TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 17
Number 4
December 2023
DOI: 10.12716/1001.17.04.12

Challenges Related to Standardization of GNSS/RNSS Shipborne Equipment by International Maritime Organization (IMO)

P. Zalewski[1], M. Bergmann[2] , R. Wawruch[3] & A. Weintrit[3]
[1] *Maritime University of Szczecin, Szczecin, Poland*
[2] *Bergmann Marine Consultants & Advisors, Germany*
[3] *Gdynia Maritime University, Gdynia, Poland*

ABSTRACT: In 2020 several member states initiated at IMO forum (NCSR subcommittee) a process to create a single set of generic performance standards consolidating all existing performance standards for shipborne satellite navigation system receiver equipment without creating any new requirements. After over 4 years the resultant generic framework for GNSS/RNSS subsystems has not been adopted yet and awaits further amendments. Analysis of the proposed standards with stress on harmonization issues of the existing, IMO recognized, global and regional navigation satellite systems and the expected impact of these generic standards of satellite navigation receivers on the maritime user are presented in this paper. Additionally the strengths, weaknesses, opportunities, and threats awaiting maritime or shipborne GNSS/RNSS equipment standardization process are outlined in the paper.

1 EGNOS L1 MARITIME SERVICE

International Maritime Organization (IMO) Navigation, Communication, Search & Rescue Subcommittee (NCSR), during its 7th session in January 2020 [IMO, 2020a], considered the proposal by Germany, Japan and Poland on a functional approach and modular structure of performance standards for shipborne equipment using radio signals for the provision of information and data for navigation, including an overview of a structure and content of performance standards for maritime radionavigation receivers. This action was based on invitation from NCSR and MSC dating back to 2018 [IMO, 2018a].

NCSR 7 agreed that the work on the development of performance standards for shipborne satellite navigation system receiver equipment should continue in the context of “satellite” navigation receiver equipment only and invited interested parties to progress the work intersessionally and submit relevant proposals to NCSR 8 for finalization. Following the invitation a non-formal intersession correspondence group coordinated by Germany was established and a proposal to NCSR 8 prepared [IMO, 2021].

NCSR 8 in April 2021 noted that the development of generic performance standards would still require further consideration and agreed this time to establish a formal Correspondence Group (CG) to finalize a draft MSC resolution by 2022 addressing, in particular, the relationship with the existing performance standards [IMO, 2021a].

NCSR 9 in June 2022 appreciated the proposal developed by CG but noted that the work under this agenda item consisted of consolidating existing performance standards and, because no urgent action was required regarding this matter, NCSR 9 agreed to postpone consideration of the documents related to CG work to 2023. The main motivation of the postponing, though not expressed directly in NCSR 9 report to MSC [IMO, 2022], was NSCR work overload by other agenda items, and possible consensus issues deemed hard to resolve during lengthy but restricted to online form only meetings due to COVID-19 pandemic times.

Finally the documents related to NCSR agenda item on “Development of generic performance standards for shipborne satellite navigation system receiver equipment”, provided by CG led by Germany [IMO, 2022a] and by United States as commentary [IMO, 2022b], were considered during hybrid (stationary and online) NCSR 10 meeting in May 2023 but with the outcome that can be recognised as not satisfactory by many maritime stakeholders. The evolution of maritime Global Navigation Satellite System (GNSS) and Regional Navigation Satellite System (RNSS) receivers’ performance standards have been thoroughly described for interested readers in [Zalewski et. al., 2022c]. In this paper the authors put stress on the developed generic framework for GNSS/RNSS subsystems performance standards, issues of its acceptance and of harmonisation of the existing standards.

