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Remarks on the further development of an integrated navigation system

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Abstract

According to the recommendation of the IMO Resolution MSC.252(83), "Adoption of the revised performance standards for integrated navigation system (INS)", the INS is introduced in order to enhance navigational safety by providing integrated and augmented functions to avoid geographic, traffic and environmental hazards. Its main task is to provide 'added value' for the officer of the watch (OOW), ship's captain and pilot, to plan, monitor or control the navigational safety and progress of the ship. The system should support navigational safety by combining, processing and evaluating inputs from different connected sensors and sources to provide information, giving timely warnings of dangerous situations, system failures and degradation of the integrity of delivered and presented information. An INS is defined as such if workstations provide multifunctional displays integrating at least the following navigational tasks (functions): route monitoring, collision avoidance and alert management. The output data contains a description of the subsystems and devices included in the INS, and the principles of their cooperation and presentation of data, but it does not present recommendations for interfacing the INS with the ship's radio communications equipment or standardised rules of operation by the user and presentation of information. These restrictions limit the possibilities of using this system in e-navigation. This paper identifies the importance of these limitations with respect to the need for further development of INSs, and presents proposals to solve this problem.

Introduction – legal aspects related to the integrated navigation system (INS)

The International Convention for the Safety of Life at Sea (SOLAS) of 1974, as amended, does not require maritime merchant vessels to be fitted with integrated navigational and/or bridge systems. According to the SOLAS Regulations V/18 and V/19.6, they may be installed on ships under the following conditions (IMO, 2014):

- They shall be subject to approval by the ship's flag state administration in accordance with the SOLAS Regulation V/18 and shall, as far as practicable, comply with performance standards not inferior to those defined in the IMO Resolution MSC.64(67) adopted on 4 December 1996, Annex 1, "Performance standard for integrated bridge systems (IBS)", and MSC.86(70) adopted on 8 December 1998, Annex 3, "Performance standard for integrated navigational systems (INS)", or MSC.252(83) adopted on 8 October 2007, "Adoption of the revised performance standards for integrated navigation systems (INS)";
- Integrated bridge systems (IBS) shall be so arranged so that failure of one sub-system is brought to the immediate attention of the officer in charge of the navigational watch (OOW) by audible and visual alarms, and does not cause failure to any other subsystem;
- In case of failure in one part of an integrated navigation system (INS), it shall be possible to operate each other individual item of equipment or part of the system separately;

- Each part of the INS performing functions assigned in the SOLAS Regulation V/19 to a specific piece of equipment or system must meet all IMO performance standards assigned to this piece of equipment or system in the resolutions mentioned in the SOLAS Regulation V/18.

As recommended by the Resolution MSC.252(83), an INS installed on ship on or after (IMO, 2007a):

- 1 January 2011, shall conform to performance standards not inferior to those specified in the Annex to this resolution;
- 1 January 2000 but before 1 January 2011, shall conform to performance standards not inferior to those specified in the Annex 3 to Resolution MSC.86(70).

Recommendation of the IMO Resolution MSC.86(70)

According to the Resolution MSC.86(70), an INS is any combination of navigational aids that provides functions beyond that of the general intent defined in the respective performance standards adopted by the IMO for individual equipment. It shall evaluate inputs from several independent and different sensors and sources, and combine them to provide information giving timely warnings of potential dangers and degradation of integrity of this information. This means that it should provide 'added value' to the functions and information needed by the officer in charge of the navigational watch (OOW) to plan, monitor and/or control the progress of the ship (IMO, 1998).

Integrity means the ability of the system to provide the user with information within a specified accuracy in a timely, complete and unambiguous manner, and alerts the user *via* alarms and indications within a specified time when the system should be used with caution or not at all. Functional integration shall meet the following requirements (IMO, 1998):

- The integrity of information should be checked by comparison of data derived independently from two or more sources if available, and verified before essential information is displayed or used;
- Information with doubtful integrity should be clearly marked and should not to be used for automatic control systems;
- Data latency should be consistent with the data requirements of the individual parts of the system;
- The validity of each part of data shall be checked before its integration;
- A failure of data exchange inside the INS should not affect any independent functionality of the integrated equipment and systems;
- A multifunction display unit shall present information and control redundantly;
- The INS shall request confirmation of the manual inputs that may cause unintended results before their acceptance, thus providing a plausibility check.

