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The Changes in Maritime Navigation and the Competences of Navigators

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The issues in this paper are a continuation of those presented previously by the authors in *The Journal*. In this paper we discuss the changes in maritime navigation and their consequences. We show the changes taking place in the ship's navigation process and in development of Maritime Navigation Safety and Efficiency System (MNSES). The relations between these two processes are examined. As the result, a probable scope of the competencies required by future navigators is proposed.

KEY WORDS

1. Marine Navigation. 2. Safety of Navigation.

1. INTRODUCTION. The safe and efficient navigation of a ship depends upon many factors which include:

- the navigational features of the ship,
- the ship's geographical environment,
- the ship's navigation process,
- Maritime Navigation Safety and Efficiency System.

Our considerations in this paper are limited almost exclusively to the latter two factors. We try to show how and why the ship's navigation process and Maritime Navigation Safety and Efficiency System are being changed together with the related competencies of maritime navigators. Therefore, the first thesis of this paper concerns the ship's navigation process – which is currently expressed as *the process of safe and efficient* ***conduct*** *of a ship at sea* – we propose a change to the process which can be expressed as *the process of safe and efficient* ***operation*** *of a ship at sea*. The second thesis can be expressed as follows: The Maritime Navigation Safety and Efficiency System (MNSES) is further quickly perfected; its role in ensuring the necessary conditions for safe and efficient conduct (operation) of ships at sea is steadily increased; and it, but especially its traffic-management and navigation-assistance systems, begins to participate directly in the navigation process of each particular ship. This paper is structured to discuss the ship's navigation process and its environment in section 2; the changes of today's maritime navigation in section 3; and the probable scope of competencies of future navigators in section 4. The conclusion is presented in section 5.

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2. THE SHIP'S NAVIGATION PROCESS AND ENVIRONMENT.

The ship's navigation process has been already presented in detail (Kopacz, Morgaś, Urbański, 2003). Therefore, we present here a basic overview.

The ship's navigation process is the one of four processes by which a ship's assignment (her main tasks, missions, etc.) is realized. The processes are:

- ship's command and control process,
- ship's platform-control process,
- ship's navigation process,
- ship's tasks realization process (i.e. the tasks defined by the kind, class, and type of the particular ship).

The objective of the ship's navigation process *is the safe and efficient conduct of a ship at sea to meet her assigned tasks*. The content of the ship's navigation process can be expressed as *the operational process, which consists of the series of navigational plans, deeds and activities performed in sequence, recurrently, and in accordance with fixed procedures operated by the master and the officer in charge of the navigation watch and bridge team, by the means of the ship's navigation system, and in response to the navigational or operational events and dangers occurring around the ship*.

The ship's navigation process is composed of several navigational sub-processes, each of which fulfils a specific task and which can be expressed as follows:

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

where:

nav = navigational process,
cin = communication and information,
wea = minimizing weather losses,
pln = voyage (mission) planning,
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 ship's navigation process,
rec = recording the ship's voyage (mission) data and navigational events.

The ship's navigation process is being performed in the ship's navigation environment, portrayed in Figure 1, which comprises:

- geographical environment,
- surrounding ship traffic,
- the Maritime Navigation Safety and Efficiency System.

The Maritime Navigation Safety and Efficiency System shown in Figure 1 is usually called the Maritime Navigation Safety System (Kopacz, Morgaś, Urbański, 2001, 2002). However, this system has for a long time been regarded not only as the Maritime Navigation Safety System but in reality as the Maritime Navigation Safety and Efficiency System. The following reasons corroborate such a statement:

- The system has for many years provided the positioning service which satisfies the needs not only of the requirements of navigational safety but also of

