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An Adaptation of an Algorithm of Search and Rescue Operations to Ship Manoeuvrability

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ABSTRACT: This article presents an overview of an algorithm to facilitate action when planning search and rescue operations, taking into account actual hydro-meteorological conditions and the maneuverability of ships involved in the search.

1 INTRODUCTION

Under provisions of international law and humanitarian considerations, ship masters are obliged to assist others in distress at sea whenever they can safely do so. The specific obligations arising from the international conventions:
- International Convention on Marine Search and Rescue;
- Regulation V/10 of the International Convention for the safety of Life at Sea, SOLAS 1974.

In 1998, based on the above regulations, the International Aeronautical and Maritime Search and Rescue Manual for Mobile Facilities (IAMSAR 2005) was developed. All officers must be familiar with its contents and be regularly trained. The manual is intended to be carried aboard every bridge. It contains the standard methods and procedures for searching, and principles of cooperation and coordination in various circumstances. However, in the stressful situations commonly encountered during SAR action, it would be useful to provide a ship's master with more modern tools for decision-making. This could be, for example, a simple algorithm that you could use in conjunction with the available data to develop an SAR action plan.

2 THE SAR ACTION ALGORITHM

The proposed algorithm is a tool whose task is to integrate one different sources of information. The final effect should be the most optimal search scheme.

Input items can be divided into two groups. The first are individual manoeuvring characteristics and bathymetric information obtained from ECDIS.

The second group are the variable elements. These are the hydro-meteorological conditions prevailing in the area;
- The observed wind speed and direction. This can be estimated by observation when approaching the place of action;
- The total water currents – these values are in the database or ECDIS (Electronic Chart Display and Information System), or provided on traditional navigation maps;

For search action to be effective there must be a pre-planned search pattern. It will be necessary to establish the starting point of the action or geographic references for the area to be searched. The following factors should be considered:

– The reported position and time of the SAR incident;
– The type of search object;
  – Person in water – not drifting in the wind, only in currents;
  – Life raft – the drift depends on the use of a ballast system or drogue. Several types of life raft should be considered (e.g. for 4, 6, 15 and 25 persons);
  – Boats – different sizes (e.g. < 5, 7, 12, and 24 m);
  – Others.
– The maximum speed at which the search vessel can proceed to the reference point in the current hydro-meteorological conditions."

The datum position is found by moving from the incident position or last computed datum position, using the drift distance in the drift direction and plotting the resulting position on a suitable chart. The type of object will determine the total drift. Values for different kinds of search object, depending on wind speeds, are given in the form of graphs in the IAMSAR manual.

