MARITIME SAFETY COMMITTEE
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WORK PROGRAMME

Proposal for a new output to develop minimum Performance Standards for Dual Frequency Multi-Constellation Satellite-Based Augmentation Systems and Advanced Receiver Autonomous Integrity Monitoring in shipborne radionavigation receivers

Submitted by IMO Member States of Australia, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, New Zealand, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and European Commission (EC)

SUMMARY

Executive summary:	This document contains a proposal for inclusion of a new output in the 2024-2025 biennial agenda of the Committee; the proposal seeks to develop minimum performance standards for Dual Frequency Multi-Constellation Satellite-Based Augmentation Systems (SBAS) and Advanced Receiver Autonomous Integrity Monitoring (ARAIM) in shipborne radio navigation receivers. The proposal has no financial impact on the shipping industry or on the IMO budget
Strategic direction:	5.2
High-level action:	5.2.4
Planned output:	No related provisions
Action to be taken:	Paragraph XX
Related documents:	IMO Resolutions A.915(22); A.1046(27); A.1036(26), A.1098(29); MSC.112(73), MSC.113(73), MSC.114(73), MSC.115(73) and MSC.233(82), MSC.401(95), MSC.432(98); IALA Recommendation R-135 and IALA World-Wide Radio Navigation Plan

Background

1 This document is submitted in accordance with MSC-MEPC.1/Circ.5/Rev.1 *(this change took place in 2016. Rev.2 was approved in 2020; need to check if this submission is in accordance with the latest guidance)* on the Guidelines on the organization and method of work of the Maritime Safety Committee and the Marine Environment Protection Committee and their subsidiary bodies on the submission of proposals for new outputs. It takes into account the High-level Action Plan for the Organization and priorities for the 2024-2025 biennium (IMO Resolution A.1098(29)).

2 Satellite navigation systems are being used by the international maritime community to fulfil carriage requirements for determining position, navigation and time (PNT) according to SOLAS Chapter V. IMO is carrying out the necessary tasks required for due recognition of the Global and Regional Navigation Satellite Systems (GNSS/RNSS) as components of World-Wide Radionavigation System (WWRNS). IMO also develops performance standards for shipborne receiver equipment, for individual GNSS and for multi-system receivers (MSC.401(95)), which includes augmentation systems and RAIM.

What is SBAS?

3 SBAS augment signals from navigation satellite systems. It improves the accuracy, availability, and reliability of GNSS by correcting signal errors while adding an integrity to GNSS signals, thereby enhancing the safety and efficiency of navigation.

4 SBAS use geostationary and non-geostationary satellites and have continent-wide service areas. SBAS use a set of monitoring or reference stations (whose positions are known precisely) to receive GNSS signals that are processed in order to obtain estimations of the errors applicable to the users (i.e. ionospheric errors, satellite position/clock errors, etc.). Once these estimations have been computed, they are transmitted as differential corrections by means of a SBAS satellite. Along with these correction messages which increase accuracy, SBAS also broadcast GNSS integrity data, thus increasing the confidence that a user can have in the satellite navigation positioning solution.

5 Satellite-based navigation systems are being used widely by the international maritime community. Today, more than 90% of GNSS receivers on board international ships are SBAS-enabled[1].

6 Flag and port States require GNSS equipment to be of an approved type. This requirement is fulfilled when ships' equipment has a type approval certificate, based on an IEC (or similar) test standard. This standard is being developed, with completion expected in 2023.

7 At the present stage, industry do not have the means to test the SBAS functionality of their receivers against any standard. The lack of a SBAS test standard to assess correctness of the position solutions offered by their equipment, also limits the possibility to understand whether mariners can rely on the provided SBAS information.

Lack of performance standards

8 To date, IMO has recognised several Global and Regional Navigation Satellite Systems (GNSS and RNSS) as components of World-Wide Radio Navigation System (WWRNS). IMO has also developed performance standards for shipborne receiver

1 https://www.transnav.eu/Article_Evolution_of_SBASEGNOS_Enabled_Devices_in_Maritime_Lopez,59,1146.html

equipment, for individual GNSS, RNSS and for multi-system shipborne radionavigation receivers (MSC.401(95)). However, there is, as yet, no performance standard for Satellite-Based Augmentation Systems (SBAS).

9 IMO Res. MSC.401 (95) on Performance Standards for Multi-System Shipborne Radionavigation Receivers was adopted in 2015. It identifies SBAS as an augmentation system for GNSS and Receiver Autonomous Integrity Monitoring (RAIM) as a mechanism to provide integrity monitoring.