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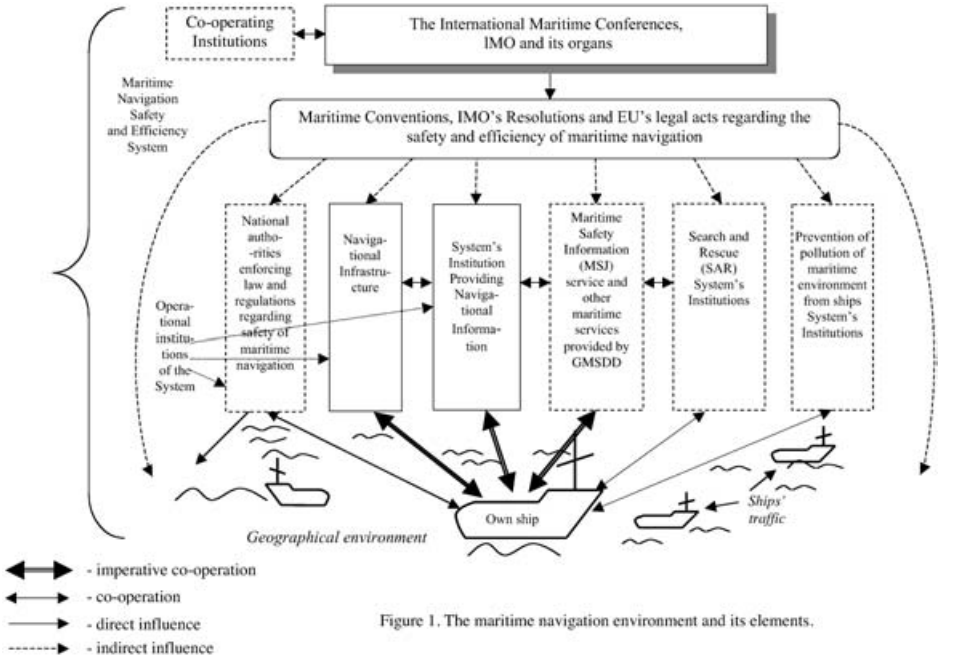


Figure 1. The maritime navigation environment and its elements.

almost all kinds of human activities being performed at sea. This is corroborated by IMO Resolution A. 915 (22) on Revised maritime policy and requirements for future Global Maritime Satellite System (GNSS) and other Resolutions.

– The System's institutions providing navigational information are also able (on payment and/or for authorised users) to provide the geographical information necessary for efficient achievement of most of the ships' tasks being undertaken at sea.

3. THE MAIN CHANGES IN MARITIME NAVIGATION. Progression in maritime navigation (as well as in other kinds of human activities) results mainly from scientific and technological progress. The most important for maritime navigation is the progress in development of the following fields of science and technologies:

– electronics, microelectronics and radio-electronics,
– computer science and informatics,
– applied physics,
– precision engineering,
– automatic control engineering,
– electronic data processing, data transmission and data presentation,
– space technologies, but especially, global positioning and radio-communication technologies.

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The progress in the above fields of sciences and technologies results mainly in:

- the integration of tools, equipment and systems constituting the ship's navigation system into an integrated ship's navigation system, coupled with integration of those systems performing the basic ship processes, into one integrated ship (operation) control system,
- the steady progression of Maritime Navigation Safety and Efficiency System (MNSES), but especially in the further development and perfection of its traffic-monitoring, traffic-management and navigation-assistance systems.

3.1. *The change to the ship's navigation process.* As was stated above, the current state of science and technology progression, especially in the development of modern information technologies, results in the integration of equipment and systems. The integration includes sub-processes and procedures not only in the subject of navigation but also the integration of navigational tools and procedures with those used for the achievement of various other ship processes and functions. However, this does not mean that the navigational sub-processes and procedures are being "absorbed" by sub-processes and procedures needed for realisation of the other ship functions. It is quite different. The sub-processes and procedures which enable the other processes, e.g. platform-control, are being added and integrated with the navigational sub-processes and procedures. The result is that all the sub-processes and procedures form part of the navigation integrated process so that the navigation process is "enriched" by the sub-processes and procedures belonging to the other ship systems. The ship's navigation safety, i.e. the safety against the external dangers towards the ship, such as collisions, groundings, dangerous hydrological and meteorological conditions – is and will remain of paramount importance. This kind of safety can be achieved only as the result of the implementation of a proper ship navigation process.

