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The Ship's Navigation Function, Ship's Navigation Processes, and Ship's Navigational Information

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This paper discusses the ship's navigation function, navigation processes, and navigational information. The relationship between these concepts and their substance are analysed in depth. However, the primary aim of this paper is to consider how the various types of navigational information and their content might be brought together in a logically defined structure as a Ship's Information System.

KEY WORDS

1. Marine Navigation. 2. Data and Information. 3. ECDIS.

1. INTRODUCTION. Today's professional journals and periodicals dealing with navigation present mainly the technological and operational aspects of maritime navigation. However, the authors' intention is to present the process of maritime navigation as a kind of logical structure of functions and information, i.e. a coherent, information process. Gathering, storing, up-dating, retrieving, processing, displaying, monitoring and controlling the flow of required navigational information, i.e. the various types and their values, constitutes the essence of the process of safe and efficient conduct of ships at sea. Therefore, a study of the ship's navigational information and its inter-relationships is the main substance of this paper.

The following aspects are presented: ships' assignment and ship's functions; the navigation function and navigation process; navigational information, its quality and its main components; standard navigational information, measurements and observations and their part in the realization of the navigation process.

2. THE SHIP'S ASSIGNMENT AND SHIP'S BASIC FUNCTIONS. Each kind of ship, defined by her class and type, has her own assignment to fulfil. The assignment is defined by the set of required tasks and missions for which realization the ship is built, equipped and her crew is trained. There are many different kinds of transport, naval, industrial and special ships and other sea-going craft that have their own particular assignments to fulfil.

The ship's assignment function is achieved by means of some defined functions or activities. The STCW Convention defines seven ship's functions as:

(a) Navigation,
(b) Cargo handling and stowage,

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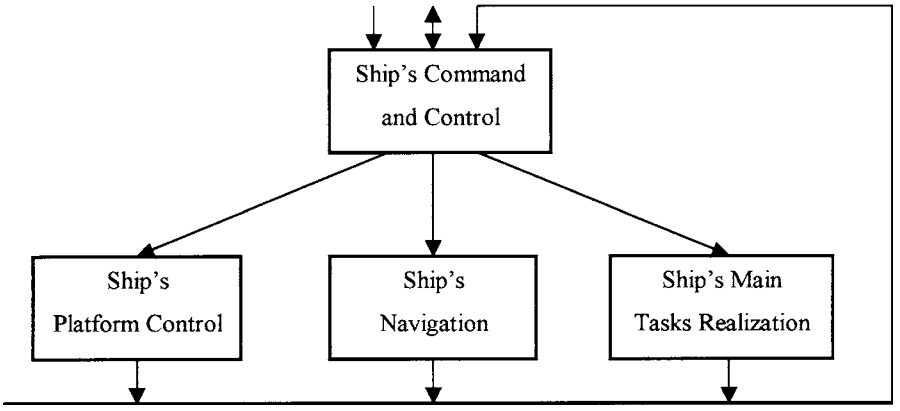


Figure 1. The four ship-operation functions realizing the ship's assignment.

(c) Controlling the operation of ship and care for persons on board,
(d) Marine engineering,
(e) Electrical, electronic and control engineering,
(f) Maintenance and repair,
(g) Radiocommunications.

The STCW Convention concerns mainly commercial transport ships. However, we are going to consider all kinds of ships, including small maritime craft. Therefore, we assume that the assignment function of each ship is being realized by means of the following four functions (Figure 1) with objectives of each defined as shown:

(a) Platform control function:
  (i) maintaining the capability of the ship's propulsion and energy supplies,
  (ii) ensuring the ship's internal (technological and operational) safety, i.e. fire protection, stability, watertight integrity, etc.
(b) Navigation function:
  (i) ensuring the safe and efficient conduct of the ship at sea,
  (ii) providing assistance to ships and/or persons in distress,
  (iii) assisting the function of completing the ship's main tasks (when appropriate).
(c) Main tasks realization function:
  (i) carrying out the tasks resulting from the ship's structure, her equipment and systems, and crew training.
(d) Command and control function:
  (i) maintaining the seaworthiness of the ship,
  (ii) communication and co-operation with shipowner/headquarters,
  (iii) co-ordination of all ship's functions,
  (iv) care of persons on board, including their readiness for using life-saving appliances,
  (v) prevention of pollution of the maritime environment, etc.