10 Resolution A.915(22) on Revised maritime policy and requirements for a future global navigation satellite system (GNSS) of 2002 foreshadows SBAS and RAIM and their evolutions. It adds: "without augmentation, GNSS accuracy does not meet the requirements for navigation in harbour entrances and approaches or restricted waters". Further, "GPS does not provide instantaneous warning of system malfunction" (annex, paragraph 2.1.1.4). Finally, there is mention the resolution should be reviewed periodically (which has, so far, not been conducted). Resolution A.915(22) also states: "augmentation provisions should be harmonised worldwide to avoid the necessity of carrying more than one shipborne receiver or other devices" (annex, paragraph 3.1.3).

11 The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) describes all elements of an SBAS relevant to maritime administrations in their Guidelines G1152 (SBAS Maritime Service). It notes test standards for (type approval) do not exist yet, although they expected to be available in the future (section 5.1).

About DFMC and ARAIM

12 Resolution MSC.401(95) on Performance Standards for Multi-System Shipborne Radio Navigation Receivers of 2015 promotes the use of augmentation systems. It mentions: "Augmentation systems use ground-based or space-based transmitters to provide augmentation data to improve accuracy and integrity for specific service areas (such as navigation in harbour entrances, harbour approaches and coastal waters)". Whereas the legacy SBAS is based on a single frequency, e.g. the GPS-like L1 signal (1575.42 MHz), and provides augmentation for GPS satellites only, the Dual-Frequency Multi-Constellation (DFMC) SBAS provides dual-frequency augmentation service for all GNSS constellations (i.e. GPS, Galileo, BeiDou and GLONASS). The DFMC SBAS receiver will need the capability to track both the L5 and L1 signals with the SBAS data (i.e. ephemeris parameters, correction and integrity information) required for the DFMC SBAS service transmitted through the L5 frequency (1176 MHz). The minimum DFMC SBAS capabilities support the same type of operational services as L1 SBAS. DFMC SBAS provides this service in much the same way as L1 SBAS, using corrections broadcasted by geostationary and non-geostationary satellites applied to the GNSS pseudorange augmented by SBAS. DFMC SBAS will offer improved availability, continuity, accuracy, and integrity by using ranging sources with two frequencies to provide ionosphere-free pseudorange measurements.

13 Advanced Receiver Autonomous Integrity Monitoring (ARAIM) is a satellite navigation capability that provides the integrity of highly available, continuous, and accurate GNSS position. ARAIM develops navigation solutions using the same GNSS satellite constellations as DFMC SBAS. ARAIM extends RAIM capability to multiple GNSS constellations, adds a dual-frequency mode, and provides additional Integrity Support Data (ISD) through a broadcast channel.

14 ARAIM includes an offline ground monitoring architecture, which provides updates on the nominal performance and fault rates of multiple GNSS constellations. This integrity data is contained in the Integrity Support Message (ISM) that is generated by an offline ground monitoring network and is provided to the receiver by means of GNSS signals. The ISM allows to monitor and update on a regular basis the performance information over the evolution of the constellation without requiring equipment changes. In this offline architecture, the ISM is not expected to be updated frequently. Both ARAIM and RAIM use the GNSS receiver to determine the satellite position integrity by monitoring the consistency of measurements.

15 The combined use of GNSS, DFMC SBAS and ARAIM is compliant with the user requirements described in IMO Res. A.1046(27) and A.915(22) for a defined service area, including navigation in harbour entrances, harbour approaches and coastal waters.

16 The ARAIM service complements the DFMC SBAS one, offering resilience to SBAS satellite outages, that frequently appear at low elevations, and enabling navigation with integrity, outside of the SBAS service areas (i.e. polar regions).

17 Radio beacon Differential GPS (DGPS) meets IMO requirements for accuracy and integrity for marine navigation in harbours areas and coastal waters. However, its coverage is limited to Medium Frequency (MF) radio ranges and it is 1990s technology. Australia, United States, Japan, United Kingdom and Republic of Ireland have discontinued their radio beacon DGPS service. DFMC SBAS and ARAIM is an alternative to DGPS.

18 In accordance with the requirements stipulated in IMO Res. A.1013(26), necessary information for the assessment of the proposal is given below.

Is the subject of the proposal within the scope of IMO's objectives?

19 The cosponsors of this proposal, some of who operate SBAS systems and GNSS constellations enabling ARAIM services, are committed to providing long-term, continuous, stable and reliable services for the users in their defined service area. SBAS and ARAIM can enhance the safety and efficiency of marine navigation. The subject is, therefore, clearly within the scope of IMO.

How is the proposed item related to the scope of the Strategic Plan for the Organization and how does it fit into the High-level Action Plan?

