IALA WORKSHOP ON ENHANCED RADAR POSITIONING SYSTEM STANDARDIZATION

WORKSHOP REPORT

29 November to 1 December 2021

Virtual workshop

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1 December 2021

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Contents

Report of the workshop on Enhanced Radar Positioning System (ERPS) standardisation

1. SESSION 1 - OPENING OF THE WORKSHOP

The workshop on ERPS standardisation was held between the 29th of November and 1st December 2021. The workshop was attended by 53 participants from 29 countries.

Simon Millyard, chair of the ENG committee and chair of the workshop, welcomed participants and went through the technical programme including the scope of the technical session and the working sessions. Simon presented the different experts involved in the discussions and recalled the expected outcomes of the week.

1.1 Welcome from IALA, Francis Zachariae - IALA Secretary-General

Francis Zachariae IALA Secretary-General welcomed participants to the workshop on Enhanced Radar Positioning System (ERPS). Secretary-General thanked the chair Simon Millyard and all the working group chairs, speakers, and participants. An amazing group of specialists and experts who will provide relevant insights about this very complicated and important subject. IALA have always tried to identify threats to the maritime services including weather, climate, visibility etc, but in an increasingly connected and technologically dependent world, new areas of vulnerability are emerging. Secretary-General recalled the celebration of the workshop on cybersecurity and underlined that both workshops are very much related dealing with vulnerability to intentional or unintentional hacking, jamming, spoofing and such like. This is of course the price of being more digital and connected and a price the maritime user and AtoN authority are willing to accept, but IALA and their members need to be well prepared and protected. It is generally accepted that GNSS is the primary position and timing sensor for maritime navigation, but it is well known there is a need for alternative resilient systems. True resilience will only be achieved by the use of complementary, dissimilar systems, such as radar, or low frequency, high power terrestrial systems, or autonomous on-board alternatives, such as inertial sensors. This is exactly the purpose of this workshop. To learn more about ERPS, proven in trials, and which uses an enhanced radar & enhanced racon to provide a vessel with position which is independent of GNSS and offers the mariner a resilient alternative.

More specifically it is the hope that the workshop will:

- Draft outlines for each standard identified during the workshop.
- Draft liaison notes (from IALA) to each organization that has been identified for each of the proposed standards, requesting the draft standards be added to their agendas.
- Proposed road map and timeline.

All this will be input to the ENG committee and incorporated into their workplan. Secretary-General highlighted his willingness to understand the project and possibilities better and how the IALA committees can better take this into account in the future work. Secretary-General sent his thanks for the continued dedication of those who plan and attend this coming week for the time you give to ensure that the committees can work more efficiently with the very important solutions to the need of resilient PNT.

1.2 Working programme of the week and expectations - Paul Mueller, Half Pi

Paul Mueller presented the different goals of the meeting:

- Education about the ERPS framework and expectation;
- Justification of the development and use of this technology;
- Identification of the organisations involved in the process for the standardisation of the ERPS and the standards applicable to the system; and,
- Planification of the work ahead was also envisaged.

Paul also underlined the need to develop some outputs as the roadmap, the draft liaison notes to other organisations identified aiming at putting ERPS on their agendas and even, drafting standard cover sheets. Such outputs will be continued on the ENG committee with the possibility to work intersessionaly.

1.3 Driver – Paul Mueller

Paul remembered the fact that resilient PNT is part of the eNavigation strategy implementation plan elaborated by IMO (MSC.1/Circ.1595). To achieve resilience in PNT service provision, it is necessary to put in place a back-up or fall-back arrangements utilising alternative techniques that do not share the failure modes of GNSS. IALA documents mention the GNSS vulnerabilities and recommendations are addressed with the purpose that maritime administrations and users take into consideration that GNSS is not secured. Even more, US administration emphasised that GNSS is not secure for navigation in some parts of the country. Paul also underlined that AIS is totally dependent on GNSS and can not be a back-up for PNT. It is a totally different system relying on GNSS and conceived for different purposes others than providing a source of PNT.

1.4 General view on ERPS concept - Guillaume Martin, AMG Microwave

Guillaume started providing some insights on GNSS vulnerabilities and the importance to provide a back-up for GNSS totally independent and with high reliability and availability of the signal. Radar beacons are nowadays receivers / transmitters in the X-band and S-band. The racon enhanced detection and identification of certain radar targets. The racon responses to the presence of ships radars by sending a characteristic signal. ERPS concept is based on the capability for eRacon to provide absolute position information encoded in its response signal to the eRadar. The concept is similar to what navigators would do by hand, using radar target azimuth and distance to triangulate a vessel's position. eRacons are essentially normal racons modified to encode their identification and position into the signal response to the radars that interrogate them. It is important to locate eRacon in a surveyed and fixed place. Two examples of position calculation were presented, with the view of only one eRacon and on view of two eRacon. The position solution could be then calculated knowing the ship true heading and with two racons, the calculation is made without knowing the ship heading. Pythagoras theorem would calculate two possible solution and one of the solutions will be discriminated with the target azimuth.

1.5 Results of ERPS trials (also IWW) - Paul Mueller

Paul presented the different test radars: Denmark (EfficienSeas Project, 2011), UK (ACCSEAS Project, 2013) and Singapore tests radar (2015 and 2017) were presented, Furuno furbished the eRadar and eRacon. Differences between UK and Singapore, Furuno tried different techniques to calculate position and account for more parameters. The Singapore sea trials are extensions to the previous trials done in Denmark and UK where the Singapore sea trials were carried out in a busy port environment and also there were several infrastructure constraints. The accuracy and availability figures are presented below:

Table 1 - Performance parametres during the Singapore trials (2017)

	One eRacon		Two eRacons or Best Two of Three		Best Available	
Trial Phase	Horizontal Error (meters)	Availability (%)	Horizontal Error (meters)	Availability (%)	Horizontal Error (meters)	Availability (%)
Static	37.5	86.7	11.9	61.9	16.5	86
Dynamic	30.3	87.4	26.2	64	25.3	87.9
Berthing	38.6	87.3	2.5	62.7	12	93.7

The following conclusions on the ERPS trials were underlined:

- Generally good performance
- Radars in busy harbours are poorly serviced by racons in general due to the important number of radars working in the same frequencies (issue addressed between IALA and CIRM):
    - Blocking of signal by other vessels
    - Racon busy transmitting
    - Racon Side Lobe Suppression (SLS) issues including too many radars at same frequency
- eRacon modulation can be visible on radar display
- Geometry is important (HDOP); careful site planning is essential
- Expected additional cost per unit for racons and radars is low
- ERPS is a candidate backup system to GNSS

1.6 Need for standardisation and appointed bodies - Pablo Racionero / Neil Sparling, Pharos Marine

ERPS showed its feseability to be a source of PNT but the system requires standardisation for it to become useful and interoperable. Pablo recalled the need to establish standards based on consensus and scientific research. The interoperability by using similar design principles for racons transmitting the signal and radar receiving these ones are expected by the manufacturers in the framework of providing safe, reliable and secure systems. Several organisations are already identified to achieve the task. It is expected that some working groups with the release of several document package would be set up. Finally, Pablo expressed the potential benefice for manufacturers, users and society by providing such standards.

1.7 Standardisation in ETSI / TG Marine - Mario Walterfang, German Federal Waterways and Shipping Administration

Mario underlined the importance of standardisation as well but having in mind the limitations that imply such process. The scope and type of the ERPS regarding the standardisation is visualised in the scheme below. It was mentioned that all type os standards should be covered:

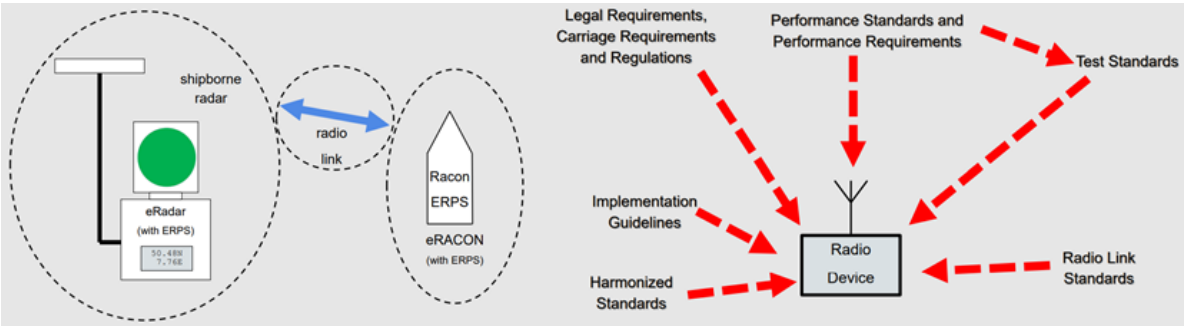

Figure 1 - Scope and type of ERPS standardisation

The main international standardisation body for ship equipment is IMO through:

- The issue of regulations and carriage requirements (SOLAS chapt. V);
- Performance requirements for services:
    - Resolution A.615(15) Radar Beacons and Transponders
    - Resolution A.222(VII) Performance Standards for Navigational Radar Equipment (amended by A.477)
    - Resolution A.278(VIII) Supplement to the Recommendation on Performance Standards for Navigational Radar
    - Equipment (A.222(VII)) Symbols for Controls on Marine Navigational Radar Equipment

- Resolution A.477(XII) Performance Standards for Radar Equipment (Revised by MSC.192(79), for older radars only).

- Performance Standards, incl. Minimum Requirements for marine devices
  - Resolution MSC.192(79): Adoption of the revised performance standards for radar equipment
  - Resolution MSC.191(79): Performance standards for the presentation of navigation related information on shipborne navigational displays

The IALA standards, recommendations and guidelines were addressed. ITU issues global radio link standards that would be considered for ERPS:

- Recommendation ITU-R M.824-4: Technical parameters of radar beacons
- Recommendation ITU-R M.1460-2: Technical and operational characteristics and protection criteria of radiodetermination radars in the frequency band 2 900-3 100 MHz
- Recommendation ITU-R M.1796-2: Characteristics of and protection criteria for terrestrial radars operating in the radiodetermination service in the frequency band 8 500-10 680 MHz

ITU also ITU issues the Radio Regulations (RR).

IEC was also identified as a key playing role in standardisation through the issue of test standards for devices (IEC62288 / IEC62388 / IEC62252). But also defines digictal interfaces for devices IEC61162.

In parallel these global standardisation bodies, some regional bodies as ETSI elaborates European Standards, harmonizing standards. The MED (2014/90/EU) is on use in Europe for Notified Bodies tests and certifies a device for compliance with performance standards applying the appropriate test standard. All other radio equipment should comply in EU with Directive 2014/53/EU. Finally, the following standards were identified for racon and radar with the action to evaluate which of these standards already cover or should be amended in regards with eRacon and eRadar:

Table 2 - Standards applying to racon and radar

	RACON	Radar	eRACON (ERPS)	eRadar (ERPS)
Legal Requirements, Regulations	national	IMO SOLAS V		
Performance Standards Performance Requirements	IMO A.615(15)	IMO A.222(VII) IMO A.278(VIII) IMO A.477(XII) IMO MSC.192(79) IMO MSC.191(79) (ETSI EN 303 676)	TBD	
Test Standards	IEC 62388 IEC 62288 IEC 62252	IEC 62388 IEC 62288 IEC 62252 (ETSI EN 303 676)		
Radio Link Standard	ITU-R M.824-4	ITU-R M.1796-2 (ITU-R M.1460-2)		
Implementation Guidelines	IALA R-101 IALA GI 1010	?		
Harmonized Standards	?	ETSI EN 302 248 (ETSI EN 302 194)		

1.8 Draft roadmap - Simon Millyard, Trinity House

Simon started his presentation mentioning the challenge and important investment ahead on benefit of providing a candidate technology for resilient PNT (rPNT) and GNSS independent and back-up system. A list of steps to development were presented to achieve effectively the integration of ERPS on the maritime domain which would finalise by the adoption of AtoN authorities and ship owners. In any case, the challenge to fullfill the requirements, standardisation and trials needed with a long term view is expected. Some issues were identified as the IMO approval and potential mandated carriage. A cost/benefit analysis, risk analysis

and political willing will define how fast or slow a disruptive technology/system will be implemented in the market.