There are three separate steps involved in the overall integration of the navigation and other ship processes to result in the existence of the ship operation control process. The first is the integration of the ship navigation process, resulting in the creation of the integrated ship navigation system. The second is the integration of the ship navigation process with the sub-processes of the other ship systems. This has resulted in the creation of the Integrated Bridge System (IBS). We may expect that the third step will be further system integration and within a few years the Integrated Ship's (Operation) Control System will be deployed. Such systems are now being developed (Kopacz, Morgaś, Urbański, 1999). Figure 2 shows the three integration steps of the navigation process with other basic processes to form the ship operation control process.

An analysis of the ship basic process objectives together with an analysis of the characteristics and operational possibilities of existing Integrated Bridge Systems leads to the conclusion that these systems incorporating all the navigational sub-processes shown by expression (1), can also affect the sub-processes of the remaining ship basic processes which are shown in Table 1. The discussion above leads to the following conclusions:

- the ship navigation process is being integrated with other basic ship processes to become one overall ship operation (navigation) process,

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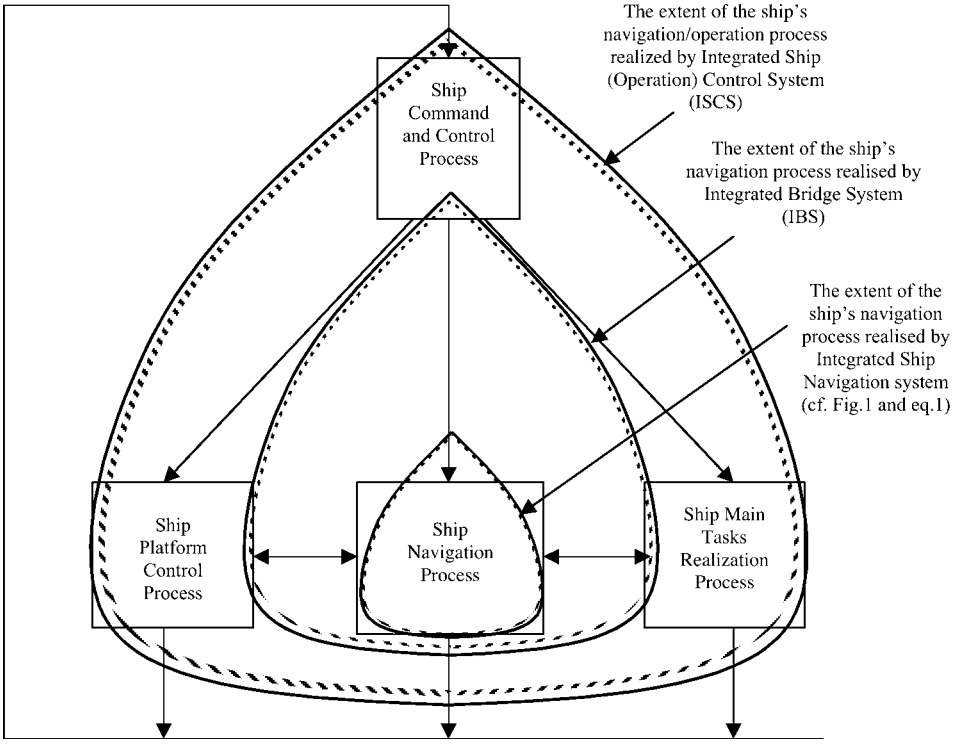


Figure 2. The extent of ship's navigation/operation process for three levels of ship system integration.

– the main objective and the content of the future ship navigation process (ship operation control process) will be safe and efficient operation of a ship at sea.