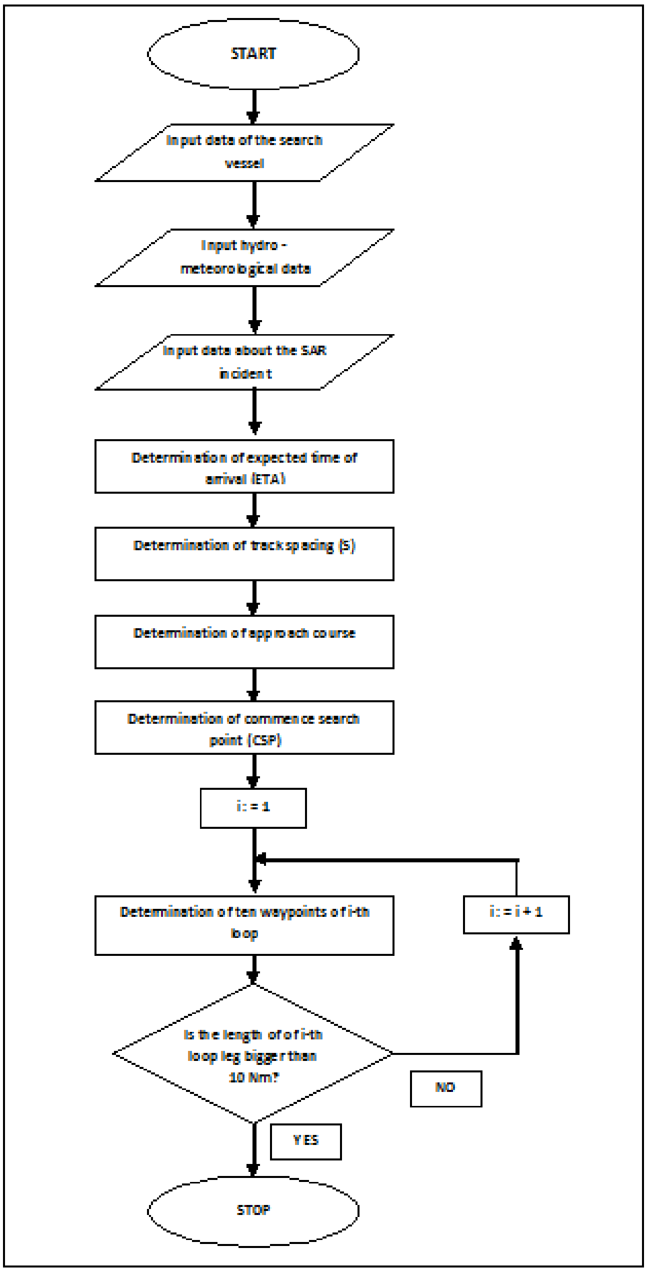

Figure 1. The SAR action algorithm

Note that the algorithm works with the ECDIS system and very easily takes into account tidal currents, whose strength and direction vary according to the date and time of the incident and duration of the rescue operation.

3 INFLUENCE OF HYDRO-METEOROLOGICAL CONDITIONS ON THE PLANNING OF SAR ACTION

Because the impact of hydro-meteorological conditions and ship maneuverability are similar, the Expanding Square Search method will be discussed in detail as a general principle for all three methods.

Using the algorithm in accordance with the guidelines of the IAMSAR manual, we derive:
– The search start point and ETA at this point;
– The most probable search area;
– The first search leg, which is usually oriented directly into the wind;
– The recommended track spacing for merchant vessels.

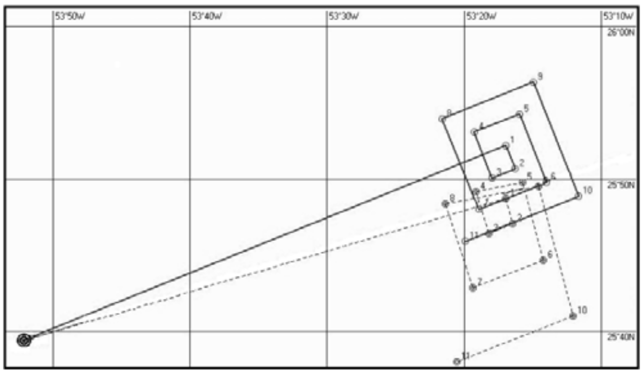

Figure 2. Diagram of Expanding Square Search taking into account the hydro-meteorological conditions
[*source: simulator TRANSAS ECDIS 3000-i*]

The database of ENC (Electronic Navigational Chart, part of ECDIS) maps, and the Electronic Chart Display and Information System provide full information about the currents, allowing more accurate navigation. The transformation of the standard method using an algorithm that calculates the impact of hydro-meteorological conditions gives some interesting results. The solid line in Fig. 2 indicates the search method assuming:
– no impact of hydro-meteorological conditions;
– the distance from the present ship position to the search start point is 33 NM;
– the search object is a six-person life raft with drogue;
– the ship's maximum speed is 10 kn;
– visibility is 5 NM;
– the search area is limited to a square with sides of 10 NM.

The algorithm used to simulate the forming part of TRANSAS ECDIS 3000-i takes into account the drift direction and speed, and the maneuvering speed of the ship. In the following simulation additional parameters to the standard search are assumed:
– Drift is 180º/1 kn;
– The maneuvering speed of the ship is 8 kn.

We get a new method of exploration marked by the dotted line in Fig. 2:
– A new search start point (1);
– New waypoints (2–10), courses and distance in each leg.

By comparing the two diagrams, we can see that the actual search area is very different from the diagram without additional data. The common area is a search area of less than 50 per cent.

The analyzed algorithm takes into account some hydro-meteorological parameters but does not include ship maneuverability (except for maneuvering speed).

4 INFLUENCE OF SHIP MANOEUVRABILITY ON THE PLANNING OF SAR ACTION

Each ship has individual maneuvering characteristics. Differences may even occur among sister ships – let alone vessels of various types, sizes, construction – caused by, for example, the location of superstructures along the hull resulting in a different reaction to a side wind. In addition, issues come with drive and control: the types and number of rudders, propellers, additional equipment (e.g. thrusters). Additionally, a ship with a classic right- -handed propeller will be maneuvered differently from one with a right-handed pitch propeller. Therefore, it will turn to the right or to the left differently. The turning circle is also dependent on variables such as loading conditions and rudder angle.

