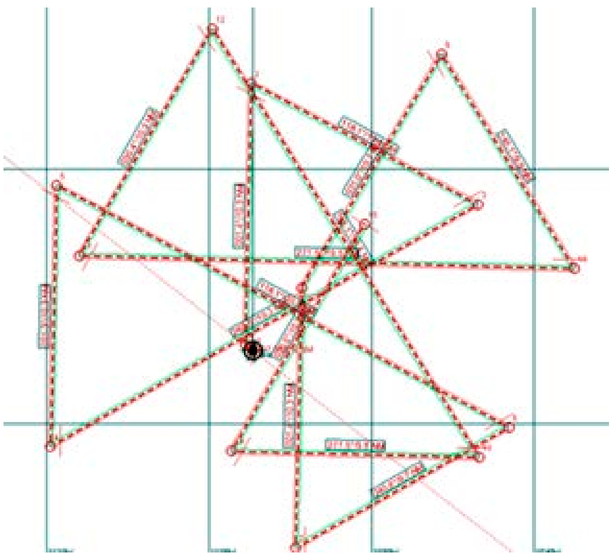

Figure 9. Sector search method

Expanding square method (SS)

The expanding square (SS) method is the most effective if the position of the survivor is known to be within a relatively small range. The commencing point is the reference position, and survival craft move around this position. Along the specified routes, *S* performs a turn of 90° to the right or the left; the route sections *S* must always be increased (Figure 10). This method is used mainly by ships and small boats to search for people or other small objects in the water (IMO, 2019b).

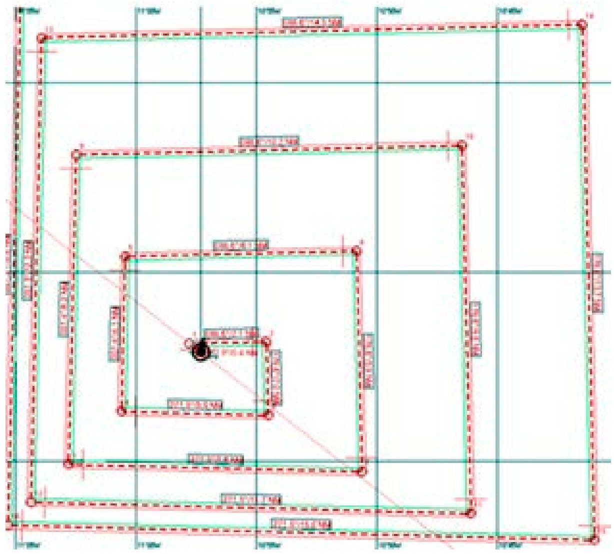

Figure 10. Expanding square search

Parallel sweep search (PS)

The parallel sweep search (PS) method is primarily used to explore large areas when the survivor location is uncertain. It is typically used when the search area must be divided into sub-areas to assign individual vessels simultaneously searching a scene. The starting point of the search is half the length of the track(s) within the rectangle in each of the two sides that form a corner. The search legs are parallel and offset from each other by a distance equal to the distances of the two detected objects (Figure 11). The search unit moves one track in the directions back and forth. This process continues until the entire search area is searched or the object is located (IMO, 2019b).

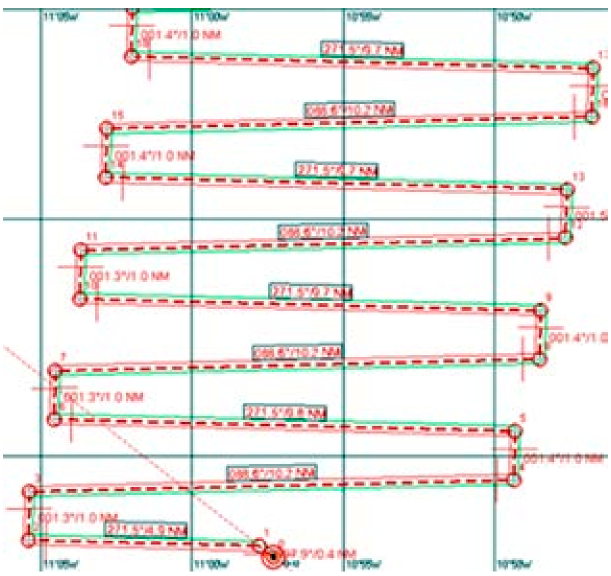

Figure 11. Parallel Sweep Search (search with helicopter assistance)

The spacing between parallel searching courses *S* (Track Spacing) is defined as the distance between the centres of adjacent strips.