20 IMO's Strategic Plan (2018-2023) has a key Strategic Direction (SD 2) to "Integrate new and advancing technologies in the regulatory framework". SD 2 urges the Organization to review existing instruments, to ensure that the application of new technologies to international shipping are conducted in a manner which continues to ensure the highest practicable standards for maritime safety, efficiency of navigation and prevention, and control of marine pollution from ships. The proposed work item will enhance technical, operational and safety management standards – Strategic Direction: section X.X.

Need or compelling need

21 Some countries are facing serious obsolescence issues in their DGNSS radiobeacon infrastructure. DFMC SBAS and ARAIM are considered by maritime authorities as a cost-effective complementary technology to provide enhanced accuracy and integrity in a worldwide matter in the case of ARAIM, and continent sized areas for SBAS.

22 Flag and port States require GNSS equipment to be of an approved type. This requirement is fulfilled when ships' equipment has a type approval certificate, based on an IEC (or similar) test standard. Importantly, though, as it is not currently possible to test SBAS

functionality (against a standard), industry does not know whether receivers are functioning correctly and whether mariners can rely on the SBAS information.

23 Noting the urgency to provide authorities and manufacturers technical guidance, the International Electrotechnical Commission (IEC), is finishing the work so that to publish a first test standard for the combined use of SBAS and RAIM by 2023, building on the IEC 61108-1 GPS test standard.

24 In order to allow for the implementation of a similar approach for multi GNSS constellations, and the adoption of DFMC SBAS and ARAIM as a safety service for the maritime community, minimum performance standards are needed. Considering the above, a new work item is necessary as soon as possible.

25 The evolution of the various GNSS elements towards DFMC is already taking place. As of today, there are four GNSS constellations which can provide navigation services worldwide and free of charge: GPS, Galileo, BeiDou and GLONASS. The availability of multiple constellations contributes to improve the GNSS position solution and minimizes the risk of having insufficient satellites within a single constellation.

26 Furthermore, states responsible for the GNSS constellations are introducing DF services gradually, such as ARAIM. The use of DF solutions can mitigate vulnerabilities of the GNSS service such as radio frequency interference affecting a single frequency.

27 As a consequence, a number of States and regions also plan to deploy DFMC SBAS services which take advantage of the availability of several constellations and frequencies and ensures a robust and safe GNSS navigation which the maritime sector can benefit from. Operational SBAS systems such as WAAS, EGNOS, QZSS and GAGAN have been providing differential corrections and integrity bounds for the L1 GPS C/A and L1 SBAS ranging signals. All current operational and future SBAS providers (i.e. China (BDSBAS), Korea (KASS), Africa (SBAS-ASECNA), Australia/New Zealand (SPAN) and Russia (SDCM)) have DFMC SBAS in their roadmap.

28 The creation of an IMO performance standard for DFMC SBAS and ARAIM services will also ensure a simpler and cost-efficient transition to the upcoming DFMC GNSS scenario. The introduction of DFMC SBAS and ARAIM is backwards compatible to current GNSS services and for all fielded shipborne receivers, however the equipment needs to be upgraded to benefit from the enhanced services that will be offered.

Analysis of the issues and implications involved, having regard to both the costs to the maritime industry, as well as the associated legislative and administrative burden, at global level

29 SBAS is funded entirely by the co-sponsors, encompassing all development, implementation and operating costs, and is compatible with other satellite-based augmentation systems. Thus, the deployment of the DFMC SBAS and ARAIM services are not expected to impose direct costs on the maritime industry. The administrative burden to the Organization and to the Member States will be minimal. A completed checklist for

"identifying administrative requirements and burdens" in accordance with MSC-MEPC.1/Circ.4/ Rev.4[2] is provided in annex 1.

Benefits which would accrue from the proposal

30 The combined use of DFMC SBAS and ARAIM will result in enhanced performance in terms of accuracy, availability, and integrity, and provide resilience of the Position Velocity and Timing (PVT) solution compared to using a standalone augmentation system.

31 DFMC SBAS and SBAS L1 provide an augmentation service, meeting the requirements as outlined in IMO Res. A.1046(27). The co-sponsors believe that the combined use of DFMC SBAS and ARAIM will further enhance the safety and efficiency of navigation for mariners compared to the available SBAS L1 services. DFMC SBAS and ARAIM will be offered as a complement to DGNSS radiobeacon infrastructure to enhance the safety of navigation in ocean, coastal waters, harbour entrances and approaches, which is not possible with standalone GNSS.