2 IMO GNSS/RNSS OBLIGATORY INSTRUMENTS IN FORCE

IMO resolutions on the worldwide radionavigation system [IMO, 2011] and on performance standards of shipborne GNSS receivers [IMO, 2000, 2000a, 2000b, 2000c, 2006, 2014, 2015, 2017, 2018, 2020] provide manufacturers with obligatory parameters for certification by IEC (International Electrotechnical Committee) and classification societies, and inform seafarers of proper receiver setup / choice to meet PVT (position, velocity, time) data accuracy and integrity in two designated maritime areas: 1) ocean waters and 2) harbour entrances, harbour approaches, and coastal waters. Contents of MSC resolutions on various shipborne GNSS radionavigation receivers include common structure of requirements:

The GNSS ”x” - subsystem receiver (display presented in the fig. 1) should:

– be capable of receiving and processing the ”x” positioning, velocity, and timing signals;
– provide position information in latitude and longitude in degrees, minutes and thousandths of minutes;
– provide time referenced to UTC;
– be provided with at least one output from which PVT information can be supplied to other equipment;
– have static accuracy such that the position of the antenna is determined to within … m (95%);
– have dynamic accuracy equivalent to …;
– have timing accuracy such that …;
– have a minimum resolution of position, i.e. latitude and longitude, of 0.001 minutes;
– be capable of selecting automatically the appropriate satellite-transmitted signals for determining the ship’s position with the required accuracy and update rate;
– be capable of acquiring satellite signals with input signals having carrier levels in the range of … dBm to … dBm. Once the satellite signals have been acquired, the equipment should continue to operate satisfactorily with satellite signals having carrier levels down to … dBm;
– be capable of operating satisfactorily under normal interference conditions consistent with the requirements of resolution A.694(17) [IMO, 1991];
– be capable of acquiring position to the required accuracy, within … min, when there is no valid almanac data;
– be capable of acquiring position to the required accuracy, within … min, when there is valid almanac data;
– be capable of re-acquiring position to the required accuracy, within … min, when subjected to a power interruption of 60 s;
– generate and output to a display and digital interface a new position solution at least once every 1 s (for a craft meeting the HSC Code [IMO, 2000d] 0,5 s is recommended);
– provide the COG, SOG and UTC outputs with a validity mark aligned with that on the position output. The accuracy requirements for COG and SOG should not be inferior to the relevant performance standards for heading and speed and distance measuring equipment (SDME) and the accuracy should be obtained under the various dynamic conditions that could be experienced on board ships;
– have the facilities to process ”x” differential data or augmentation data.
– should indicate whether performance of ”x” is outside the bounds of requirements as specified in A.1046(27) [IMO, 2011].

Figure 1. Example of a contemporary minimum keyboard display or human-machine interface of GNSS shipborne receiver.

The table 1 below covers references to IMO performance standards and IEC standards met by the exemplary GNSS multisystem shipborne navigation receiver.

Table 1. Example of a GNSS shipborne receiver manufacturer’s certificate confirming meeting the IMO and IEC standards.

Function	IMO Per. Standard	IEC Test Standard
GPS	MSC.112(73)	IEC61108-1
GLONASS	MSC.113(73)	IEC61108-2
DGNSS	MSC.114(73)	IEC61108-4
MULTI(*)	MSC.115(73)	…
Alert Management	MSC.302(87)	IEC62923-1/-2

* Combined GPS/GLONASS

3 GENERIC GNSS/RNSS PERFORMANCE STANDARDS AT IMO NCSR 10

The document resultant from CG work, finalized in the beginning of 2022 [IMO, 2022a], provides a functional approach and modular structure for performance standards for shipborne satellite navigation system receiver equipment providing position, navigation and time (PNT) data and associated information to watchkeeping team and shipboard applications, e.g. electronic chart display and information system (ECDIS), automatic identification system (AIS), integrated navigation system (INS), global maritime distress and safety system (GMDSS), long range identification and tracking system (LRIT), ship security alert system (SSAS), bridge alert management system (BAM), voyage data recorder (VDR) and other equipment like radar, echosounder, marine weather forecast system, etc. The applicability of the approach was proved by the exemplary implementation of a performance standard for shipborne Quasi-Zenith Satellite System (QZSS) and BeiDou Navigation Satellite System (BDS), as well as Galileo receiver equipment, into the proposed modular documentation structure.

The figure 2 presents structure of the proposed generic performance standards for shipborne GNSS receivers providing PNT data and associated information.