Track line search (TS)

This method is typically used when an object (plane or ship) disappears from its route and is used during the initial phase of the search (Figure 12). The search can be carried out along one side of the track, then the return takes place in the opposite direction on the other side (TSR). Searching can also be performed along the planned track, and once on each side; then, the search continues along the route and no longer returns (TSN). This method is easy to plan and implement and is most often used to search for planes because they have a high speed.

Contour search (OS)

This method is used in areas where there is a rapid change in height (Figure 13).

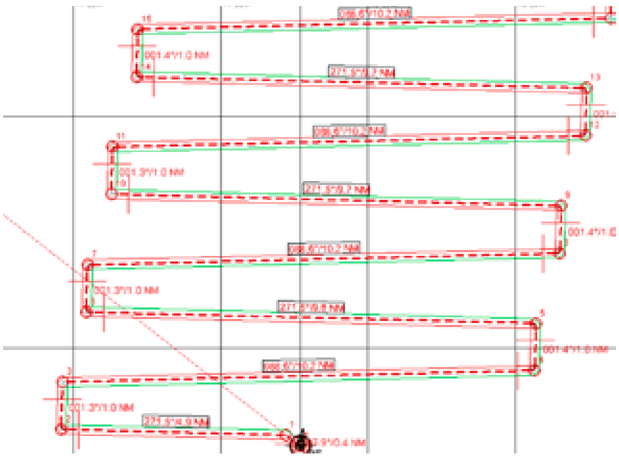

Figure 13. Contour search

The research scheme Selecting

In the simulated SAR action, the following search formulas were selected (Figure 14):
- ship SAR – VS,
- ship SAR – VS,
- helicopter EC-145 – PS,
- helicopter BK-117 – PS.

Monte Carlo simulations were used in the SAR module (Figure 15) because this method can be used to determine which areas to search for an object when there are many independent random variables.

The information about the planned operation is displayed in the main window. The SAR report is presented in the *Rescue Operation Report* window to provide basic information about the planned search (Figure 16).

Assessing the probabilities of object detection and successful SAR action

To calculate the POD (Probability of Detection) and POS (Probability of Success), the program includes the information in the Annexes (L, M, N) in the IAMSAR Manual Volume II "Mission