32 The DFMC SBAS service offers many advantages when compared to the legacy SBAS service in terms of availability, accuracy, and integrity.

- Availability:
  - DFMC SBAS enables the provisioning of an SBAS service in regions of active ionosphere, the enhanced service mitigates the effect where the availability of an L1 SBAS service would be low.
  - The DFMC SBAS design addresses the limitations of the L1 SBAS service to augment multiple constellations.
  - The use of an additional frequency in DFMC SBAS provides additional resiliency to radiofrequency interference (RFI) on L1.
- Accuracy:
  - DFMC SBAS enabled receiver can select a good set of ranging sources from multiple constellations to improve the geometry (Dilution of Precision) of the GNSS satellites used in the position solution.
- Integrity:
  - DFMC SBAS provides a higher reliability and improved integrity schemes at ranging level.

33 The ARAIM service comprises of several major advantages compared to the legacy RAIM such as a higher reliability and integrity schemes. ARAIM has the ability to dynamically enhance the integrity data allowing an improved availability and continuity of service. ARAIM expands the ability to monitor multiple fault cases (i.e. common mode and multiple independent failures), unlike RAIM.

34 The development of an IMO performance standard and the associated IEC Test standard will help national maritime authorities to optimise and recapitalize their DGNSS radiobeacon infrastructure, enabling the possibility to invest in those areas that are especially

[2] See MSC-MEPC.1/Circ.4/ Rev.4, annex 5.

critical from the safety of navigation perspective, and complementing the service with DFMC SBAS and ARAIM, which will provide enhance accuracy and integrity.

Do adequate industry standards exist?

35 No IMO performance standards exist for DFMC SBAS and ARAIM for shipborne receiver equipment.

Scope of the proposal and output

36 The scope of the proposal and requested output is the development of minimum performance standards for DFMC SBAS and ARAIM for shipborne receivers.

Human element

37 The proposal is consistent with IMO's objectives and takes into consideration the human element guidance and principles in IMO Res. A.947(23), in an effort to minimize the impact on the role and workload of Officer of the Watch. The completed human factors checklist from MSC-MEPC.7/Circ.1 is set out in annex 2.

Priority and target completion date

38 DFMC SBAS and ARAIM are expected to be operational worldwide starting in 2028. To ensure there is an IEC test standard in place by then, the following timeline is foreseen. An IMO performance standard should be finalized by 2026, following which work on an IEC standard can commence, to be completed by 2028.

- Therefore, the development of this performance standard is proposed as a high-priority work and should be addressed as soon as practicable within the working arrangements of the Organization.

Committee and/or subsidiary body(ies) essential to complete the work

39 The work should be assigned to the Sub-Committee on Navigation, Communications and Search and Rescue (NCSR).

Estimation of the number of sessions needed to complete the work

40 It is estimated to complete the work in 2 sessions of the NCSR Sub-Committee.

Action requested of the Committee

41 The Committee is invited to consider this proposal and include it in the post-biennial agenda of the NCSR Sub-Committee, with the aim to conduct the work in the 2024-2025 biennium.

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ANNEX 1

CHECKLIST FOR IDENTIFYING ADMINISTRATIVE REQUIREMENTS AND BURDENS

The Checklist for Identifying Administrative Requirements and Burdens should be used when preparing the analysis of implications required of submissions of proposals for inclusion of unplanned outputs. For the purpose of this analysis, the terms "administrative requirements" and "burdens" are defined as in resolution A.1043(27), i.e. administrative requirements are defined as an obligation arising from future IMO mandatory instruments to provide or retain information or data, and administrative burdens are defined as those administrative requirements that are or have become unnecessary, disproportionate or even obsolete.

Instructions:

(A) If the answer to any of the questions below is **YES**, the Member State proposing an unplanned output should provide supporting details on whether the burdens are likely to involve start-up and/or ongoing cost. The Member State should also make a brief description of the requirement and, if possible, provide recommendations for further work (e.g. would it be possible to combine the activity with an existing requirement?).

(B) If the proposal for the unplanned output does not contain such an activity, answer **NR** (Not required).