3. THE SHIP'S NAVIGATION FUNCTION. The navigation function is achieved in the form of the navigation process, which constitutes the series of

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navigational plans, deeds and activities performed in sequence, recurrently, and according to the navigational events and hazards occurring in the ship's surroundings, in accordance with fixed procedures operated by the bridge team, whose objective is the safe and efficient conduct of the ship at sea.

The navigation process is normally divided into the following sub-processes:

(a) planning the voyage,
(b) steering and manoeuvering and avoiding any dangers,
(c) monitoring the ship's track and surrounding situation and, when necessary,
(d) modifying the track or undertaking any other necessary action,
(e) recording voyage data.

However, the authors suggest dividing the navigation process into nine, more distinct, therefore more evident sub-processes, as expressed by the following conjunction formula and illustrated in Figure 2.

$$\text{nav} = [\text{cin} \wedge \text{vpl} \wedge \text{wea} \wedge \text{ste} \wedge \text{pos} \wedge \text{man} \wedge \text{rde} \wedge \text{mco} \wedge \text{rec}], \quad (1)$$

where:

nav = navigation process,
cin = communication and information, but especially, acquisition, storing, up-dating and retrieving standard navigational information,
vpl = voyage planning,
wea = minimizing the ship's weather losses,
ste = steering the ship,
pos = positioning the ship,
man = manoeuvring and handling the ship, when necessary,
rde = responding to distress signals and navigational emergencies, when necessary,
mco = monitoring and controlling the navigation process, i.e. monitoring the ship's navigational environment and her track; avoiding collisions and groundings; modifying the course, speed and planned track if necessary; and regularly checking the navigational equipment and systems, and safety systems.
rec = recording the ship's voyage data and navigational events.

It should be stressed that the sub-process 'monitoring and controlling' (mco) is the main navigation sub-process while executing a passage. It monitors and controls all the other sub-processes. To a great extent, it is executed by the officer-in-charge of a navigational watch.

The navigation process (nav), as well as each navigation sub-process, can be also expressed by the following formula:

$$\text{nav: (Prin, Stpr)} \rightarrow \text{Napa}, \quad (2)$$

where:

Prin = the primary navigational information,
Stpr = standards and procedures (proper to each particular sub-process) of the information's transformation,
Napa = navigational parameters (information after transformation).

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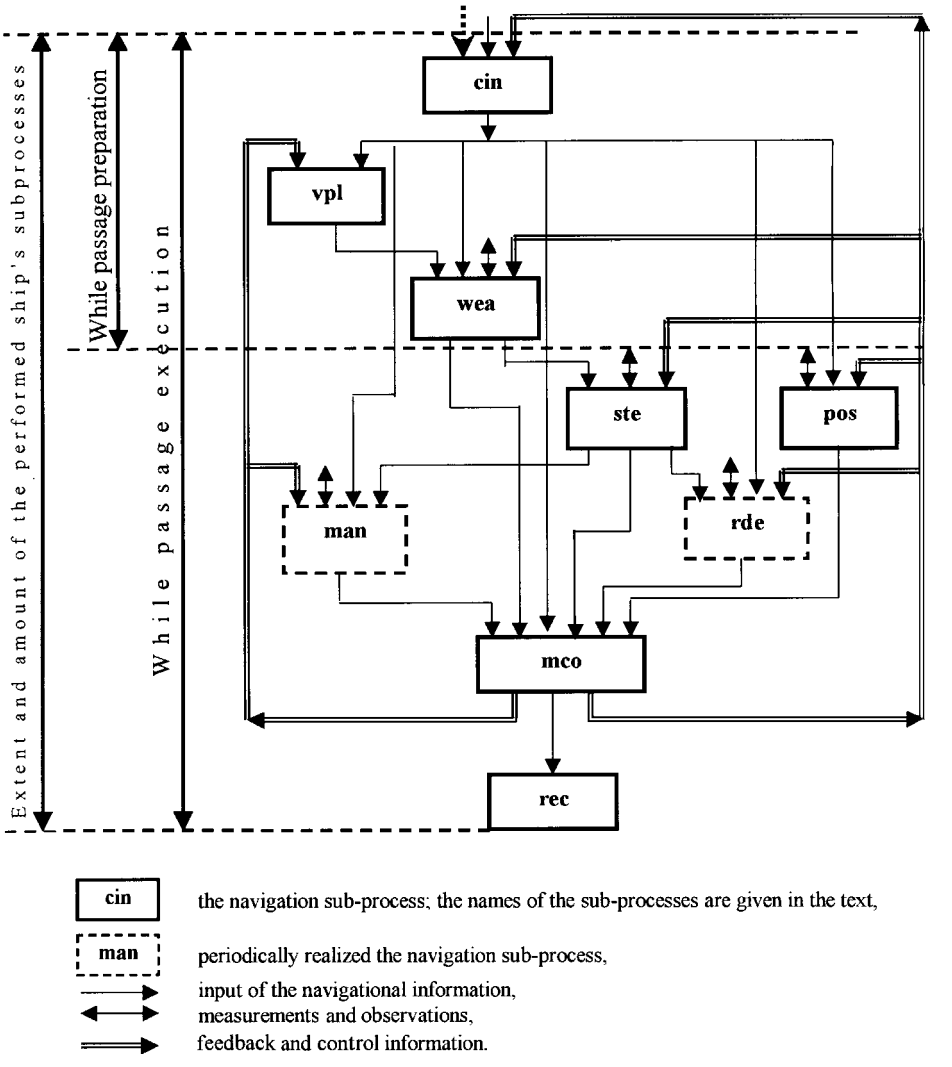