1.9 Question and answers

The following questions raised during the session:

- *What is the range of ERPS?* Within coastal and harbours approaches about 10 miles.
- *What kind of information can racon send to radar?* The location of the racon has been surveyed with standard surveyed methods to determine such location. That will allows to ship to calculate its position with the known location of the racon. It remains a challenge to calculate the position in busy harbours. The location of the racon is the information provided to the ship radar. Morse code signal is sended from the racon to the radar. The first assumption of ERPS is that the ship can not know its own position (from a conventional GNSS source in case of non availability of GNSS), ERPS provides the capability to compute the ship position without this initial ship location.
- *Some concers were expressed in regards with racon delays* – delay of 500 ns that means 75mtrs. ERPS has to consider such delay and should be standardised. The delay will also dependent of the radar/racon manufacturer because of the non standardisation.
- *New generation of racons could also imply different racon response.* US recommends to update the racon technology in response to the newest solid state radars (different to the current radars – magnetron). This also faces a lack of standardisation, there are recommendations on current radar/racon working with solid state for manufacturers. This is not only an ITU issue but something that could be developed between manufacturers and users (mariner). One of the points of this workshop is what organisations should be involved in this standardisation.
- *Does have racon to be registered or can any eRacon work without any register (as for AIS stations)?* Radar does not need to have any pre-knowledge for where eRacon are located.
- *Is it intended that ERPS will be used for S-band or would be a system for X-band? S-band would be included for standardisation purposes*? Most common use being X-band, then standardisation could be just focused on these ones.
- *Related to the discussions on ERPS capability on new solid state radars, it should be prioritised to establish specifications for the signal out from the racon and the specification for the equipment that is going to receive it. After that, the issue on how to make sure that the signal is available both magnetron and solid state radar could be stressed.*
- *Encoding of racon position into its return requires frequency modulation techniques that is only available on new technology solid states radars. The return would be like a pulse in conventional magnetron radars. Would the system be restricted only to s-band for the moment? Can this technique also be used on magnetron radars?*There is no technical reason why a magnetron radar can not receive these pulses. Depending on the receiver that would be used, a modification is just required to take an encoded modulated message then a magnetron radar could work with ERPS. During the trials, position is encoded using FSK modulation in the leading dash of the racons' Morse code response. The type of preferred modulation that would be used in the future is also a matter to be addressed.
- *What is the experience related to the realistic range of ERPS during the trials?* 10 miles in Denmark and UK and smaller in Singapore. More powerful radar will be seen in a longer distance, return signal from the Racon to the Radar is never a problem. The issue with the radar is the sensitivity because of the very wide band available. The location of eRacon each 30 NM would provide an effective service as assess.
- *The question related to integrity monitoring for the position of radar beacon and the ability to turning off, authenticate and validity checks on the data transmission was raised.*

1.10 Brainstorming on organisations involved

Michael Hoppe, ENG WG3 vice chair, chaired the session setting the scene on organisation and standardisation areas that would be considered in the development of ERPS and would be further assessed during the working period. The following areas of standardisation were identified or proposed to be evaluated:

- eRadar: addressing SOLAS or non SOLAS, use of an stored almanac that may include also classical racons
- eRacon: implementation of a time stamp, configuration of a secure channel, calibration of the device, surveyed and validated position, sensitivity
- On air (spectrum): authentication
- PNT (interfacing): absolute positioning, ranging, operationnal performance parameters, MSR 401 (95), PNT information tool…
- Integrity monitoring: possibility to implement a time stamp

The participants raised as well the following matters and technical questions:

- The assessment of valides uses cases would be a task to be progressed
- The implementation of ERPS should be done through X-band or S-band or/and both or even solid state radars
- Technical considerations should also be given to the calibration of devices, equipment.
- A good alternative to provide authentication could be a digital almanac including all type of AtoN and even connected devices. Participants also seen that processing radars which is modulated, authentication of the eRacon signal could be a challenge. In case of using an almanac, it should be considered the origin of the data and what data should be included.

A roadmap was also stressed during the session and would be likely developed during the working sessions, however, some milestones and workflows were retained:

- (ITU) WWRC 2023 (agenda already complete) / 2027
- IMO liaisons to inform about the work item that would progress in IALA. Documentation from IMO would be relevant to update

2. WORKING GROUP SESSIONS - DRAFT STANDARDS

2.1 Working group 1 - Technical standard

2.1.1 Executive summary

The following tasks were assess and requires further consideration in IALA:

- It was noted that Furuno has a patent on the ERPS approach, albeit with an understood intention to make it freely available. IALA to consult with Furuno to seek confirmation that this will be the case. Pub. No.: US 2013/0265188A1 - Pub. Date: Oct. 10, 2013. Ernest Batty provided a copy of the patent to the secretariat.
- The WG reviewed the current status of Radar and Racon standardisation and investigated what would need to be amended or introduced to support ERPS. It was agreed that a request for a new work item would probably be required from the IMO and that it should be worded to ensure it supports the wider resilient PNT case, rather than focus on ERPS only, in order to prevent a conflict with the development of other IALA interests (such as R-mode).
- Consideration was given to the need for standards or amendments within the IEC, ITU, IALA and others, recognising that a stable, agreed, definition of ERPS would be required before much of the real work could start, but getting items on the relevant agendas could start earlier.
- It was noted that there are political and technical questions to address before too much work could be taken forward. There is a political question on the development of IEC standards for Racons as

it seems there are none currently and therefore introducing some may require discussion regarding potential implications before any technical elements are considered.

2.1.2 Possible future work areas for IALA

- Support a review of the ERPS technical approach to understand whether it could be improved, prior to starting the standardisation work
- There may be a benefit in IALA instigating a survey of mariners regarding the need for Racon to be triggered by S-band radar. It was noted that IALA should check with CIRM and Nautical Institute to see if they have already done such an exercise.
- It was noted that there is no single representative body for Racon and Radar manufacturers and that there would be a benefit in bringing them and other interested stakeholders together to discuss ERPS, this could be a role for IALA.

2.1.3 Introduction

The group was chaired by Alan Grant, ENG WG3 chair. The following matters were stressed according to the terms of reference identified in 0.