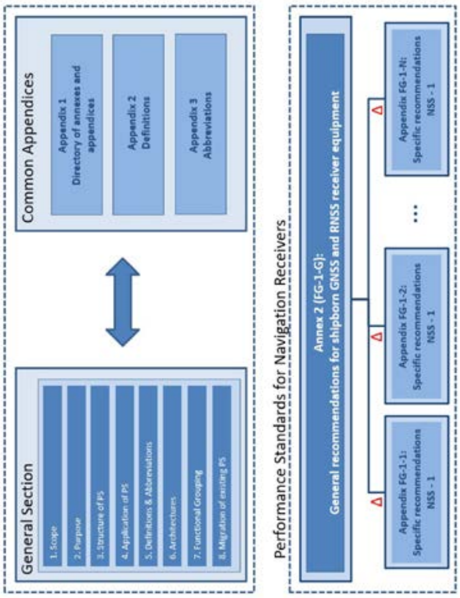

Figure 2. Structure of the proposed generic performance standards for shipborne GNSS receiver equipment (source: [IMO, 2022a]).

Such a structure allowed for differences in installed equipment and implementation options, measurements principles, supported functionalities, signal sources, scope of data as well as usability in specific regions. Concurrently, the generic performance standards provided a harmonized and logically structured compilation of recommendations for shipborne radionavigation receivers providing position, velocity and time (PVT) data and associated information by using radio signals from one or more radio navigation services, according to the modular concept. For these performance standards, a radionavigation receiver is characterized as an entity with the ability to carry out at least the following:

1. the conversion of radio waves into signals by means of antennas and radio frequency front-ends;
2. the determination of PVT data and associated information by means of signal and data processing; data management with other equipment and systems including input and output data, status information, configuration parameters, control data and alerts;
3. if applicable, a human-machine interface (HMI) to display the provided data for navigation and to enable the configuration and control of the shipborne equipment. The HMI should either be integrated with the equipment itself or be provided as an external component, as part of a multi-functional display.

The functional / technical architectures of the expected three receiver's configurations are presented in the figures 3, 4, and 5. They comprise the following elements:

- antenna with RF frontend;
- signal and data processing including PNT data processing (PNT-DP), if applicable;
- increased accuracy, integrity monitoring and alert management, if applicable;
- data management to facilitate the data exchange for input/output messaging, configuration, controlling, alerting, and status reporting, if applicable.

They are categorised by a human-machine interface (HMI). The HMI for input (configuration, controlling) and output (data, alerts, status report) to facilitate human-machine interactions can be either:

1. intrinsically built into receiver's structure (figure 3) or
2. with increased automation, the operational use of HMIs for controlling, alerting or reporting, may be rendered obsolete - therefore, the corre-sponding architecture of the radionavigation re-ceiver would not contain the HMI (figure 4) or
3. the modular arrangement of a radionavigation receiver may result in a separation of the HMI from the original receiver, as illustrated in the figure 5.

A separation of the HMI from the original receiver or architecture without HMI results in additional recommendation that the receiver and the HMI should be equipped with a standardised bi-directional interface to exchange the output data and associated information and to control alerting and reporting from the receiver for proper operation.

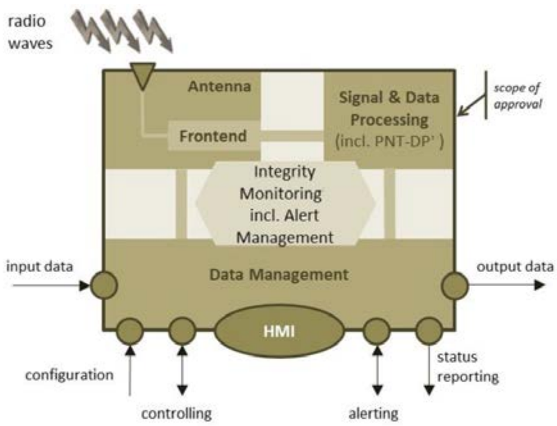

Figure 3. Architecture of the shipborne GNSS receiver with HMI included (source: [IMO, 2022a]).