The INS shall acquire, process, store and distribute different types of information and data while applying an agreed consistent common reference system. An alarm management system complying, as a minimum, with the recommendation of the IMO Resolution A.830(19) adopted on 23 November 1995, "Code on alarms and indicators", should be provided by the INS.

Resolution MSC.86(70) defines three categories of INS (IMO, 1998):

- Category A for a system providing as a minimum, the information of position, speed, heading and time, each clearly marked with an indication of integrity;
- Category B for a system able, in addition to the functions realised by INS category A, to automatically, continually and graphically indicate the ship's position, speed and heading and, where available, depth, in relation to the planned route as well as to known and detected hazards, and correspondingly able to provide information needed for decision support in avoiding hazards;
- Category C for a system providing means to automatically control heading, track or speed and monitor the performance and status of these controls, in addition to the functions realised by INS category B.

Amendments introduced by the Resolution MSC.252(83)

The purpose of the performance standards defined in this resolution is to support the proper and safe integration of navigational functions and information, to allow the installation and use of an INS on-board ships, instead of stand-alone navigational equipment, and to promote safe procedures for the integration process both for comprehensive integration and partial integration of navigational functions, data and equipment. The INS supplements the functional requirements of the individual performance standards for particular navigational equipment and systems adopted by the IMO. Depending on the position of the ship's flag state

administration, Resolution MSC.252(83) may permit an INS being allowed to substitute for some carriage requirements of navigational equipment, as equivalent to other means under SOLAS Regulation V/19. In this case, the INS should comply with the performance standards mentioned in this resolution, and for the relevant tasks of these performance standards, with the applicable modules of the performance standards for the following navigational equipment: automatic identification system (AIS), electronic chart display and information system (ECDIS), echo sounding system (ESS), electronic position fixing system (EPFS), heading control system (HCS), radar system, speed and distance measuring device (SDMD) and track control system (TCS) (IMO, 2007a).

The described resolution does not change the general definition of an INS. According to its recommendation, the purpose of an INS is to enhance the safety of navigation by providing integrated and augmented functions to avoid geographic, traffic and environmental hazards. It supports safety of navigation by evaluating inputs from several sources, combining and integrating them to provide 'added value' for the operator to plan, monitor and/or control safety of navigation and progress of the ship, and to give them timely alerts of dangerous situations, system failures and degradation of integrity of the presented information. The system shall present timely, correct and unambiguous information to the users, and provide subsystems and subsequent functions within the INS and other connected equipment with this information, also supporting mode and situation awareness (IMO, 2007a).

Resolution MSC.252(83) removes the division of the INS into three categories (A, B and C), distinguishing them instead by the functions (tasks) performed by the system. An INS is defined as such if workstations provide multifunctional displays integrating at least the three following tasks (IMO, 2007a):

- Route monitoring;
- Collision avoidance;
- Alert management.

Additionally, the INS may provide manual and/or automatic navigation control functions, and comprise navigational tasks such as: 'Route planning', 'Navigation control data' and 'Navigation status and data display', including the respective sources, data and displays which are integrated into one navigation system.

As previously (according to the Resolution MSC.86(70)), an INS shall verify the availability, integrity, plausibility and validity of the acquired, combined, processed, evaluated, distributed and presented data. The integrity of information should be checked by comparison of the data derived independently from at least two sensors and/or sources, if available, but an approved back-up should be available for the following INS sensors and sources only (IMO, 2007a):

- EPFS;
- Heading measurement;
- Speed measurement;
- Radar;
- Chart database.

Data which does not pass the plausibility and validity checks with a positive result should not be used by the INS and should not affect functions that are not dependent on these data, unless the relevant performance standards specifically allow use of invalid data.