Figure 2. The navigation process and its sub-processes.

The navigation process is performed using the ship's navigation system, by which term we mean: 'the arrangement of all shipborne navigational equipment and systems, properly connected and, where appropriate, integrated in order to enable safe and efficient conduct of the ship at sea'. The necessary sets of the shipborne equipment and systems, constituting the ship's navigation systems, are defined in the Chapter V of SOLAS Convention.

It should also be stressed that the ship's navigation systems are becoming more and more integrated and performing more of the other functions of the ship (Figure 1). This is particularly true with the latest integrated control systems (ICS). Integrated Bridge Systems (IBSs), which are already widely used, can be considered as the early variant of the ICSs. Integrated Bridge Systems allow not only all the navigation sub-processes to

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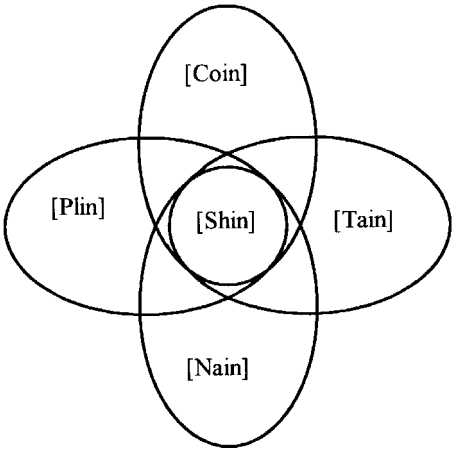


Figure 3. The set of the ship's information and its constituent subsets.

be monitored and controlled but also many sub-processes of other operating processes, such as:

(a) Command and control process,
(b) Platform control process, and
(c) Main tasks realization process.

4. THE SHIP'S NAVIGATIONAL INFORMATION, ITS QUALITY AND ITS MAIN COMPONENTS. The ship's navigational information is a constituent part of the ship's information, which can be expressed by the following formula:

$$[\text{Shin}] = [\text{Coin}, \text{Plin}, \text{Nain}, \text{Tain}], \tag{3}$$

where:

[Shin] = the whole set of ship's information,
[Coin] = command and control information,
[Plin] = platform control information,
[Nain] = navigational information,
[Tain] = information necessary for performing the ship's tasks and missions.

The set of ship's information [Shin] can thus be expressed by the sum of the constituent, mutually inclusive sets (Figure 3).

$$[\text{Shin}] = [\text{Coin}] \vee [\text{Plin}] \vee [\text{Nain}] \vee [\text{Tain}]. \tag{4}$$

The ship's navigational information is the kind of information that describes the whole environment of maritime navigation, i.e.:

(a) geographical environment,
(b) maritime navigation safety system,
(c) own ship (being conducted at sea),
(d) surrounding shipping traffic.

The ship's navigational information should meet some defined requirements; it should be: adequate, comprehensive, timely acquired, updated, and easy to gather,

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store, retrieve and display in the most suitable form for use in the navigation process.