Figure 12. Track line search

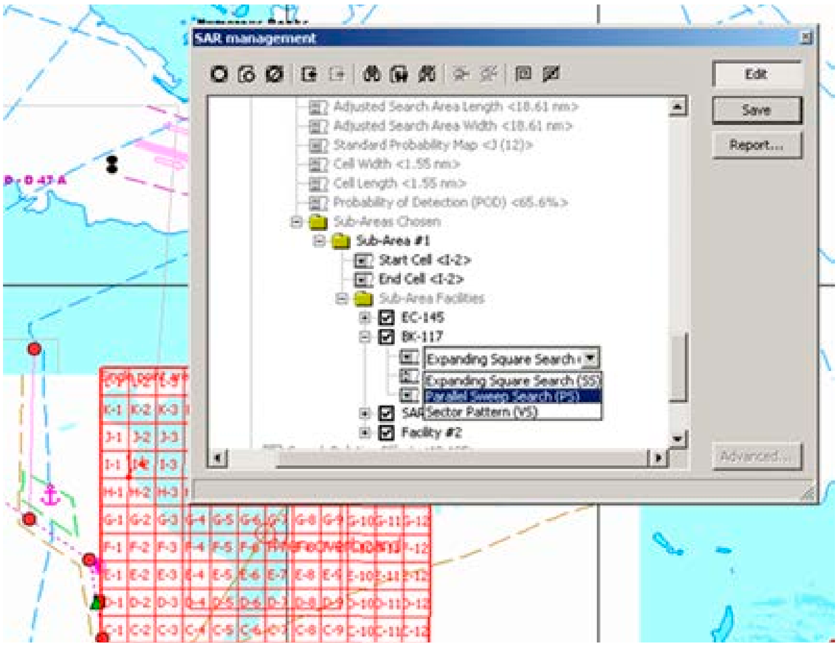

Figure 14. The choice of prospecting methods

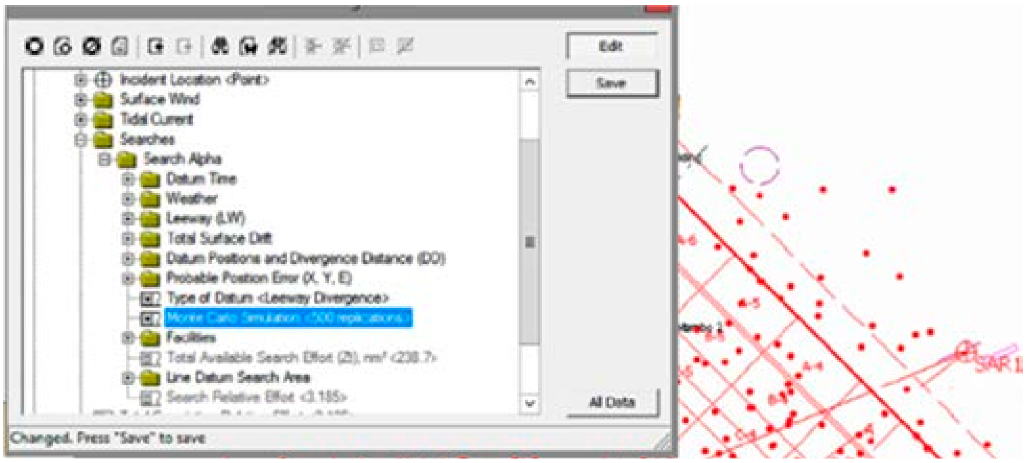

Figure 15. Application of the Monte Carlo method

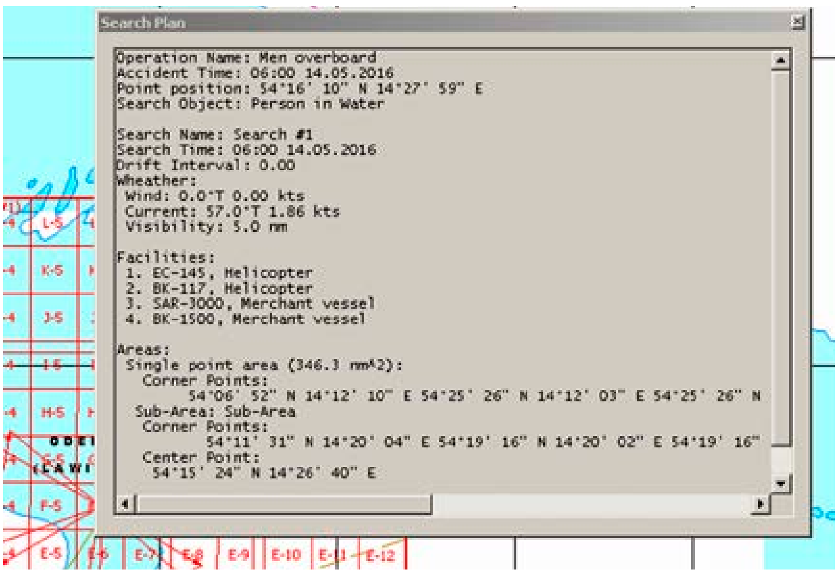

Figure 16. SAR Rescue Operation Report window

Coordination”. This makes it possible to estimate the POD of an object from graph N-10, as stated in the IAMSAR Volume II, and based on graph N-11, to determine the POS of an action.