2.1.4 Discussions

Discussions were broken down to key areas of which the main points are captured below, with the intention of supporting further discussions at a future meeting of the ENG Committee.

2.1.4.1 ERPS technical description

- The technical description needs to be reviewed and refined to explore whether the approach adopted to date can be improved.
- Likely to be an academic type study/committee review that would need to be funded, potentially by interested parties rather than specific organisations.
- Need to consider modulation schemes and overall approach to confirm it's sensible and appropriate.
- Timeline: Could be started and fed into the standards work.

2.1.4.1.1 Develop overall aim and description of approach

There is a need to develop an overal aim for ERPS and a description of how it is anticiapted to work. There are a number of open questions that this would then address.

- Provide direction on open questions - S &X band triggering of eRacons for example.
- Determine aspects such as the permitted delay in Racon responding – should that be subject to calibration or standardised (i.e. set a limit or performance range between x and y)? Current approach is offered as being <700ns but likely to be design dependent.
- Is ERPS a backup or complementary system - how will it be used? Will it be used all of the time as part of a system of systems approach or only used in times of GNSS outage?
- Is the aim to come up with an absolute position and/or a range? Discussed that ERPS provides a position – but there's a question of whether it should provide a range and known location information (i.e. act as a pseudolite) for combination with other ranging systems. There are likely to be pro's and con's to each.
- Given the use of pulse compression techniques in solid state radar, the question was raised on the potential use of un-modulated pulse? It was discussed that identification of the eRacon may be an issue and location may not be sufficiently accurate, but it could be explored.
- Racon is mentioned in S-201 which captures aspects of ERPS and chart accuracy and should be taken into consideration. Query current accuracy of ECDIS charts. Interface between racon and chart data is also an open question - ERPS seeks to avoid the need to refer to other data.

- How accurate do we need to have the position of the Racon and how is that captured in S-201 format currently? (accuracy in demo was in the order of 1m, based on AIS data - offering almost 20m accuracies). Potential to use an Almanac of data.
- How is the final position data used - does it feed into the MSR or other type of receiver?
- Need to consider data authentication and cybersecurity. Also important to ensure initial set up is correct and tested. It was also discussed that the user's receiver would benefit from having the ability to flag an input that fails a plausibility test with the option to allow the mariner to de-select that input. This is more a receiver consideration but supports the wider integrity discussions.
- SOLAS and non-SOLAS user groups - potential to mandate carriage on larger SOLAS vessels?

2.1.4.2 Radar requirements

2.1.4.2.1 IMO

It was noted that there would be a need to invite the IMO to consider how ERPS would affect current standards and other IMO Instruments.

- Consider whether this needs a new agenda item? Perhaps offer it as part of a resilient PNT topic to avoid conflict with R-mode. There is a benefit to raise awareness of ERPS within the IMO initially.
- On the topic of the need for a new IMO work item specific to ERPS, it was noted that historically there was a "user selectable mode" captured within previous ITU documents, which was not specifically mentioned within the corresponding IMO instrument. This seems to show a method of making an operational change at the ITU level potentiually without needing a change at the IMO. This raises a question on whether there is a need to have an IMO doc? Potentially a route to consider if time is an issue.
- IMO Resolution 615 (1987) is quite old but offers a general description of Racon and Radar interaction and offers some specifications.

2.1.4.2.1.1 S band radar requirements regarding Racons

- It was noted that the IMO removed the requirement for S-Band radar to trigger racons. This doesn't meant they don't, rather its down to manufacturers to decide whether they continue to do so. Clearly this has implications on the design and use of eRacons.
- The group felt that it would be pertinent to seek clarification from the IMO as to whether the need to trigger Racons at S-Band does exist and whether the wording could be amended to reflect a "nice to have" rather than a definite yes or no. It was understood this requirement was removed to allow solid state radar to develop.
- Is there a maritime need for Racons to be triggered at S-Band? What does the mariner want regarding? Possible role for IALA to gauge interest from mariners via Nautical Institute survey (or other avenues)
- consider eRacon to support solid state radar.
- It was noted that solid state radar is not standardised.

2.1.4.2.2 IEC

The IEC develop test standards which would need to be updated. The following points were noted.

- IEC standards exist for SOLAS radar, non-SOLAS radar but not for racons.
- Question on whether there should be something for eRacons if there's nothing for conventional Racons? What are the technical and political implications? Likely to need some form of standardisation.

- CIRM supports the development of the IEC standards on Radar but these are currently focused on shipborne radar. Is there a role for IALA to encourage support to Racon standards within CIRM too?
- For Info - IEC has produced test standards for AIS base stations and ship based systems to support AIS AtoN.
- IEC test standards confirm performance but regional standards may look wider than performance.

2.1.4.2.3 ITU

ITU deal with spectrum elements and while the frequency band will not change, the introduction of new modulation and additional data may indicate a change of use (to be confirmed).

2.1.4.2.3.1 Possible need to go to WRC

- Not clear yet, but may be a need to review the radio regs to check whether the change of modulation is within the current approved designation, if not a change may be required (radio positioning v comms etc). This is likely to require expert advice. General feeling is this may not be required - depending on review of current wording.
- TGMarine/ETSI has previously discussed seeking a new band for solid state radar in support of inland waterways, but this was not progressed as it was anticipated that a natural switch to solid state radar would occur by the time a new frequency was allocated.
- Adding data to the channel could leave it subject to additional rules - i.e. EU data legislation for a communications system.

2.1.4.2.4 ETSI

2.1.4.2.4.1 Shipborne radar not part of ETSI

There may be a need to consider ETSI from the wider harmonisation perspective. While not performance requirements *per se* the European RED brings in restrictions on how the system is used – i.e. efficient use of spectrum, security etc. These seek to support harmonisation but do bring in other requirements and constraints.

2.1.4.2.5 CIRM

- It was recognised that CIRM doesn't represent all radar and racon manufacturers, but may be a good body to seek assistance from on the following questions:
    - Should all Racons detect solid state radar modulation? If so, it is anticipated that the specification of current racons may need to change.
    - How should Racon data back to the radar be recognised? Guidance from radar manufacturers may be required to agree a common approach in lieu of standards.
- Consider special racon pulse.