1. Notification and reporting? Reporting certain events before or after the event has taken place, e.g. notification of voyage, statistical reporting for IMO Members, etc.	NR ☑	Yes ☐ Start-up ☐ Ongoing
Description: (if the answer is yes)		
2. Record keeping? Keeping statutory documents up to date, e.g. records of accidents, records of cargo, records of inspections, records of education, etc.	NR ☑	Yes ☐ Start-up ☐ Ongoing
Description: (if the answer is yes)		
3. Publication and documentation? Producing documents for third parties, e.g. warning signs, registration displays, publication of results of testing, etc.	NR ☑	Yes ☐ Start-up ☐ Ongoing
Description: (if the answer is yes)		
4. Permits or applications? Applying for and maintaining permission to operate, e.g. certificates, classification society costs, etc.	NR ☑	Yes ☐ Start-up ☐ Ongoing

Description: (if the answer is yes)		
5. Other identified burdens?	NR ☑	Yes
Description: (if the answer is yes)		

ANNEX 2

CHECKLIST FOR CONSIDERING HUMAN ELEMENT ISSUES BY IMO BODIES

Instructions: If the answer to any of the questions below is: (A) **YES**, the preparing body should provide supporting details and/or recommendation for further work. (B) **NO**, the preparing body should make proper justification as to why human element issues were not considered. (C) **NA** (Not Applicable) - the preparing body should make proper justification as to why human element issues were not considered applicable.	
Subject Being Assessed: (e.g. Resolution, Instrument, Circular being considered) Deployment of EGNOS for the international maritime community	
Responsible Body: (e.g. Committee, Sub-committee, Working Group, Correspondence Group, Member State) **Sub-Committee on Navigation, Communication, and Search and Rescue (NCSR)**	
1. Was the human element considered during development or amendment process related to this subject?	☑Yes ☐No ☐NA
2. Has input from seafarers or their proxies been solicited?	☑Yes ☐No ☐NA
3. Are the solutions proposed for the subject in agreement with existing instruments? (Identify instruments considered in comments section)	☑Yes ☐No ☐NA
4. Have human element solutions been made as an alternative and/or in conjunction with technical solutions?	☑Yes ☐No ☐NA
5. Has human element guidance on the application and/or implementation of the proposed solution been provided for the following:	☑Yes ☐No ☐NA
• Administrations?	☑Yes ☐No ☐NA
• Ship owners/managers?	☑Yes ☐No ☐NA
• Seafarers?	☑Yes ☐No ☐NA
• Surveyors?	☑Yes ☐No ☐NA
6. At some point, before final adoption, has the solution been reviewed or considered by a relevant IMO body with relevant human element expertise?	☑Yes ☐No ☐NA
7. Does the solution address safeguards to avoid single person errors?	☑Yes ☐No ☐NA
8. Does the solution address safeguards to avoid organizational errors?	☐Yes ☑No ☐NA
9. If the proposal is to be directed at seafarers, is the information in a form that can be presented to and is easily understood by the seafarer?	☑Yes ☐No ☐NA
10. Have human element experts been consulted in development of the solution?	☐Yes ☑No ☐NA
11. **HUMAN ELEMENT**: **Has the proposal been assessed against each of the factors below?**	
☐ CREWING. The number of qualified personnel required and available to safely operate, maintain, support, and provide training for system.	☑Yes ☐No ☐NA
☐ PERSONNEL. The necessary knowledge, skills, abilities, and experience levels that are needed to properly perform job tasks.	☑Yes ☐No ☐NA

□ TRAINING. The process and tools by which personnel acquire or improve the necessary knowledge, skills, and abilities to achieve desired job/task performance.	☑Yes □No □NA
□ OCCUPATIONAL HEALTH AND SAFETY. The management systems, programmes, procedures, policies, training, documentation, equipment, etc. to properly manage risks.	□Yes □No ☑NA
□ WORKING ENVIRONMENT. Conditions that are necessary to sustain the safety, health, and comfort of those on working on board, such as noise, vibration, lighting, climate, and other factors that affect crew endurance, fatigue, alertness and morale.	□Yes □No ☑NA
□ HUMAN SURVIVABILITY. System features that reduce the risk of illness, injury, or death in a catastrophic event such as fire, explosion, spill, collision, flooding, or intentional attack. The assessment should consider desired human performance in emergency situations for detection, response, evacuation, survival and rescue and the interface with emergency procedures, systems, facilities and equipment.	□Yes □No ☑NA
□ HUMAN FACTORS ENGINEERING. Human-system interface to be consistent with the physical, cognitive, and sensory abilities of the user population.	☑Yes □No □NA

Comments:

(1) Justification if answers are NO or Not Applicable.
(2) Recommendations for additional human element assessment needed.
(3) Key risk management strategies employed.
(4) Other comments.
(5) Supporting documentation.

The justification as to why human element issues were not considered NO or NA (Not Applicable) is as follows:

(8) This will not have effect on organizational procedures and hence errors.
(10) It was not considered necessary to engage specialist support as the human element benefits are quite straightforward in this proposal.
(11d) Not considered appropriate.
(11e) Not considered appropriate.
(11f) Not considered appropriate.

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