According to international regulations contained in resolution A.751(18), 1993, Interim Standards for Ship Maneuverability, each ship with a length of 100 m or more, as well as chemical tankers and LPG tankers built after 1994, must have certain maneuvering standards. In practice, maneuvering standards are known to all ships, as they allow for safe operation.

From the point of view of course alterations during SAR action, in addition to maneuvering speed, the only significant parameter that should be considered is turning ability. According to the rules, the turning ability of the ship is considered satisfactory if the advance does not exceed 4.5 ship lengths, and the tactical diameter does not exceed five ship lengths, both to the right or left, at a rudder angle of 35 degrees.

In the case of a ship of length 200 m, the diameter of the acceptable theoretical turning circle is thus approximately 800–1000 m. In the case of a specific vessel (e.g. type B 517/2), the minimum turning circle diameter is approximately 600 m, which corresponds to three ship lengths. However, it should be noted that this is the diameter of the fixed turning circle, which is measured in a situation when the ship is already moving in a circle. If the ship has to change course by approximately 90 degrees from its position when moving along a fixed course, this is a very important parameter defined as *advance*. This describes the distance a vessel will continue to travel ahead on her original course while engaged in a turning maneuver. It is measured from that point at which the rudder is placed hard over, to when the vessel arrives on a new course 90 degrees from the original.

After the rudder is turned, a ship does not immediately adopt a circular, due to the inertia related to the mass of the vessel. The ship makes additional headway until it adopts a circular course in a predetermined direction (Fig. 3).

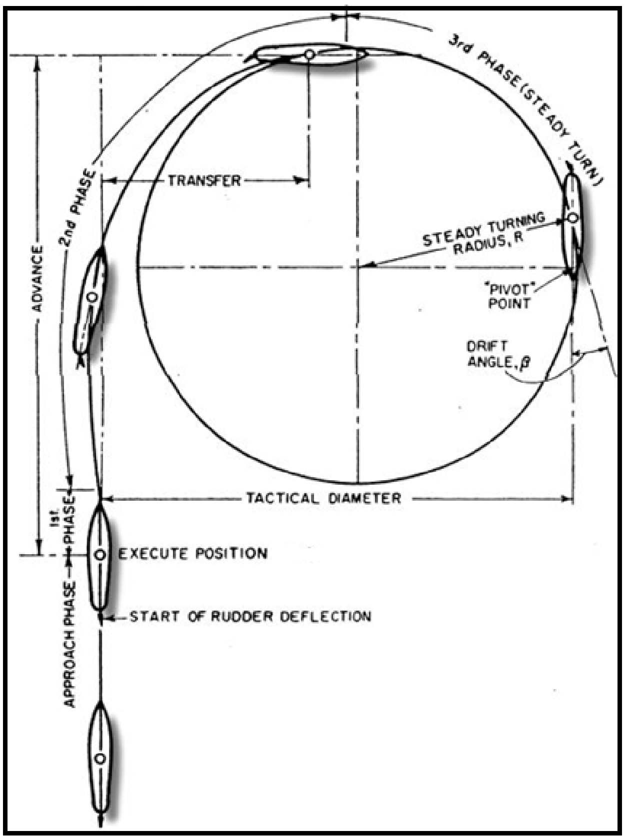

Figure 3. Ship manoeuvring parameters
[*source: http://www. titanicology.com*]

Disregarding advance during an SAR action may result in two problems, particularly in the first legs of the spiral.

The **first problem** is that the ship will not be able to physically perform the maneuver. The calculated route between two waypoints will be too short for the execution of two changes of course (Fig. 4).

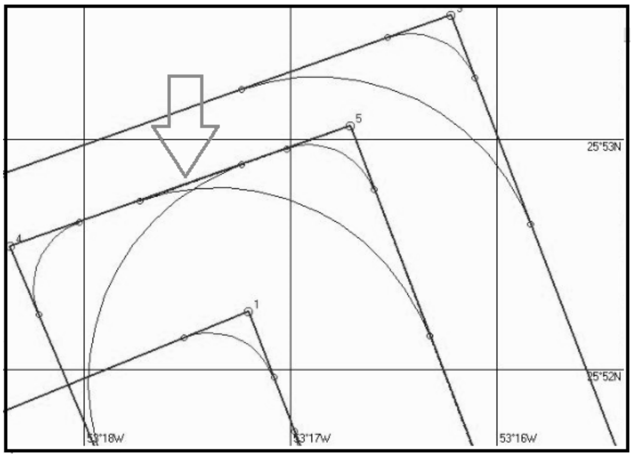

Figure 3. The place where the execution of the next course alteration is impossible
[*source: simulator TRANSAS ECDIS 3000-i*]

Conflicting assumptions about search patterns contained in the IAMSAR manual and the maneuverability of ships exist due to the fact that the manual has been developed as a universal source for rescue units, war ships and aircraft, which have better turning ability. However, it is noted in the manual on page 183 that it is difficult for aircraft to fly a leg close to datum if it is less than 2 NM. A similar situation applies to ships. The only appropriate solution taking into account maneuverability is to extend certain legs and inform the operator of this as soon as possible.