2.1.4.2.5.1 interaction with manufacturers to agree scope

- May need a separate workshop with all stakeholders to understand how we can all work together to bring ERPS together if there are no standards for solid state radar/racon interaction.
- Will need to agree baud rates, frequency shift, error correction etc. and explore open questions. Need to agree a technical specification to support standards etc.

2.1.4.3 Racon requirements

Racon elements are likely to be included in the above, with the following exceptions.

- ITU:
    - ITU 824 - would need updating to reflect ERPS and to harmonise it with other documents.
- ETSI:

- Racon would be part of RED (Receiver Equipment Directive) which brings in additional requirements for Europe. The approach is being explored by inland waterways radar so would be benefical to follow similar approach.
- Similar approaches to RED in different geographical regions - i.e. FCC, China, Australia etc.

2.1.4.4 Interoperability testing:

- There will be a need to consider interoperability testing to ensure eRacon and eRadar from dissimilar manufacturers work correctly.

2.2 Working group 2 – Portrayal / interfacing and Regulatory

2.2.1 Executive summary

The WG2 had a meeting on 30th November to discuss and deal with the following topics:

- **ERPS Portrayal/Interface standard:** How should eRadar display or forward the derived data?
  - What data should be displayed/interfaced
    - Lat and Long, Valid (Integrity),
    - Source identicator (like $G for GPS)
  - Where to display/interface?
    - ECDIS chart, S200
    - Symbolisation of an ERPS position
  - Onboard PNT
    - MSR MSC.401 (95)
    - PNT DP Guideline MSC.1/Circ. 1575
    - Others
  - Identified Radar standards which needs to be updated
    - IMO performance standards
    - IEC
    - IALA ARM committee (draft LN)
    - IHO (LN)
    - Others
- **Regulatory aspects**: the following table depictes the document and action identified:

Table 3 - Actions identified within interantional organisations

	Organisation addressed	Actions identified
Legal Requirements, Regulations Performance Standards Performance Requirements	IMO	- Recognised as part WWRNS A.1046 (22) - SOLAS Chapter V? - Update of existing Radar PS - Draft an input (information paper) to IMO to ask for a new agenda item
Display chart systems (S200)	IHO	LN S24X domain could be used Action requested_ - Reserve ERPS portrayal data blocks
Test Standards	IEC RTCM	Type approval for ERPS IMO PS providing the minimum requirements TC80 which needs to be ask for a new work item Get advice from other colleagues, e.g. from USCG
Recommendations, Guidelines	IALA	- Update Guideline 1147 - Already part of new work plan of ENG Committee - Present work/results from trials to other organisations (IEC, ITU, IHO,...)
Others?		

- **Roadmap:** a roadmap was established taking into account the number of workflows and a activities estimated for the provision of the service:

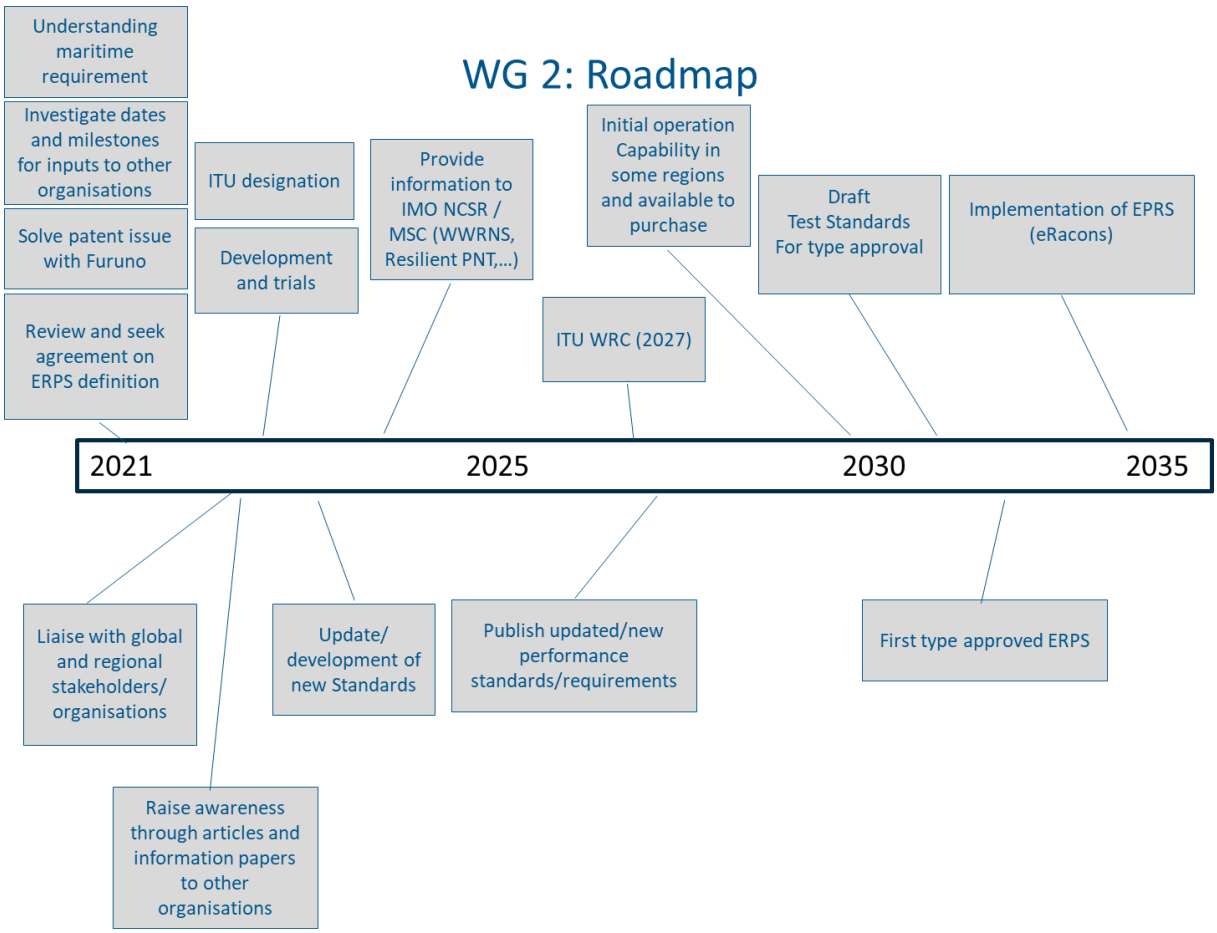

Figure 2 - ERPS implementation roadmap

- **A information paper to IMO** was drafted providing an extended insight into ERPS technology which can be considered to serve as a independent backup to GNSS to provide resilient PNT, please refer to ANNEX D.