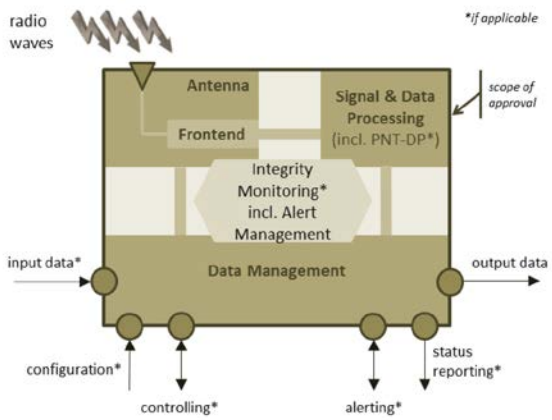

Figure 4. Architecture of the shipborne GNSS receiver without HMI (source: [IMO, 2022a]).

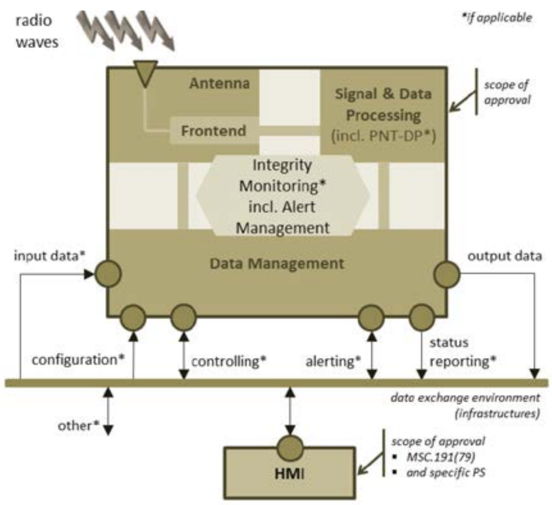

Figure 5. Architecture of the shipborne GNSS receiver with separated HMI (source: [IMO, 2022a]).

If available, the radionavigation receiver may also use data from augmentation and correction services to improve the performance of PVT data and to provide associated integrity and status information. Future radionavigation receivers with changed functionality should be represented by new functional groups.

The CG has also worked on satellite based augmentation systems (SBAS) issue and prepared a suggestion on how to include SBAS systems (e.g., WAAS, EGNOS) as additional annexes to this generic performance standard. Additionally, United States in their commentary document have added the functionality to detect and indicate to the user by signal to noise ratio (SNR) values the presence of radio frequency interference from in-band emission that could be experienced on board ships. This has paved a way to possibility to include SBAS functionality, SNR and integrity data processing according to the current research [Zalewski, 2020].

Finally, it was agreed by the CG that these performance standards have been developed under the scope of the consolidation of existing and when available future GNSS performance standards also featuring capabilities of radionavigation receivers. Existing recommendations of current single GNSS and RNSS performance standards have been integrated within these performance standards. The performance recommendations are identical to those given by the single system performance standards and have been consolidated within the annexes of these performance standards without raising new or additional recommendations. The current single GNSS or RNSS performance standard should remain in force until it is superseded by the single GNSS or RNSS performance standard adopted as a system-specific annex of the new generic standard.

4 ISSUES IDENTIFIED AT IMO NCSR 10 AND MSC 107

Firstly, during the discussion at IMO NCSR 10 [IMO, 2023] not all but five out of the six recognized GNSSs administrations supported the adoption of the new draft performance standards, though all them were involved in CG work and consented to these standards when the report was submitted.

Secondly, the representative of one of the recognized GNSSs noted that the draft resolution setting out the framework without including specifications of minimum functions to be achieved by receivers could not be the performance standards, hence merely giving the guidance and as such should not be a resolution. If a guidance was developed, it should be disseminated as a circular similar to the Guidelines for shipborne position, navigation and timing (PNT) data processing [IMO, 2017a], which had been developed as associated guidelines to resolution on Performance standards for multi-system shipborne radio navigation receivers [IMO, 2015]. The NCSR work group concluded that some additional work to fully address this concern is necessary. In this context, it was recalled that:

1. when this output had been discussed and agreed, the intention was to create a single set of generic performance standards consolidating all existing performance standards for shipborne satellite navigation system receiver equipment, without creating any new requirements;
2. to meet the current performance standards definitions and ensure no unnecessary type approval are required, the proposal developed by the CG addressed that by presenting a "framework" for future development of general and specific recommendations for shipborne radionavigation receivers providing PNT data and associated information;
3. it was very important that the outcome of this work is confirmed and agreed, in particular, by those Member States that had established systems already recognized by the Organization. This includes GPS (United Sates), GLONNAS (Russian Federation), Galileo (European Commission), BDS (China), IRNSS (India) and QZSS (Japan);
4. that it was also important to confirm the application of any new resolution to be adopted in terms of existing and new installations and whether this would revoke or supersede previous resolutions adopted by the Organization.

Thirdly, some other comments were expressed, such as that the proposed performance standards have covered also new stipulations for some systems instead of consolidating only the current ones. For instance the functionality of receiver autonomous integrity monitoring (RAIM) was included for all GNSS/RNSS receivers, but currently not all performance standards require that the results of RAIM should be used for the provision of status and integrity information contributing to alert management and an integrity warning of system malfunction, non-availability or discontinuity, and they should be provided to users within 10 sec. Similar concern arises regarding SNR or augmentation data needed by advanced RAIM (ARAIM). The EUSPA research shows that maritime users still have very basic knowledge of RAIM algorithms in GNSS receivers and their interpretations [EUSPA, 2021].

The discussion at NCSR finalized with request to MSC for extension of the completion year to 2024 and alteration of the scope of this output to develop a framework document instead of strict performance standards. Anyway, the MSC during its 107 session noted that the urgency and possible implications for existing performance standards of a change of scope of the output (consolidation of performance standards) had not been thoroughly considered by the NCSR, and NCSR had too high current workload to proceed with this output right away. Doubts if the intended application of the new resolution would be both for existing and newly installed receivers were also expressed. So, the final decision was not to agree to extend the target completion year of the GNSS/RNSS performance standards output and to move the output "Development of generic performance standards for shipborne satellite navigation system receiver equipment" to the post-biennial agenda until a clear indication of the new scope of the work is conducted and information on the associated implications are provided by the NCSR.

5 DISCUSSION

Some of the concerns raised by the opposition to the new generic performance standards for shipborne satellite navigation system receiver equipment can be mitigated rationally:

1. Developing a standard to combine all GNSS PS into a single PS.
   As described in the report of the CG, the CG recognized that there are both common aspects for all GNSS/RNSS, as well as certain aspects of the individual PS which only apply to the individual systems given their different technologies used. As such the development of a single minimum PS applicable for all GNSS/RNSS receivers would not adequately address all system specific requirements currently described and agreed to by IMO in the individual PS. To resolve this issue the CG developed the presented structure of the Generic PS to contain the minimum PS aspects applicable to all GNSS in the annex of the draft MSC Resolution. But to also capture the aspects of the individual GNSS PS only applicable to an individual PS, appendices are suggested to contain specific receiver requirements for any GNSS/RNSS to be included in the new Generic GNSS/RNSS receiver PS. This way a single MSC resolution is suggested to address both generic as well as individual PS components.
2. The Generic GNSS/RNSS PS should reduce the administrative burden and avoid the need for type new approvals for existing systems.
   To address this concern the recommended new MCS Resolution should include a numbering and versioning schema for both the generic part (Annex) as well as the individual parts per GNSS/RNSS (Appendices). The type approval would be executed with both the generic specifications (Annex) as well as the applicable individual parts (Appendix or, for multi receivers Appendices). If a system is to be certified for BDS as an example, it would be certified according to version 1 of annex relevant part as well as version x of relevant appendix. This way the addition of a next appendix (for example for Galileo) will have no affect to any BDS receivers, as well as any changes to another appendix.
3. The current GNSS/RNSS system administrations should individually be able to decide of the migration from the individual PS to the Generic PS.
   The shifting of data from current individual performance standards to the new generic template is in sole discretion of GNSS/RNSS system administration – the performance standards in new format must be input to MSC, adopted and the previous ones revoked. It is recommended to perform this migration once an update of the system PS is necessary, as then new type approval is necessary anyhow. Member states or organizations (like EC) who do not want to switch to new template will have their standards written as they are, until the time they decide to suggest amendments to the PS of the GNSS/RNSS they are responsible for.
4. The suggested PS doesn't include an existing GNSS/RNSS and as such is currently not applicable to any system.
   This is a correct statement, and it is intentionally done this way. During the development of the framework of this single generic PS all existing GNSS/RNSS have been included as appendices. This was done to ensure that all existing GNSS PS can be merged into the suggested Generic Standard. But to avoid unnecessary administrative actions, like re-type approval, only a template has been developed. The appendix FG-1-1 for QZSS, FG-1-2 for Galileo and FG-1-3 for BDS have been added for illustration purposes only. According to stipulations in the proposed standard the respective organization could decide when they want to migrate.
5. The document with United States comments [IMO, 2022b] or other additional requirements.
   Additional requirement for GNSS/RNSS equipment could be added individually to a system relevant appendix. New functional requirement would not have to be applicable to existing individual GNSS/RNSS PS or it can reduce the administrative burden to the organizations as by one simple addition to the generic part it becomes applicable to all included GNSS/RNSS PS.