The **second problem** is the increased difficulty of detecting the search object. We should take into account the shifting of individual legs as a result of the impact of hydro-meteorological conditions. Changing their parameters, taking into account maneuverability, the distance between the legs of the spiral is increased to a value exceeding the recommended track spacing, thus making it more difficult to detect the search object (marked area). Earlier course alterations (dashed line) can avoid this and allow a thorough search.

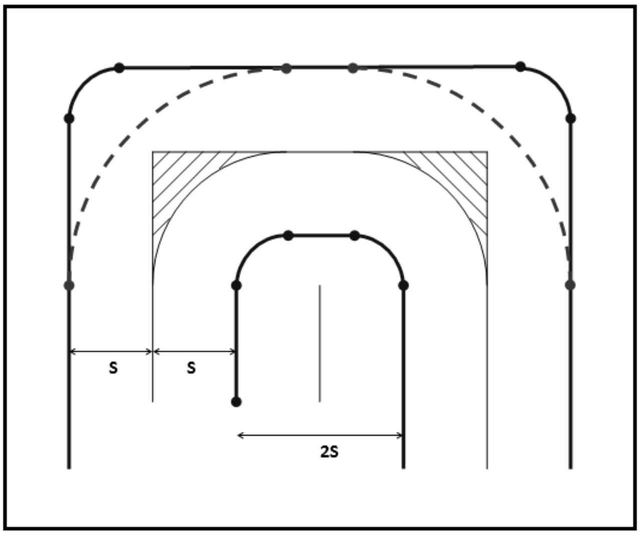

Figure 5. Blind sectors and a solution to the problem

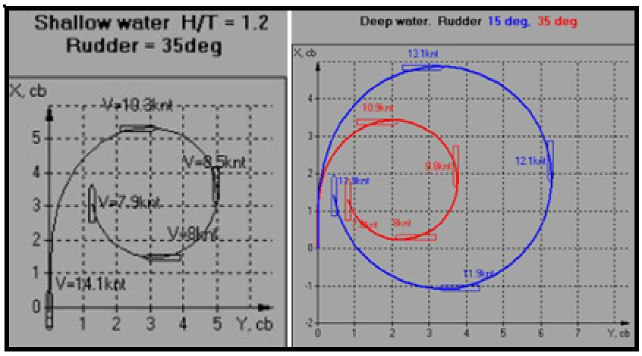

Figure 6. Effect of shallow water on the ship maneuvering parameters at initial speed 16 kn.
[*source: simulator TRANSAS ECDIS 3000-i*]

The maneuvering speed that the algorithm should take into account during calculations is related to the ship's maneuverability in shallow water. Shallow water is the area whose depth is limited to that which does not affect the wave generated by the vessel. A clear, noticeable effect on the maneuverability of the vessel occurs at a depth of about 2–2.5 times the draft. In the ECDIS system, the operator declares draft to determine safety parameters such as safety depth or safety contour. ENC data contains information about the available depth. Therefore, the algorithm can take into account the impact of shallow water during calculations.

5 CONCLUSION

The modern application of security regulations should be proactive, providing the ability to predict and anticipate events, a role that can be used as an algorithm for planning search and rescue action and working with the ECDIS system, and include an option for adaptation to an individual ship. So, it must solve three basic problems:
- the impact of weather conditions and their changes over time;
- The impact of ship maneuverability;
- Integration with other systems supporting navigation.

In addition, it should be simple and intuitive to use, so that the operator can successfully use it without special training. The input and output data should be presented in a form satisfactorily comprehensible to operators and provide convincing arguments to take specific actions.

The use of such a method does not involve high costs, but does bring long-term benefits. The new algorithm can be used throughout the life of the vessel.

The proposed system integrates existing and operated components. The combination of several elements into one should translate directly into shorter time to assess the situation, and thus directly to increased safety of navigation and efficiency of search and rescue action.

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