3.2. *The Changes in Maritime Navigation Safety and Efficiency System.* The Maritime Navigation Safety and Efficiency System (MNSES) has been presented in detail in our papers Kopacz, Morgaś, Urbański, 2001, 2002. They make it clear that the main objective of the MNSES is to create and maintain the conditions necessary to ensure the safe and efficient conduct (operation) of all ships at sea, and to enforce the related laws and rules on all users of the sea. Every ship, in the process of her safe and efficient conduct (operation) at sea, is exploiting the conditions created by the MNSES for all ships. There are many factors which force the further development and perfection of the MNSES. These include:

– the danger of marine environment pollution from ships, especially those which carry dangerous goods (crude oil, gas, etc.), is still very high,
– there is a steady growth in the numbers of ships and maritime craft, especially recreational and sports craft and this results in an increased of danger of collisions, groundings, etc.
– there is a steady increase in the fixed objects at sea being created by the exploitation industries (pipe lines, drilling towers, etc.),

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Table 1. The sub-processes performed by the Integrated Bridge System (IBS).

No	The sub-processes of the ship's basic processes
	Ship platform-control process
1	Operate the propulsion plant remote controls
2	Monitor and operate the energy supply and auxiliary machinery
3	Monitor fire prevention protection systems and, when necessary, activate the fire fighting systems and crew alarm
4	Monitor the ship's stability
5	Monitor the watertight integrity
…	and others
	Ship command and control process
1	Maintain radio-communication services
2	Operate intercommunication system (INTERCOM)
3	Monitor the safety and security of persons on board; readiness for use of live saving appliances; and response to "man overboard"
4	Monitor and prevent maritime environment from pollution
…	and others
	Ship main tasks realization process
	a) transport vessels
1	Monitor safety and security measures while loading and discharging cargo
2	Monitor the cargo and maintain correct storage conditions in holds and on deck
	b) combat vessels
1	Maintain air, surface and underwater observation
2	Detect, track, identify and target the correct dangers/targets
3	In extreme situations, weapon deployment
…	and others

– there is a steady growth in human activities being carried out at sea, especially in Exclusive Economical Zones (EEZ) and in coastal areas,
– there is still a very high level of accidents at sea which result from human factors.

The following factors enable and guarantee further improvements to the MNSES:

– further development of global and reliable radio-communication systems,
– further improvements to and the extension of, global positioning systems,
– further improvements to electronic data processing, transmission, display and recording technologies,
– further development and improvements to the INTERNET and other public means of global communication.

These factors result in further development and improvement to MNSES generally, but particularly in the development of navigational infrastructure. The most characteristic features of MNSES development are improvements to the local traffic-management and navigation-assistance systems and the development of regional and international traffic monitoring and traffic-management systems.

One of the characteristic features of today's maritime navigation development is the steady increase in dependence of the ship navigation processes upon the MNSES. Maritime navigation, even at the beginning, was dependent upon the coastal navigational infrastructure (lighthouses, fires, buoys, beacons, etc.). The dependence

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of ship navigation upon the coastal navigational infrastructure has increased rapidly since the deployment of radio at sea. Besides the navigational infrastructure, many institutions that provide ships at sea with standard navigational information have come into being. (See Figure 1). The deployment of GMDSS was a further large step which increased the dependence of a ship's navigation process upon the MNSES.

We are now witnessing further very important increases in dependence of the ship navigation process upon the MNSES. This increase manifests itself in the rapid development of the ship-traffic and navigation-assistance systems such as: Ships Routing Systems, Ships Reporting Systems (SRS), Vessel Traffic Services (VTS), Automatic Identification Systems (AIS) and others. In addition to local systems, regional and even international traffic-management and traffic monitoring systems are being developed.