6 CONCLUSIONS

To outline some of the strengths, weaknesses, opportunities, and threats awaiting maritime GNSS standardization process, a SWOT analysis is presented in the Table 2.

Concluding:

1. Adoption of generic GNSS/RNSS/SBAS receiv-ers performance standards will be possible if common consensus between IMO recognised GNSS/RNSS administrations is reached.
2. IMO MSC agreed to include in its post-biennial agenda an output on "Development of procedures and requirements for the recognition of augmentation systems in the World-wide radionavigation system", with one session needed to complete the item; and an output on "Development of performance standards for dual frequency multi-constellation satellite-based augmentation systems (DFMC SBAS) and advanced receiver autonomous integrity monitoring (ARAIM) in shipborne radionavigation receivers", with two sessions needed to complete the item.
3. Inclusion of integrity, continuity and availability parameters requires adoption of standard algorithm of protection level calculation for high level RAIM / ARAIM. There is a disagreement in maritime community over practical values of time scope for continuity, availability and integrity.
4. Maritime users still have very basic knowledge of RAIM algorithms in GNSS receivers and their interpretations.

Table 2. SWOT analysis of maritime GNSS standardization process.

Strengths: 1) building on expertise coming from 20 years of research on IMO GNSS policy 2) established IMO standardization guidelines and proceedings 3) SOLAS vessels navigation is of key importance in terms of safety and efficiency of sea transport	Weaknesses: 1) some requirements are almost impossible to comprehend or justify, e.g., accuracy for oceanic navigation which is several orders of magnitude better than that of the nautical charts, or continuity requirements over a period of 15 minutes, irrespective of the type of vessel and of the maneuver / operation phase 2) lack of clear identification of maritime user operation specific requirements
Opportunities: 1) strong support from European Union Agency for Space Programme (EUSPA) and EU 2) trends such as the e-navigation, e-maritime services, and MASS initiatives by IMO, the activities of a multi-system receiver performance standard and generic GNSS performance standard	Threats: 1) reluctance of maritime community to changes resulting in extra costs 2) lengthy procedure of new inputs finalization at IMO 3) the environmental/physical/radio electrical constraints applicable to the vessel and/or the operation/phase of navigation

REFERENCES

[1] EUSPA (2021), Report on Maritime and Inland Waterways User Needs and Requirements – outcome of the EUSPA user consultation platform, GSA-MKD-MAR-UREQ-229399, Issue/Revision: 3.0.

[2] IMO (1991), A.694(17), General Requirements for Shipborne Radio Equipment Forming Part of the GMDSS and for Electronic Navigation Aids. International Maritime Organization: London, UK, 1991.

[3] IMO (2000). MSC.112(73), Adoption of the Revised Performance Standards for Shipborne Global Positioning System (GPS) Receiver Equipment; International Maritime Organization: London, UK, 2000.