Navigational information [Nain] can be divided into two main types: standard navigational information [Stin], and measurements and observations [Meob]. This statement can be expressed as follows:

$$[\text{Nain}] = [\text{Stin, Meob}]. \tag{5}$$

Standard navigational information is the information that is acquired from external sources. Such information is received both while voyage planning and executing the voyage. Measurements and observations are information obtained from the ship's own navigational sensors (Figure 2).

5. STANDARD NAVIGATIONAL INFORMATION, TYPES AND CONTENT. It was stated above that the ship's navigational information describes the whole environment of maritime navigation. This is true; however, the practice of using this information necessitates transforming it into the following kinds of standard navigational information, i.e.:

(a) information describing own ship and her navigational characteristics [Ship],
(b) information describing the geographical and navigational environment [Envi],
(c) information describing the operational environment [Oper],
(d) information describing the legal environment [Lega].

The above can be expressed as follows:

$$[\text{Stin}] = [\text{Ship, Envi, Oper, Lega}]. \tag{6}$$

The ship's information [Ship] must include: dimensions [Dime], stability characteristics [Stab], manoeuvering characteristics [Mane], sea-going characteristics [Sego], characteristics and parameters of the navigational equipment and systems [Eqsy], giving the expression:

$$[\text{Ship}] = [\text{Dime, Stab, Mane, Sego, Eqsy}]. \tag{7}$$

The set of the geographical and navigational environment information [Envi] must contain: chart information, i.e. the information that constitutes the content of paper navigational charts and nautical publications or content of the databases of the electronic navigational charts [Char], maritime safety information that updates the chart information, disseminated by the GMDSS (Global Maritime Distress and Safety System) [Msin], long-term weather information for minimizing adverse weather losses (Figure 2) [Ltin], giving the expression:

$$[\text{Envi}] = [\text{Char, Msin, Ltin}]. \tag{8}$$

The set of the chart information [Char] can be expressed as follows:

$$[\text{Char}] = [\text{Hrol, Hgra, Infr}], \tag{9}$$

where: [Hrol] stands for the hydro-meteorological information, [Hgra] stands for the hydrographical information, and [Infr] stands for the navigation infrastructure information.

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The set of the hydro-meteorological information [Hrol] can be expressed as follows:

$$[\text{Hrol}] = [\text{Clim, Ocea}], \tag{10}$$

where: [Clim] stands for the average values describing the sea climate, [Ocea] stands for the seawater parameters of importance for maritime navigation.

The set of hydrographical information [Hgra] can be expressed as follows:

$$[\text{Hgra}] = [\text{Dept, Isob, Grou, Obst, Tide, Curr, Vari, Topo}], \tag{11}$$

where: [Dept] stands for the sea depths (soundings), [Isob] stands for the isobaths, [Grou] stands for the kinds of bottom grounds, [Obst] stands for the ship wrecks and other kinds of fixed obstacles, [Tide] stands for sea-tide parameters, [Curr] stand for sea-current parameters, [Vari] stands for magnetic variation, and [Topo] stands for the topographical elements and features of importance for maritime navigation.

The set of navigation infrastructure information [Infr] can be expressed as follows:

$$[\text{Infr}] = [\text{Ways, Aids, Assi}], \tag{12}$$

where: [Ways] stands for characteristics of the seaways and manoeuvring areas (fairways, artificial canals, anchorages, passing areas, etc.), [Aids] stands for characteristics of aids to navigation (floating and fixed sea marks, land- and space-based electronic position-fixing systems, etc.), and [Assi] stands for characteristics of the traffic – management and navigation – assistance systems (pilot services, traffic separations schemes, ship reporting systems, vessel traffic services, automatic identification systems, etc.). It should be emphasized that each kind of navigation infrastructure information [Infr] must also contain a proper subset of the procedural data (when and where necessary) for navigational use of this information by ships.

The maritime safety information [Msin], being disseminated by the GMDSS, can be expressed as follows:

$$[\text{Msin}] = [\text{Warn, Weat, Sari}], \tag{13}$$

where: [Warn] stands for the navigational warnings, [Weat] stands for weather forecast information, and [Sari] stands for search-and-rescue information.