Taking all the above into consideration we can conclude that we have to deal not only with the further increase of dependence on MNSES of the ship navigation process but we also have to deal with a new kind of dependence, i.e. with the direct "interference" of the MNSES, especially its traffic-monitoring and traffic-management systems, in the navigation processes of particular ships. It is likely that this "interference" of the MNSES into the navigation processes of particular ships will increase steadily.

4. THE SCOPE OF COMPETENCES FOR FUTURE NAVIGATORS. Before we attempt to formulate the scope of competencies for future navigators, we sum up the recent changes in maritime navigation. Taking into account the above discussion, statements and conclusions, the changes of navigation may be expressed as follows:

- the current ship navigation process defined as "*the process of safe and efficient* ***conduct*** *of a ship at sea*" is being transformed into the ship navigation/operation process which can be defined as "*the process of safe and efficient* ***operation*** *of a ship at sea*",
- the Maritime Navigation Safety System is being transformed into Maritime Navigation Safety and Efficiency System (MNSES) and should be thus named. This System realizes the process (mega-process) of creating and maintaining the conditions necessary for ensuring safe and efficient conduct (operation) of all ships at sea, as well as enforcement of the related laws and rules on all users of the sea,
- the ship navigation/operation process is becoming more dependent on MNSES,
- the ship navigation process is also becoming, to a higher degree, to be controlled not only by the ship's navigator (operator) but also by the operators of the MNSES, especially these who are operating the traffic monitoring, traffic-management, and navigation-assistance systems.

These changes will influence the qualifications of navigators in the future. By the term "future navigators" we mean the ships' deck officers, i.e. ships' operators, who will operate the ships at sea, as well as the specialists employed in maritime coastal institutions dealing with the maritime safety and efficiency issues, i.e. specialists who manage and operate the Maritime Navigation Safety and Efficiency System. The competencies of future navigators are and will be defined by the (steadily amended)

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Table 2. The proposed subject curricula for future navigators.

No	Curricula
1	Core curriculum
2	Navigation/Nautical science curriculum
3	Ship's platform control (marine engineering) curriculum
4	Ship's special tasks realization curriculum
5	Ship's command and control curriculum
6	Maritime-Navigation-Safety–and-Efficiency-System's management and operation curriculum
7	STCW-Certification supplementary curriculum
8	Other supplementary curricula

Table 3. The navigation curriculum.

No	Topics
1	Basic and advanced navigation (terrestrial navigation)
2	Celestial navigation
3	Electronic navigation
4	Radar navigation (including radar and ARPA courses)
5	Hydrometrics and meteorology
6	Seamanship and ship handling
7	Law on sea and basic maritime laws
8	Rules of the Road procedures
9	Response to ship emergencies
10	Response to distress signals at sea
11	Bridge watch-standing

Convention STCW 78/95, as well as by the other IMO legal acts. Nonetheless, we want to express our own opinion and proposals regarding this question.

The proposed education-subjects' curricula of future navigators are shown in Table 2. We discuss only headings 1, 2, 3, and 6 of Table 2, the remaining headings depend in great detail upon the type of ship (merchant, naval, etc.).

(1) The core curriculum should comprise:
- humanities (including foreign languages),
- social sciences (including economics),
- mathematics,
- informatics,
- engineering sciences (applied physics, electronics, automatics, chemistry, hydro-acoustics, etc.).

(2) The curriculum of navigation/nautical science should ensure competencies (knowledge, understanding and proficiencies) in extent not lesser than required by STCW Convention. The teaching topics of this curriculum are shown in Table 3.

(3) Ship platform control (Marine engineering) curriculum should include:
- Ship structure and stability,
- propulsion plant and energy supplying sources and procedures,

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Table 4. The Maritime navigation research areas.