Available updated electronic navigational charts (ECS) and other navigational databases (tide tables, list of radio signals, *etc.*) should be used as common data sources for an INS. Implementing ship's route planning tasks, the system should allow voyage planning as recommended by the IMO Resolution A.893(21) on Guidelines for voyage planning, and shall provide means for (IMO, 2007a):

- Storage, loading and dissemination of the route plan;
- Checking of the defined (introduced) route plan against hazards based on the planned minimum under keel clearance (UKC) as specified by the mariner and manoeuvring limitations of the ship (allowed turning radius, the maximum value of the rate of turn (ROT), etc.), if available in the INS;
- Drafting and refining the route plan against meteorological information if available in the INS.

In the 'Route monitoring' task, an urgency manoeuvring procedure should be available at the display, taking set and drift into consideration. The display of additional different route-related information on the chart display is permitted, *inter alia* (IMO, 2007a):

- Tracked radar targets and AIS objects;
- Received safety related messages – so-called maritime safety information (MSI), such as AIS safety-related and binary messages and warnings received by NAVTEX;
- Initiation and monitoring of man-over-board and SAR manoeuvres (search and rescue and man-over-board modes);
- Tidal, current, weather and ice data.

Limitations in the INS development

One of the major constraints in the further development of integrated navigation systems is the lack of recommendations in the Resolution MSC.252(83):

- For interfaces connecting the INS to the radio communications equipment installed on ships according to the requirements of the of the SOLAS Chapter IV "Radio communications", Part C "Ships requirements";
- Regarding operational questions associated with the usage of the system and methods of presentation of information on a multifunction display.

In accordance with the requirements of the SOLAS Convention, one of the mandatory INS functions, route monitoring, can be realised only on an updated electronic navigation chart (ENC) presented on a multifunction display unit fulfilling all IMO performance standards for ECDIS. Regulation V/27 of the SOLAS Convention, "Nautical charts and nautical publications", states that nautical charts and nautical publications, such as sailing directions, lists of lights, notices to mariners, tide tables and all other nautical publications necessary for the intended voyage, shall be adequate and up to date (IMO, 2014).

In addition, as already noted in the previous chapter, the INS shall provide a means for drafting and refining the route plan against meteorological information, and may present additional different route-related information such as received maritime safety information (MSI), information from updated navigational publications, navigational and weather warnings, and tidal, current, weather and ice data if available in the INS. ENC and digital navigational publication may be corrected manually by the officer of the watch (OOW), but the process of their updating will be more efficient and less time-consuming if it is carried out automatically by the system after receiving corrections through the ship's radio communications (GMDSS) equipment. Technically, this is already possible and implemented on some ships, but it requires connection of an INS or an ECDIS as its subsystem to the ship's GMDSS equipment. The issue is that Resolution MSC.252(83) does not require that connection, and the IMO did not specify performance standards for interfaces necessary for this purpose. The aforementioned resolution contains only two general recommendations (IMO, 2007a):

- In cases where sources perform functions of the INS, these functions and interfaces should conform with the relevant parts of the performance standards defined in this resolution;
- Standardised and approved communication protocols for interfaces fulfilling the requirements of the IEC Standard 61162 for digital interfaces for navigational equipment within a ship should be used where possible.