POD is the probability of detecting an object located within the exploration area and depends on the coverage of the exploration area ratio, the observation method, and the search conditions. The coverage ratio of the area was automatically calculated by the program (1.293). For the conducted simulation, the program automatically calculated the probability of detecting an object; the POD equalled 89.7% (Figure 17).

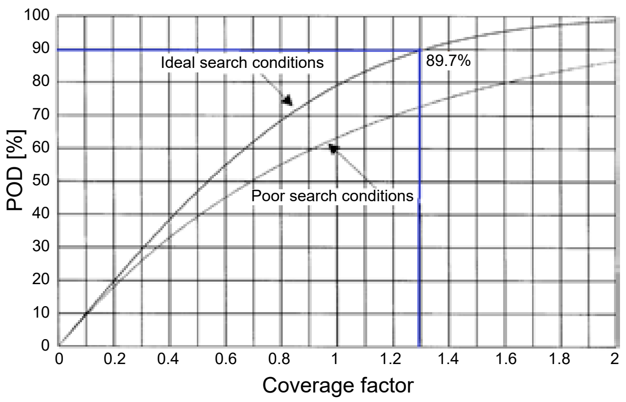

Figure 17. Average probabilities of detection (POD) over an area for visual searches using parallel sweeps (IMO, 2019a)

Based on previously-entered data, the program automatically calculates the value of the cumulative effort of Cumulative Relative Effort (ZRC), which is the sum of all previous efforts and the next scheduled search. The value was 8.296, which allows the POS to be calculated (IMO, 2019a). POS is the probability of finding an object in a certain search time and amounted to 68.8% (Figure 18).

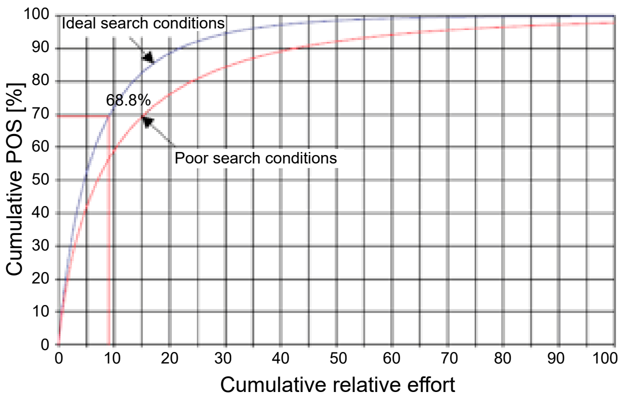

Figure 18. Cumulative probability of success for optimal searches of a datum (IMO, 2019a)

Rescue action planning

The following block diagram for the VTS operator receiving the distress message was developed based on the rescue operation using the SAR module (Figure 19).

Conclusions

Search and rescue operations can be divided into three stages: defining the search area, choosing the rescue resources, and determining the search routes. SAR action parameters continuously change during each of the subsequent stages. A SAR action planning algorithm was created based on the many established schemes, and it divided actions into three stages. Despite the best preparedness, planning a rescue operation was fraught with difficulties that influenced the SAR plan’s effectiveness. The action effectiveness primarily depended on the accuracy of the received information, the time elapsed, and the on-scene conditions.

Weather conditions and time of day affected the outcome of the coordinator’s decision. The operator must decide on the specific search methods, the size of the search area, and the proper selection of the forces and resources assigned to the action.

The SAR module of the Navi-Harbour system makes it possible to quickly plan an action (especially if there is an available database of rescue resources and units, which accelerates their selection), as well as the modification of individual action parameters.

The program calculates the probability of the detection of the searched-for item and information about the effectiveness of the planned action. This permits a quick analysis of the selection of units involved in the action by simulating several available options, and the configuration of resources that will provide the greatest probability of success.

Since the coordination of actions occurs under stressful conditions, and decisions should be taken quickly, the VTS operators must be fluent in its use. Thus, periodic retraining is required in this area, since functions rarely used in everyday practice tend to become somewhat alien to potential users. Most significantly, the use of the tools described in this paper represent the ability to convert processed information into time-saving, and thus life and environment-saving, operations.