No	The research areas of maritime navigation (Knowledge domains of maritime navigation)
1	Ship navigational characteristics and ship navigation equipment and systems
2	Ship handling methods and procedures
3	Geographical environment and its influence on ship safety and on task achievement efficiency
4	Navigational infrastructure its establishment and maintainance
5	Navigational information and its services, including MSI service
6	Navigational process and sub-processes, their realization modules and systems
7	Maritime navigation legal issues
8	Basic navigational standards, including training, certification and watch-keeping
9	Traffic-management and navigation-assistance systems and procedures
10	Ship-in-distress procedures
11	Response to distress at sea, and ship SAR procedures
12	Ship procedures for prevention of maritime environment pollution
13	Methods and procedures for navigational support of special tasks, industrial works and other activities
14	Issues of integration of ship navigation process with other basic processes into the ship operation process
15	Measures and methods of the navigational evaluation and estimation of the basic elements of the MNSES
16	Process of creation and the maintainence of the necessary conditions to ensure safe and efficient conduct (operation) of ships at sea

- fire fighting and damage control systems,
- operation of the platform control gears and systems, etc.

(6) Maritime-Navigation-Safety–and Efficiency-System's management and operation curriculum:

- International Maritime Organization (IMO), its structure, objectives, tasks and realization procedures,
- Institutions co-operating with IMO (IHO, WMO, IALA, ITU-R, IEC, ISAO, etc.),
- IMO's Conventions, Resolutions, Circulars, etc., their passing and amendment procedures,
- Operational institutions of the Maritime Navigation Safety and Efficiency System (law-enforcement, navigational infrastructure, institutions providing with navigational information, GMDSS and its services, SAR system, prevention of pollution of maritime environment from ships institutions, etc.),
- Requirements regarding navigational services (positioning, information providing, Maritime Safety Information, etc.),
- Measures and methods of evaluation and estimation of "safety of navigation" and "navigation efficiency",
- Means and methods of ensuring safety and efficiency in ports and port-approaches, coastal waters, and in open sea,
- Local (ports, special areas), national (State), regional (Baltic Sea, North Sea, E.U. waters, etc.) and global Maritime Navigation Safety and Efficiency Systems,

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- Operational and economical issues of establishing, maintaining and operating the Maritime Navigation Safety and Efficiency Systems.

The changes of maritime navigation will influence now and in the future not only the education process of future navigators but also the study and research of maritime-navigation problems. We show the basic research areas of maritime navigation in Table 4.

5. CONCLUSIONS. We have presented the most important changes taking place in maritime navigation. The reasons and the results of these changes have been discussed and described. The two most important are that first, the ship navigation process is being transformed into the process of safe and efficient **operation** of a ship at sea. The second important change is the further increase in dependence of the ship navigation process upon MNSES, and that the ship's navigation (operation) process is beginning to be directly controlled not only by the ship's navigator but also by the MNSES operators.

Our considerations also draw the following more general conclusions:

- maritime navigation, considered as a specific kind of knowledge, understanding and proficiencies, is becoming a more integrated knowledge. Besides its main issues, i.e. the issues regarding the ship's navigation operation process, maritime navigation begins, to a greater extent to incorporate the issues of the Maritime Navigation Safety and Efficiency System. It also identifies the means and ways of the process realised by this System, i.e. the process of creating and maintaining the conditions necessary for ensuring the safe and efficient conduct (operation) of all ships at sea, as well as enforcing the related laws and rules on all users of sea. The scopes of competencies, given in last section of this paper, also corroborate this statement,
- the knowledge, understanding and competencies of maritime navigation are also in increasing degree taught, in proper scope, by the operators of MNSES, but especially by the operators of the elements of this System which directly participates in the conduct (operation) of ships at sea,
- maritime navigation, and especially its parts which deal with means and ways of ensuring the safety of navigation of ships at sea, should be taught not only to those operating ships but also to the operational personnel of the MNSES.

The authors are aware that their statements and conclusions may be controversial. However, these statements and conclusions, according to the authors, constitute the logical results from the changes of maritime navigation. Therefore, the authors' belief is that their statements and conclusions may be useful for education as well as for research and development process regarding the maritime navigation.

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