2.2.2 Introduction

The group was chaired by Michael Hoppe, ENG WG3 vice chair. The following matters were stressed according to the terms of reference identified in 0.

2.2.3 Discussions

- A first discussion was performed to gather information how to portrayal and interfacing the position information derived in the ERPS. The result is provided on slide 3 of the attached presentation
- The WG further identified the appropriate regulatory bodies which could support portrayal and interfacing of ERPS position information. Further the group discussed the required actions to be taken and the possible way how to liaise with the various standardisation organisations m. Table 1 on slide 4 provide the results collected during the WG session.
- The WG considered a possible roadmap for the implementation of a future ERPS based on information presented by Simon Millyard at the plenary session (29th November). The result is a first draft roadmap as provided on slide 5 in the attachment.
- To progress standardisation work at IMO, the WG started the development of an input paper to IMO which should inform IMO about EPRS and to enable further work at IMO with respect to a new work item. This new work item should enable to consider ERPS as a candidate system for resilient PNT as a backup to GNSS within the WWRNS and to revise existing performance standards for on board radar equipment. The draft paper is provided as a working document which should become an input document to ENG15, added in ANNEX D.

- The WG chair thanks all attendees for their contribution

3. CLOSING SESSIONS

3.1 Review of workshop highlights

The working group chairs reviewed the report seeking for comments. The following highlights were identified:

- Need a review of the technical approach of the ERPS
- ERPS is a valid candidate of rPNT, on a technical perspective
- ERPS supports the IMO eNav SIP in terms of rPNT
- Number of technical and political challenges to be resolved
- Opportunity to engage sister organisation to take technologies into practical systems to provide rPNT

3.2 Roadmap and organisations involved

The initial roadmap developed in WG2 was reviewed and presented in Figure 2 - ERPS implementation roadmap.

3.3 Closing remarks

Simon Millyard was very pleased about the participation and contributions received during the 3 days workshop. It was seen as a kick-off for the ERPS standardisation workflow in IALA.
Francis Zachariae congratulated the work done with specific activities to be developed in the IALA framework. The need to provide rPNT has been in th scene for years now but the provision and development of PNT services indepent of GNSS is a task assigned in IALA that would be progressed in the coming ENG committees and next work plan.

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ANNEX B PROGRAMME FOR THE WEEK

DAY 1 – Monday, 29 November 2021

Time (UTC)	Activity	
1000 – 1200	**Session 1 – Opening of the Workshop**	**Chair: Simon Millyard**
5 min	Welcome from IALA	Francis Zachariae
10 min	Working programme of the week & expectations	Paul Mueller
15 min	Driver	Paul Mueller
15 min	General view on ERPS concept	Guillaume Martin, AMG Microwave
15 min	Results of ERPS trials (maritime and IWW)	Paul Mueller, Half-PI
15 min	Need for standardisation and appointed bodies	Pablo Racionero / Neil Sparling, Pharos Marine
15 min	Standardisation in ETSI / TG Marine	Mario Walterfang, WSV
15 min	Draft roadmap	Simon Millyard
5 min	Q&A	
1150 – 1200	**Break**	
1200 – 1300	**Session 2 - WG Session – Draft standards**	**Chair: Michael Hoppe / Ronan Boyle**
40 min	Plenary session: Brainstorming on organisations involved and formation of working groups	
20 min	Assignment of break-out groups to create outlines for draft standards WG1 - Technical standard: • ERPS Over the air protocol • ERPS Radar operational standard • ERPS Racon operational standard WG2 - Portrayal / interfacing and Regulatory • ERPS Portrayal standard • Regulatory aspects • Roadmap	

DAY 2 – Tuesday, 30 November 2021

Time (UTC)	Activity	
1000 – 1115	**Session 3 – WG Session – Draft standards**	**Chair: Alan Grant / Michael Hoppe**
75 min	Continuation on working sessions	
1115 – 1130	**Break**	
1130 – 1300	**Session 4 – WG Session – Draft standards**	**Chair: Alan Grant / Michael Hoppe**
90 min	Continuation on working sessions	
1300 – 1400	**Steering Committee meeting (including WG (vice) chairs and rapporteurs)**	

DAY 3 – Wednesday, 1 December 2021

Time (UTC)	Topics	
1000 - 1100	**Session 5 – Plenary session**	**Chair: Alan Grant / Michael Hoppe**
30 min	Review of working group reports	
30 min	Roadmap and organisations involved	
1100 – 1115	**Break**	
1115 - 1215	**Session 6 – Report of WG**	**Chair: Paul Mueller / TBC**
30 min	Report of WG	Alan Grant / Michael Hoppe
30 min	Review draft LN	Paul Mueller
1215 - 1300	**Session 7 – Workshop reporting closing**	**Chair: Simon Millyard**
35 min	Review draft workshop report	IALA Secretariat
10 min	Closing remarks	IALA Secretariat

ANNEX C TERMS OF REFERENCE OF THE WORKING GROUPS

WG1 – Technical standard

Based on the presentations, comments and questions made at the plenary, WG1 is requested to;

- consider (ERPS Over the air protocol / ERPS Radar operational standard / ERPS Racon operational standard)
- identify technical documents enabling the interoperability of enhanced radar positioning
- propose text for future liaison notes to organization identified
- propose topics that may be considered in future IALA work programme for IALA Committees regarding the current and near future of standardization of ERPS providing inputs to a possible road map (elaborated by WG2); and
- submit a report to plenary by 1st of December 2021.

WG 2 – Portrayal / interfacing and regulatory

Based on the presentations, comments and questions made at the plenary, WG2 is requested to;

- consider (ERPS Portrayal / interfacing standard / Regulatory aspects / Roadmap)
- identify the regulatory bodies and anticipate actions where WG2 could propose them
- propose text for future liaison notes to organization identified
- propose topics that may be considered in future IALA work programme for IALA Committees regarding the current and near future of standardization of ERPS with a possible road map; and
- submit a report to plenary by 1st of December 2021.