The long-term weather information [Ltin] (8) is used primarily for ship-weather routing and is disseminated mainly by the ship-routing agencies and some maritime hydro-meteorological offices (Bracknell, Norfolk, Monterey, etc.).

The set of the operational information [Oper] (6) should include: information regarding navigational tasks of ship [Nata], instructions and orders issued by ship's owner or ship's charterer [Orde], the necessary amount of the technological and operational information needed for maintaining and controlling the ship's platform and command and control equipment and systems [Tech], ship-in-distress procedural information (response to navigational emergencies) [Dist], and search-and-rescue procedural information (for assistance of ships and/or persons being in distress) [Sarp], giving the following expression:

$$[\text{Oper}] = [\text{Nata, Orde, Tech, Dist, Sarp}]. \tag{14}$$

The set of the legal information regarding the navigation process [Lega] (6) should include: basic regulations regarding the Law at Sea (United Nation Convention on Law of Sea – UNCLOS III) (territorial waters, prohibited areas, exclusive economic

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zones, right of the harmless passage, etc. in areas of ship's operation) [Uncl], the regulations regarding the international maritime (and navigational) safety, contained in the basic maritime conventions (SOLAS 74, COLREG 72, MARPOL 73/78, STCW 78/95, SAR 79, LL 66, TONNAGE 69, CSC 72, ILO 147 Conventions) [Conv], regional (EU Directives, Convention on the protection of the marine environment of the Baltic Sea area, etc.), national and local (harbour) regulations regarding the maritime safety and marine environment protection [Regu], giving the following expression:

$$[\text{Lega}] = [\text{Uncl, Conv, Regu}]. \tag{15}$$

It should be stressed that maritime geographical information systems, such as ECDIS (Electronic Chart Display and Information System) are now developing rapidly. The main tendency for the further development of these systems is their adaptation to maintain all the information needs of a ship, i.e. not only the need for geographical information. However, the final type of information constitutes now, and will constitute in the future, the main substance of these systems (WECDIS/ ECDIS-N).

6. NAVIGATIONAL MEASUREMENTS AND OBSERVATIONS.

The standard ship's navigational information [Stin], presented above, is sufficient for proper planning of a voyage. However, it is insufficient for safe and efficient conduct of ships at sea. The reasons are:

(a) the constant changes of the hydro-meteorological conditions,
(b) the changes in the operation of the navigational infrastructure (changes of infrastructure elements, procedures, etc.; breaks in operations, and many other reasons),
(c) unknown shipping traffic, especially in confined and constrained waters,
(d) the possibility of unexpected dangers occurring in the ship's surroundings at any moment.

In general, the ship's measurements and observations are necessary for:

(a) activating and maintaining the navigational process accordingly to the planned voyage and received orders,
(b) detecting all the navigational dangers occurring in the ship's surface and sub-surface environment, and counteracting them in a timely and proper manner,
(c) comparison (by monitoring and matching) of to what degree the characteristics of the real geographical and navigational environment suit the expected characteristics.

According to equation (5), the ship's measurements and observations [Meob] can be expressed as follows:

$$[\text{Meob}] = [\text{Meas, Obse}], \tag{16}$$

where: [Meas] = are the ship's measurements, i.e. all the settings and indications of the navigational equipment and systems, such as ship's logs, gyroscopic and magnetic compasses, steering gears, engine room telegraph, propeller revolutions, as well as many other indications of ship's behaviour, etc. (Figure 2); [Obse] = direct audiovisual,

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as well as radar (ARPA), hydro-acoustic and other kinds of observations of the ship's surroundings, carried on by the bridge team (state of weather, sea state, shipping traffic, buoys, depth, wrecks, different obstacles, etc. (Figure 2).

7. CONCLUSIONS. This paper has analysed in detail the ship's navigation function, its navigation process and navigational information. These considerations are based almost exclusively on the performance logic of these processes.

Although the above only briefly mentions the present technological level of development of navigational equipment and systems, and the navigation regulations and requirements in force today, both were taken into account in forming the above statements and conclusions.

The authors' belief is that the logical formalization of the ship's navigation process and its sub-processes is of great importance for education in maritime navigation. Furthermore, such detailed consideration of the ship's navigational information can be useful for further development of the maritime Geographical Information Systems (GIS), but especially for their transformation into Ships Information Systems (SIS).

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