The second limitation is the operational problems associated with the usage of the system and methods of presentation of information on a multifunction display. According to the recommendations of the points 1.3 and 2.1.1 of the analysed resolution, an INS aims to ensure that, by taking human factors into consideration, the workload is kept within the capacity of the operator in order to enhance safe and expeditious navigation and to complement the mariner's capabilities, while at the same time to compensate for their limitations. Currently manufactured systems do not fully meet these recommendations. There are not uniform rules for handling and presenting information and manufacturers offer systems which vary greatly in this respect. For this reason, there is a need to learn the principles of use of each system separately, as in the case of ECDIS where the IMO introduced two obligatory courses: the basic generic ECDIS course, and training in order to acquire skills in the use of a particular system. The biggest problems are for sea pilots, e.g. Baltic pilots, who may encounter ships operated on systems from different manufacturers, integrating and presenting different types of data and information in different manners. For this reason, they refer to the indications on multifunction displays very conservatively and mistrust them. There is IMO Circular SN/Circ.243 dated 15 December 2004, "Guidelines for the presentation of navigation-related symbols, terms and abbreviations", and issued on its basis Standard of the International Electrotechnical Commission IEC 62288, "Maritime navigation and radio communication equipment and systems – Presentation of navigation-related information on shipborne navigational displays – General requirements, methods of testing and required test results". They apply to all shipborne navigational systems and equipment but their implementation shall ensure that abbreviations and symbols used for the display of navigation-related information in all shipborne navigational systems and equipment are presented in a consistent and uniform manner only; therefore they do not solve the identified problem.

It seems that these two operational limits mean that INSs do not always fully meet the requirement of SOLAS Regulation V/15, "Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures".

According to this regulation, all decisions which affect bridge design, the design and arrangement of navigational systems and equipment on the bridge, and bridge procedures, shall be taken with the aim of, *inter alia* (IMO, 2014):

- Facilitating the tasks to be performed by the bridge team and the pilot in making a full appraisal of the situation and in navigating the ship safely under all operational conditions;
- Promoting effective and safe bridge resource management;
- Enabling the bridge team and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardised symbols and coding systems for controls and displays;
- Allowing for expeditious, continuous and effective information processing and decision-making by the bridge team and the pilot;
- Preventing or minimising excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the bridge team and the pilot;
- Minimising the risk of human error and detecting such error, if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action.

INS operational limitations and recommendations of the IMO Circular MSC/Circ.982

As mentioned earlier, an INS is defined as such if workstations provide multifunction displays integrating at least 'Route monitoring', 'Collision avoidance' and 'Alert management' tasks. Particular workstations are defined in the IMO Circular MSC/Circ.982 dated 20 December 2000, "Guideline on ergonomic criteria for bridge equipment and layout", and two standards published by the International Organization for Standardization: ISO 8468, "Ships and marine technology – Ship's bridge layout and associated equipment – Requirements and guidelines", and ISO 14612, "Ships and marine technology – Ship's bridge layout and associated equipment – Additional requirements and guidelines for centralised and integrated bridge functions".

Circular MSC/Circ.982 lists two workstations corresponding to the INS tasks (IMO, 2000):

- Workstation for navigating and manoeuvring;
- Workstation for monitoring.

The first is a main workstation for ship's handling conceived for working in a seated or standing position with optimum visibility and integrated presentation of information and operating equipment to control and consider ship's movement. It should be possible from this place to operate the ship safely, in particular when a fast sequence of actions is required. The second is a workstation from which operating equipment and surrounding environment can be permanently observed in a seated or standing position. When several crew members are working on the bridge, it serves for relieving the navigator at the workstation for navigating and manoeuvring and/or for carrying out control and advisory functions by master and/or pilot (IMO, 2000).

In the ISO standards the two above mentioned stations are named (ISO, 2004; 2007):

- Primary navigation, traffic surveillance and manoeuvring workstation;
- Secondary navigation workstation.

The first is defined as a workstation with a commanding view used by navigators when carrying out navigation, traffic surveillance and manoeuvring functions. The second is a back-up workstation for navigation, which may also be used by an assisting navigator when required (ISO, 2004; 2007).

Controls and displays at the workstations for navigation, traffic surveillance and manoeuvring should enable the user (ship master, OOW and pilot) to:

- Continuously monitor the automatically displayed position of the ship in relation to the route, the surrounding waters and other ships, and manoeuvre the ship, including performing of anti-collision manoeuvres;
- Monitor the accuracy of the electronic chart system by cross checking the chart and radar alignment when applicable;
- Monitor all alarm conditions on the bridge and acknowledge warnings and alarms when applicable;
- Contact by radiotelephone with other ships, vessel traffic service (VTS) operators, harbour master officers and submit reports required by a ship reporting system.