INTERNATIONAL MARITIME ORGANIZATION

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SUB-COMMITTEE ON NAVIGATION, COMMUNICATIONS AND SEARCH AND RESCUE
xth session
Agenda item xx

NCSR x/INF.X
xx Month 202n
ENGLISH
Pre-session public release: ☒

ERPS, for resilient navigation

Submitted by [TBD], (Cosponsors [TBA])

SUMMARY

Executive summary:	The input paper provides an extended insight into a new approach towards a terrestrial radio navigation system suitable as stand-alone maritime positioning system and back-up system for today's satellite navigation systems. The ERPS technology offers…. The ERPS technology can be considered to serve as a independent backup to GNSS to provide resilient PNT. The ERPS is based on existing, mature and robust technology. It is anticipated that this facility will be delivered to existing systems by way of software update
Strategic direction, if applicable:	e-Navigation, resilient PNT, MASS?
Output:	x.x
Action to be taken:	Paragraph 35
Related documents:	Resolution A.915(22), and A.1046(27), MSC.401(95), MSC.432(98), MSC.1/Circ.1575; SN.1/Circ.329; SN.1/Circ.334 Add radar specific resolutions (see list)

Introduction

1 Within the strategy for the development and implementation of e-Navigation and the developed Strategic Implementation Plan (SIP) resilient positioning and navigation has been recognised as an indispensable prerequisite for maritime safety of life, safe transport and environmental protection.

2 Within this scope the need for resilient Positioning, Navigation and Timing (PNT) information has been recognised to support safe operation and collision avoidance of vessels, as well as for comprehensive management of marine infrastructure such as marine aids to navigation in coastal and restricted waters.

3 Specifically, the IMO e-navigation strategic implementation plan considered existing and future Global Navigation Satellite Systems (GNSS) as a strategic key element, within the availability of navigation data from Electronic Position Fixing Systems (EPFS), to satisfy the demand for the provision of reliability, resilience and integrity to bridge equipment.

4 With respect to the vulnerability of signals from global, as well as Regional Navigation Satellite Systems (RNSS) to interference, whether intentional or not, multiple dissimilar and uncorrelated PNT sources are recommended by IMO to achieve resilient PNT.

5 Terrestrial radio navigation signals use different frequency bands, transmitter powers and message architectures and can provide similar navigation performance to GNSS while having dissimilar failure modes.

6 In accordance with the information given above, this paper introduces a proven concept of Enhanced Radar Positions System (ERPS) by using signals from Racons to provide position information to the ships Radar.

7 Both IMO documents, the "*Performance Standards for Multi-System Shipborne Radionavigation Receivers"* (MSC.401 as amended) as well as the "*Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing*" (MSC.1/Circ. 1575) developed by the IMO, are seeking to provide means of resilient positioning, navigation and timing by the combination of multiple and highly dissimilar PNT sources like GNSS and explicitly demanding a terrestrial source of position data, if available - The ERPS technology qualifies to fill todays gap towards resilient PNT.

[TBD]

- E.g. addressing existing IMO resolutions and performance standards

Introduction to enhanced radar positioning system

8 ERPS is a simple concept in which the eRacon provides unique position information encoded in its response signal to the eRadar. The concept is similar to what navigators would do by hand, using radar target azimuth and distance to triangulate a vessel's position. eRacons are essentially normal racons modified to encode their identification and position into the signal response to the radars that interrogate them. The eRacon position (latitude, longitude and elevation) is surveyed and entered as static parameters in the eRacon configuration, therefore eRacons must be located at fixed sites and not placed on buoys. The eRacon identification and surveyed position data is encoded by the eRacon using modulation in the leading dash of the racon Morse code response.

9 The Morse code response is received by the eRadar and is demodulated to extract the identification and position data from the eRacon. To calculate the position, it is necessary either to have:

- A single eRacon signal together with own ship heading; or
- Signals from two or more eRacons.

10 Knowing the measured azimuth and range (distance) of the eRacon targets, and the received position (latitude, longitude and elevation) of the eRacons, eRadars calculate and report positions for their own vessels. If available, multiple eRacons are used simultaneously to improve position accuracy.

11 There is no dependency on GNSS. The vessels' own positions can be calculated without external data.. Calculated positions can be transmitted to the connected navigation systems, such as ECDIS and others bridge equipment, through standard NMEA sentences. ERPS uses WGS84 datum. ERPS technology seeks to add a layer of resiliency to ports and waterways by diversifying position information inputs to the navigation system with accurate, reliable, and real-time positioning systems independent of GNSS.

12 ERPS is suitable for use in port approach, coastal waters navigation areas and inland waterways. Due to the need to have at least one eRacon in view, ERPS is unsuitable for use in Ocean waters. ERPS can be useful for navigation around or across windfarms and oil fields.

Table 1 ***PNT System Performance Requirements***

	Port approach and coastal waters
Accuracy (95% Horizontal Navigation System Error (HNSE))	10 m
System Integrity*	Within 10s
Signal Availability	99.8%
Continuity	99.97% (over 15 min)

*Integrity warning of system malfunction, non-availability or discontinuity should be provided to users within 10s.
IMO Resolution A.1046 operational Requirements

ERPS Technology

13 Knowing the measured azimuth and range of the eRacon targets, the speed and heading of their own vessels. their own antenna elevation and rotation characteristics, along with the received

positions (latitude, longitude and elevation) of the eRacons, eRadars calculate and report positions for their own vessels

14 ERPS can be used in various use cases to derive a position

One eRacon Solution

$$\begin{cases} x = x_1 - l_1\cos(\pi/2 - \theta_H - \theta_1) \\ y = y_1 - l_1\sin(\pi/2 - \theta_H - \theta_1) \end{cases}$$

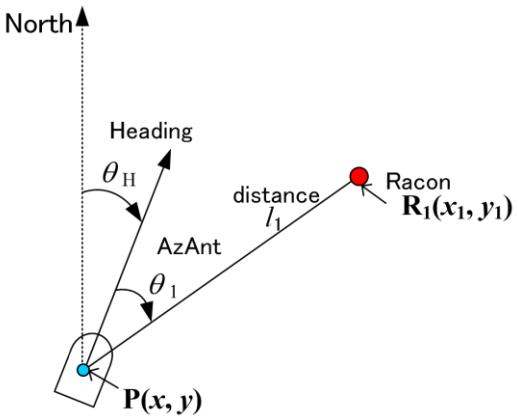

Figure 1 One eRacon Solution

In this case, the eRadar sees only one eRacon, but can use its own true heading to calculate a position solution.