[4] IMO (2000a). MSC.113(73), Adoption of the Revised Performance Standards for Shipborne GLONASS Receiver Equipment; International Maritime Organization: London, UK, 2000.

[5] IMO (2000b). MSC.114(73), Adoption of the Revised Performance Standards for Shipborne DGPS and DGLONASS Maritime Radio Beacon Receiver Equipment; International Maritime Organization: London, UK, 2000.

[6] IMO (2000c). MSC.115(73), Adoption of the Revised Performance Standards for Shipborne Combined GPS/GLONASS Receiver Equipment; International Maritime Organization: London, UK, 2000.

[7] IMO (2000d). MSC.97(73), International Code of Safety for High-Speed Craft (HSC Code). International Maritime Organization: London, UK, 2000, amended by MSC.175(79), MSC.222(82), MSC.260(84), MSC.271(85), MSC.439.(99)

[8] IMO (2001). A.915(22), Revised Maritime Policy and Requirements for A Future GNSS; International Maritime Organization: London, UK, 2001.

[9] IMO (2006). MSC.233(82), Adoption of the Performance Standards for Shipborne Galileo Receiver Equipment; International Maritime Organization: London, UK, 2006.

[10] IMO (2011). A.1046(27), World Wide Radionavigation System; International Maritime Organization: London, UK, 2011.

[11] IMO (2014). MSC.379(93), Performance Standards for Shipborne Beidou Satellite Navigation System (BDS) Receiver Equipment; International Maritime Organization: London, UK, 2014

[12] IMO (2015). MSC.401(95), Performance Standards for Multi-System Shipborne Radionavigation Receivers; International Maritime Organization: London, UK, 2015.

[13] IMO (2017). MSC.432(98), Amendments to Performance Standards for Multi-System Shipborne Radionavigation Receivers (RESOLUTION MSC.401(95)); International Maritime Organization: London, UK, 2017.

[14] IMO (2017a). MSC.1/Circ.1575, Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing; International Maritime Organization: London, UK, 2017.

[15] IMO (2018). MSC.449(99), Performance Standards for Shipborne Indian Regional Navigation Satellite System (IRNSS) Receiver Equipment; International Maritime Organization: London, UK, 2018.

[16] IMO (2018a), Document MSC 99/22, Report of the Maritime Safety Committee on its 99th session; International Maritime Organization: London, UK, 2018.

[17] IMO (2020). MSC.480(102), Performance Standards for Shipborne Japanese Quasi-Zenith Satellite System (QZSS) Receiver Equipment; International Maritime Organization: London, UK, 2020.

[18] IMO (2020a), Document NCSR 7/6, Draft Performance standard for shipborne equipment using radio signals for the provision of information and data for navigation; International Maritime Organization: London, UK, 2020.

[19] IMO (2021), Document NCSR 8/4/1, Performance standards for shipborne satellite navigation system receivers providing position, navigation and time data

and associated information; International Maritime Organization: London, UK, 2021.
[20] IMO (2021a), Document NCSR 8/14/1, Report to the Maritime Safety Committee; International Maritime Organization: London, UK, 2021
[21] IMO (2022), Document NCSR 9/24, Report to the Maritime Safety Committee; International Maritime Organization: London, UK, 2022.
[22] IMO (2022a), Document NCSR 9/5, Report of the Correspondence Group on Development of Generic Performance Standards for shipborne satellite navigation system receiver equipment; International Maritime Organization: London, UK, 2022.
[23] IMO (2022b), Document NCSR 9/5/1, Comments on document NCSR 9/5; International Maritime Organization: London, UK, 2022.
[24] IMO (2023), Document NCSR 10/22, Report to the Maritime Safety Committee; International Maritime Organization: London, UK, 2023.
[25] Zalewski, P. (2020), Integrity Concept for Maritime Autonomous Surface Ships' Position Sensors. MDPI Sensors 2020, 20, 2075. https://doi.org/10.3390/s20072075
[26] Zalewski, P.; Bąk, A.; Bergmann, M. (2022c). Evolution of Maritime GNSS and RNSS Performance Standards. MDPI Remote Sensing 2022, 14, 5291. https://doi.org/10.3390/rs14215291.