From the foregoing description, it arises that the INS should be installed on both mentioned workstations and that it allows the OOW to perform parts of his tasks only. Similarly, as shown below, the INS integrates part of the equipment, control units and indicators of those workstations only.

The MSC circular describes in detail the recommended minimum equipment of each bridge workstation. According to its recommendations, the workstation for navigating and manoeuvring (primary

navigation, traffic surveillance and manoeuvring) should be fitted *inter alia* with (IMO, 2000):

- Navigational equipment: AIS, automatic visual position indicator and information of position fixing systems, ECDIS, heading and/or track control system (adjustment), radar with radar plotting aids;
- Indications for: gyro and magnetic compass headings, pre-set heading, water depth including depth warning adjustment, time, wind direction and velocity, air and water temperature, speed (possibly longitudinal and lateral), rudder angle, rate-of-turn, propeller revolutions (actual and desired), main engine revolution in the case of reduction geared engine, propeller pitch in the case of controllable pitch propeller, torque, starting air, lateral thrust, group alarms (with aids for decision-making);
- Signal transmitter for: whistle, automatic device for fog signals, general alarm, Morse signalling light;
- Automatic device for emergency alarm;
- Controls for: main engine(s) including crash manoeuvres and emergency stop, thrusters and main rudder (including override facility);
- Controls for console lighting and remote control for search light;
- Two-way VHF radiotelephone (walkie-talkie) with charging connection and/or paging system;
- Internal communication equipment and public address system (if applicable);
- VHF point with channel selector;
- Steering mode and position selector switches and rudder pump selector switch;
- Sound reception system (if applicable);
- Acknowledgement of the bridge navigation watch alarm system BNWAS.

The workstation for monitoring (secondary navigation workstation) shall be fitted with (IMO, 2000):

- Radar and radar plotting aids;
- Signal transmitter for whistle;
- Acknowledgement of BNWAS;
- Indications for: propeller revolutions, pitch of controllable pitch propeller, speed, rudder angle, gyro compass heading, time, rate-of-turn, water depth and alarms;
- Internal communication equipment;
- VHF point with channel selector.

INS as a subsystem of the integrated bridge system (IBS)

Now 20 years of age but still valid and cited in the SOLAS Regulation V/19, IMO Resolution MSC.64(67) adopted on 4 December 1996, "Adoption of new and amended performance standards", recommends the ship's flag and port state administrations to ensure that integrated bridge systems (IBSs) installed on ships on or after 1 January 1999 conform to performance standards not inferior to those set out in the Annex 1 to this resolution, "Recommendation on performance standards for integrated bridge systems (IBS)". According to the recommendation of this annex, an IBS is defined as a combination of systems which are interconnected in order to allow centralised access to sensor information or command (control) from workstations, with the aim of increasing safe and efficient ship management by suitably qualified personnel. It should support systems performing two or more of the following operations (IMO, 1996):

- Passage execution;
- Communications;
- Machinery control;
- Loading, discharging and cargo control;
- Safety and security.

Interfacing to an IBS should comply with the IEC 1162 Publication as relevant to international marine interface standards.

An INS forming part of an IBS should allow the task of 'Passage execution' to be conducted. An IBS performing two operations – 'Passage execution' and 'Communication' – shall solve the problems indicated in chapter 3 associated with a lack of connection between the INS and ship radio communications (GMDSS) equipment. In order to achieve this, the IMO should amend Annex 1 to the Resolution MSC.64(67).