Two eRacon Solution

$$\begin{cases} (x - x_1)^2 + (y - y_1)^2 = l_1 \\ (x - x_2)^2 + (y - y_2)^2 = l_2 \end{cases}$$

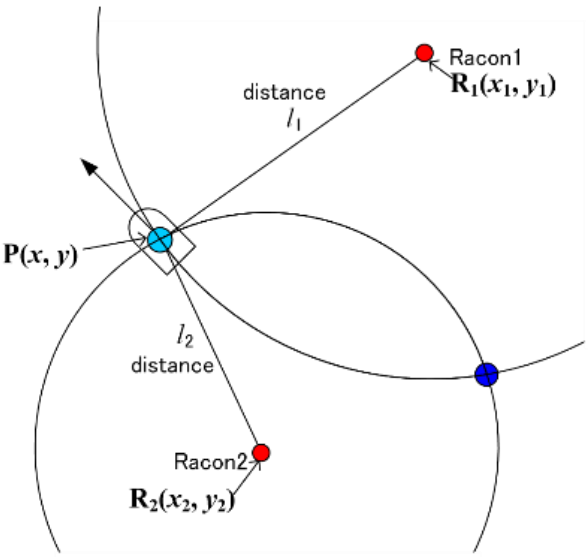

Figure 2 ***Two eRacon Solution***

With two eRacons, the radar calculates a position solution that is independent of the heading of the vessel. To note, this example shows the use of Pythagoras' Theorem with target ranges to calculate two possible solutions. Target azimuths are used to discriminated between the two solutions.

Two of Three or more eRacon Solution

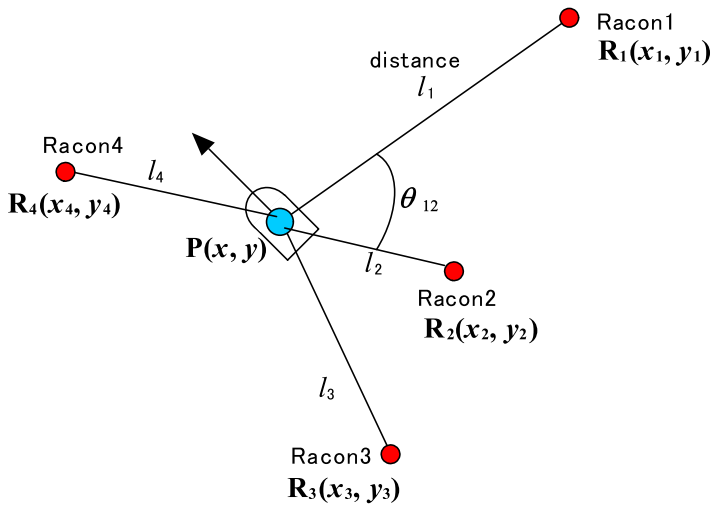

Figure 3 ***Two of Three eRacon Solution***

With more than two eRacons, the eRadar choose the two that provide the best solution (please refer to geometry discussion in Section 4). Once the two best are selected, then a position solution can be calculated similarly to the two-eRacon example. In this example, possible good solutions might use Racon 1 and Racon 4, Racon 4 and Racon 3, Racon 1 and Racon 2, Racon 2 and Racon 3, or Racon 1 and Racon3. Using Racon 4 and Racon 2 shows worst case geometry.

Installation

15 eRacons can be installed at any location that would normally be chosen for a racon. eRacons will appear as normal racons when interrogated by non-ERPS radars. Sites should be chosen per existing racon recommendations and guidelines.

16 Position solutions are dependent on geometry among the eRadar and eRacons. The problem is similar to Horizontal Dilution of Precision (HDOP) for GNSS systems. Wikipedia gives this definition: "Dilution of precision (DOP), or geometric dilution of precision (GDOP), is a term used in satellite navigation and geomatics engineering to specify the Error propagation as a mathematical effect of navigation satellite geometry on positional measurement precision." HDOP is specific to the horizontal position solution.

17 To improve geometry, additional eRacon sites may be needed to give better geometry to a higher number of likely eRadar positions.

Conclusion

18 Resilient PNT is considered as a high-level goal for safety of life at sea, safe transport and an important step towards environmental protection. Today, PVT information are provided from global and regional navigation satellite systems. These suffer from the same vulnerabilities and as a result the PNT information lacks of integrity and resilience.

19 Resilience and high-level integrity can be obtained by taking advantage of navigation data from multiple sources with uncorrelated errors. The ERPS technology qualifies as a gap-filling opportunity to finally provide resilient PNT and high-level integrity assessments. The Organization

identified the need for resilient PNT in its e-Navigation Strategy and RCO 5 of the aligned strategic implementation plan.

20 Various implementations and research projects demonstrate the performance of ERPS being able to provide a positioning accuracy of [TBD] in coastal waters and as such qualifying for a GNSS backup as well as for a solely terrestrial positioning system.

21 ERPS is a terrestrial radio navigation system. As such serving as the desired terrestrial component described in the IMO Performance Standard for Multi-System Shipborne Radionavigation Receivers" (MSC.401 as amended). Within the concept of the "Multi-System Shipborne Radionavigation Receivers" Performance Standard and in support of additional integrity assessments, as described by the "Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing" (MSC.1/Circ. 1575), the inauguration of ERPS regional services can be considered as a significant step into resilient PNT availability in coastal areas, and demanding waters.

22 [TBD]

Actions requested of the Maritime Safety Committee

23 To review existing performance standards for on board radar and radar beacons equipment to enable the new positioning functionality as provided in the annex.

24 To revise existing performance standards for on board radar equipment to enable the new positioning functionality as provided in the annex.

***

References

ANNEX

[Revised radar performance standard]