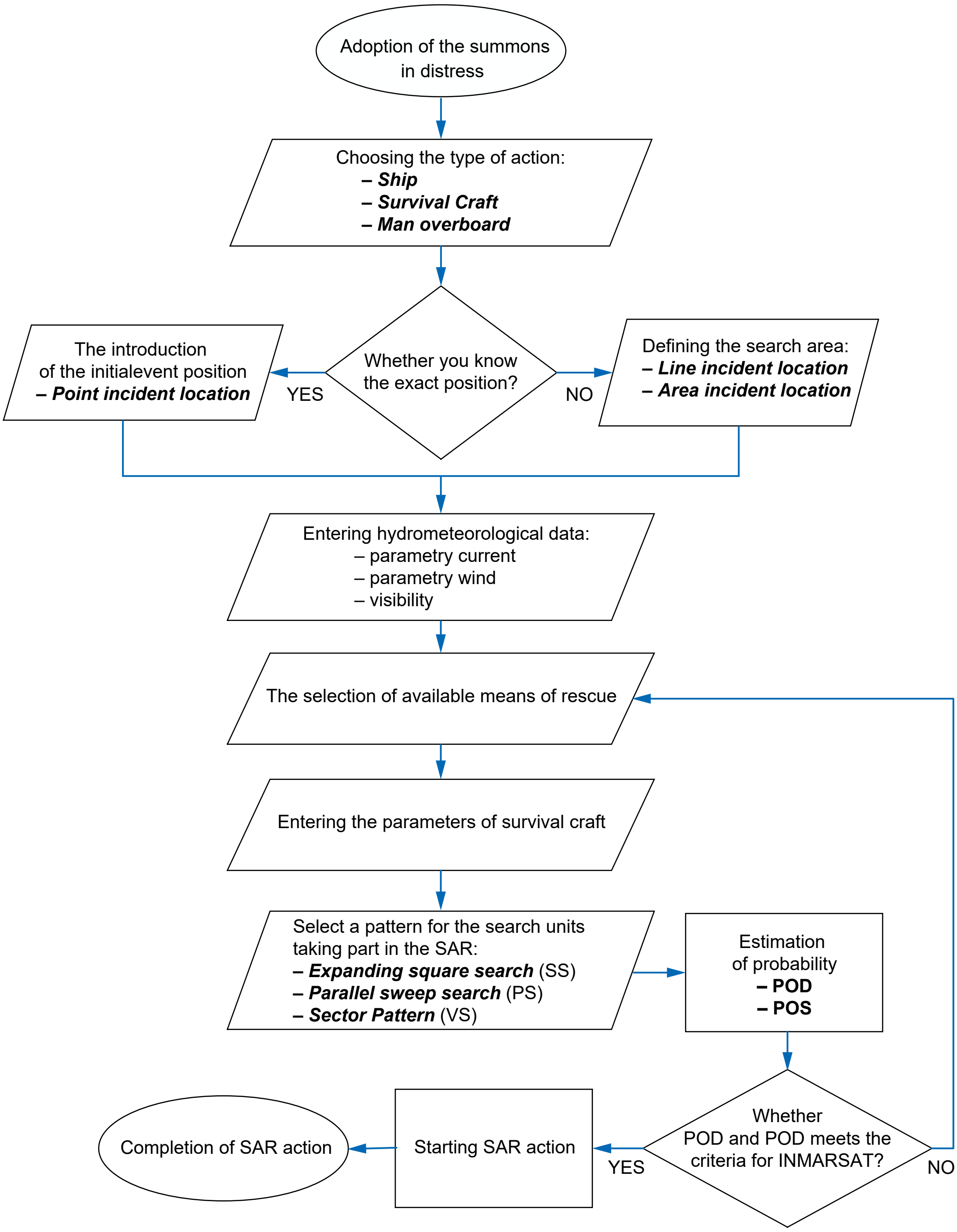

Figure 19. The block diagram of rescue action planning

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