INS as a tool of e-navigation

The idea of e-navigation, the possibility of its development and implementation, as well as the Polish approach to this subject identified at an early stage of the work of the Correspondence Working Group on e-navigation created at the IMO are presented in the works published *inter alia* by A. Weintrit (Weintrit & Wawruch, 2006; Weintrit et al., 2007a; 2007b; Weintrit, 2007; 2011; 2013), D. Filipkowski (Filipkowski and Wawruch, 2010; Filipkowski, 2013) and D. Petraiko (Petraiko, Wake & Weintrit, 2009). The key structural components of e-navigation later defined the base of user needs, which as approved by the IMO Maritime Safety Committee (MSC) are *inter alia* (IMO, 2014a; Wawruch, 2014):

1. Accurate, comprehensive and up-to-date electronic navigational charts (ENC) covering the entire geographical area of a vessel's operation.
2. Accurate and reliable electronic positioning signals, with 'fail-safe' performance, probably provided through multiple redundancy, e.g. on-board receivers of different satellite and terrestrial radio navigation systems or inertial navigation devices.
3. Provision of information on vessel route, course, manoeuvring parameters and other status items (hydrographic data, ship identification data, passenger details, cargo type, security status, etc.), in electronic format.
4. Transmission of positional and navigational information in relations: shore-to-ship (e.g. by vessel traffic services (VTS), coastguard centres, hydrographic offices), ship-to-shore and ship-to-ship.
5. Accurate, clear, integrated, user friendly display of the above mentioned information on-board and ashore (e.g. using integrated bridge system (IBS) or integrated navigation system (INS)).
6. Information prioritisation and alert capability in risk situations (collision, grounding, etc.), both on-board and ashore.

The component listed in point 5 explicitly requires installation of the functions of 'Passage execution' and 'Communications' on the workstations for navigating and manoeuvring and for monitoring IBS performance, or connection of the INS to the ship's GMDSS equipment.

As potential e-navigation solutions defined on the basis of identified user needs and gap analysis were listed following tasks (Wawruch, 2014; IMO, 2014b):

- S1 Improved, harmonised and user-friendly bridge design;
- S2 Means for standardised and automated reporting;
- S3 Improved reliability, resilience and integrity of bridge equipment and navigation information;
- S4 Integration and presentation of available information in graphical displays received *via* communication equipment;
- S5 Information management;
- S6 Improved access to relevant information for search and rescue;
- S7 Improved reliability, resilience and integrity of bridge equipment and navigation information for shore-based users;
- S8 Improved and harmonised shore-based systems and services;
- S9 Improved communication of VTS service portfolio.

Five prioritised solutions numbered as S1, S2, S3, S4 and S9 were selected from the abovementioned list and recognised as those with the most priority on the basis of a formal safety assessment (FSA) conducted using two criteria (IMO, 2013a):

- Seamless transfer of data between various equipment on-board;
- Seamless transfer of electronic information and data between ship and shore and *vice versa*, and in relation to ship-to-ship and shore-to-shore.

An additional function of an integrated system, not currently constituent in the tasks mentioned as e-navigation solutions, that may be considered is a decision support system as proposed by Z. Pietrzykowski (Pierzykowski, Borkowski & Wołejsza, 2012) and presented by Poland at the IMO in 2013 (IMO, 2013b).

As part of the FSA, the following Risk Control Options (RCOs) were identified as providing effective risk reduction in a cost-effective manner (Wawruch, 2014; IMO, 2014b):

- RCO 1 Integration of navigation information and equipment including improved software quality assurance;
- RCO 2 Bridge alert management;
- RCO 3 Standardised mode(s) for navigation equipment;
- RCO 4 Automated and standardised ship-shore reporting;
- RCO 5 Improved reliability and resilience of on-board PNT systems;
- RCO 6 Improved shore-based services;
- RCO 7 Bridge and workstation layout standardisation.

In order to harmonise and standardise shore-based services rendered for ships under different situations and/or locations, they were grouped and are described as Maritime Service Portfolios (MSPs). The IMO Sub-Committee on Safety of Navigation (NAV) noted a preliminary list of 16 MSPs comprising the following services: maritime assistance (MAS), maritime safety information (MSI), telemedical maritime assistance (TMAS), nautical charts and publications, ice navigation, meteorological information, real-time hydrographic and environmental information, VTS, local port, pilot, tugs and vessel shore reporting, and search and rescue (SAR) (Wawruch, 2014).

An INS fulfilling the recommendations of the Resolution MSC.252 (83) provides key structural components of e-navigation mentioned in points: 1 and 2 fully, 3, 5 and 6 in part (in relation to navigation) and 4 (after connecting it to the ship's radio

communications equipment). Without an INS or IBS, it will be impossible to implement all of the nine aforementioned tasks of e-navigation. The discussed system allows the provision of effective risk reduction in a cost-effective manner, fulfilling risk control options (RCO) numbers 1, 3 and 5, and partially 2 (bridge alert management). This means that having been connected to the ship's GMDSS equipment, an INS will be a very useful tool for e-navigation.

Following the recommendations of the IMO Circular MSC/Circ.982, it should be possible for communication to be carried out with shore-based services in the scope of different MSPs by the master, OOW and pilot, sitting or standing at the workstations for navigating and manoeuvring or monitoring. Information and data received from shore-based services shall be automatically presented on monitors installed on those workstations too. The simplest technical solution for achieving this goal is to connect the INS to the ship's GMDSS equipment.

Conclusions

The bridge team and pilot are required to use 'any means available' to safely navigate the ship, including by visual position fixing and lookout as well as communications with external sources of information such as other traffic and VTS stations, and the design of integrated systems should therefore support the use of all means and their correlation (IMO, 2013c). An INS should enhance navigational safety by providing integrated and augmented functions to avoid geographic, traffic and environmental hazards. It shall be installed on the workstations for navigating and manoeuvring and for monitoring, enabling the ship's captain, OOW and pilot to execute the safe passage of the ship along a planned route. This means that it should facilitate the exchange and presentation of all data and information necessary to achieve these objectives. Planning of the ship's route and conducting sea passage in a safe and efficient manner requires access to current weather forecasts, navigational and meteorological warnings and other information transmitted by shore-based services described as Maritime Service Portfolios (MSPs).

As it was described in the previous chapters, the major constraints limiting the further development of INSs is the lack of recommendations in the Resolution MSC.252(83):

- For interfaces connecting the INS to the radio communications equipment installed on ships according to the requirements of the of the SOLAS Chapter IV, "Radio communications", Part C "Ships requirements";
- Regarding operational questions associated with the usage of the system and methods of presentation of information on a multifunction display.

The first limitation can be removed in two ways:

- By introducing, instead of an INS, an integrated bridge system (IBS) implementing two functions: 'Passage planning and execution' and 'Communications';
- By extending the functions performed by an INS.

The first solution requires a thorough amendment of the Annex 1, "Recommendation on performance standards for integrated bridge systems (IBS)", to the Resolution MSC.64(67) made in accordance with the recommendations of the IMO Circular SN.1/Circ.274, "Guidelines for application of the modular concept to performance standards" (IMO, 2008), and therefore can be time consuming. The second solution requires the development of new modules to the revised performance standards for integrated navigation systems (INS) described in the Resolution MSC.252(83), as it is suggested in the proposal presented by China and Norway during the third session of the IMO Sub-Committee on Navigation, Communications and Search and Rescue (NCSR) in March 2016 (IMO, 2015a; 2015b). This solution appears to be more effective and easier to implement. The revised performance standards for INSs are modular and can be revised in an easy manner by adding new modules to deal with the new demands and standards as the industry develops new systems and technology.

As recommended in the Circular SN.1/Circ.265, "Guidelines on the application of SOLAS Regulation V/15 to INS, IBS and bridge design", the bridge team and the pilot shall focus on handling the ship rather than on operating the INS (IMO, 2007b). Correspondingly, seafarers shall be provided with a standardised, simple and effective interface for the control and monitoring of navigational systems. This can be achieved by introducing guidance on the standardised mode (S-Mode) of operation of navigational equipment and systems. Equipment and systems, after switching on S-Mode with a single button action, shall default to a standard display and present a standard user interface for pre-defined tasks. Currently there is no definition of this mode of operation. It should be prepared and accepted by the IMO, but the introduction of an INS with an S-Mode should solve operational questions associated with the usage of an integrated system, and different

methods of presentation of information on a multifunction display.

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