e-NAV14 Information paper

Agenda item 9.7

Task Number 11

Author(s) / Submitter(s) N Ward

Radar Positioning - Trials results and feasibility analysis

# Summary

## Radar positioning trials have been carried out in the UK, as part of the Resilient PNT stream of the ACCSEAS Project. The trials were performed off the East coast of England using an experimental, solid-state radar provided by Furuno and enhanced racons provided by Tideland. The racons were installed at Southwold and Lowestoft lighthouses. The radar was installed on THV Alert and this vessel was used for the trials. Although the installations of the radar on board the vessel and of the racons at the lighthouses were of a temporary nature and not in ideal positions, the system was shown to be effective and the results indicated ranges and accuracies that could be achieved with an operational system. These results were then used for a preliminary assessment of the viability of radar positioning as an option for achieving the resilient PNT required for e-Navigation. The initial conclusions are that the system can provide the required performance for a complementary positioning system to GNSS, although the range would be limited. The cost in terms of infrastructure, would be manageable. However, the timescale for implementation would be very long, since all existing radars would have to be replaced and international consensus would be needed.

## Purpose of the document

The Committee is invited to note the results of these trials and the analysis, when considering options for resilient PNT and the future of racons.

## Related documents

None.

# Background

The IMO Maritime Safety Committee has stated that “e-navigation systems should be resilient and take into account issues of data validity, plausibility and integrity for the systems to be robust, reliable and dependable. Requirements for redundancy, particularly in relation to position fixing systems should be considered”.

Recognising that Global Navigation Satellite Systems are likely to provide the primary means of positioning for e-Navigation, but are inherently vulnerable to interference, the GLA carried out a study of alternatives to GNSS that could provide positioning if the primary system was interrupted. One of the options considered was an enhanced radar AtoN infrastructure, in conjunction with New Technology (NT) Radar. The enhancement of radar AtoN, in particular racons to provide position and identity, has been proposed in papers submitted to IALA and earlier trials were carried out with a single racon as part of the EfficienSea INTERREG Project in the Baltic.

**3 DISCUSSION**

The report of the trials and feasibility analysis is contained in the annex to this paper.

**ANNEX**

**Radar Positioning – Trials Results and Feasibility Analysis**

**Background**

Resilient PNT is one of the main themes of the INTERREG IVB Project ACCSEAS in the North Sea Region and the radar positioning trials reported here were performed as part of this project.

The radar option has the advantage that there is a mandatory carriage requirement for an X Band radar on all SOLAS vessels over 300 GT. This radar is primarily used for collision avoidance, but has the capability of giving position relative to targets in known locations, such as radar beacons (racons). However, converting such fixes to a position on a chart (paper or electronic) is a manual process.

In order to provide a direct position output from a radar that can be fed automatically to an ECDIS or other plotting and display equipment, the positions of the targets must be available in a suitable format and the radar must be provided with the processing capability to calculate the position and convert it to an appropriate digital message.

The companies that provided the experimental radar and enhanced racon for the EfficienSea trial had carried out further development, including an improved modulation scheme and were willing to cooperate on a more extensive trial, using two racons. This was planned to represent a realistic coastal navigation scenario, using two lighthouses on a low-lying stretch of coastline.

**1 Introduction**

Reliable positioning is recognised as one of the fundamental requirements for the successful implementation of e-Navigation. Although Global Navigation Satellite Systems will be the primary method, all GNSS are vulnerable to interference, deliberate and accidental, because of their extremely low signal strengths. Reliance on a single position source, with known vulnerability, is not an acceptable risk, particularly when almost all e-Navigation services require a position input to work. Therefore the provision of resilient Positioning Navigation and Timing (PNT) is an essential prerequisite for e-Navigation to succeed.

Radar positioning is seen as an attractive backup option for GNSS, because it is independent and potentially uses equipment that is already provided. However, there are a number of problems that would need to be resolved. Firstly the radars now fitted to the vast majority of vessels do not have the processing capability for absolute positioning and the radar Aids to Navigation (AtoNs), principally radar beacons (racons), only provide limited information about their identity - a Morse character that is not unique. Radar AtoNs giving a unique identifier and/or position would be needed to provide automatic positioning by radar.

These trials were intended to determine whether the technical problems could be solved. However, there are several other hurdles that need to be overcome, if such a system is to become a practical component of resilient PNT. In particular, suitable radars would need to be fitted to all vessels, sufficient enhanced radar AtoNs would have to be provided and standards would need to be brought into line. Training would need to be provided and nautical publications and navigational procedures would need to be updated. A preliminary assessment of the cost and timescale for these developments was carried out using the results obtained from these trials.

**2 Objective**

The aim of the project is to determine the technical, regulatory and economic feasibility of the radar positioning option.

The objective of the trial was to demonstrate the potential performance of radar positioning, in terms of accuracy and range.

**3 Acknowledgements**

This trial was made possible by the kind cooperation of Furuno in providing the experimental radar and technical personnel and of Tideland in providing the enhanced racons and technical support. The officers and crew of THV Alert gave every assistance possible in carrying out the trials. The Trinity House Marine Section provided invaluable support in arranging the installation, Trinity House Operations and Planning Centre coordinated the vessel’s location and issued navigational warnings and the Procurement Section facilitated the import and export of the equipment. The Navigation Directorate advised on the trials location and warning notices required and Legal and Risk section arranged insurance for the equipment during the trials and legal agreements with the equipment providers.

**4 Trials Location**

The racons were installed at Lowestoft and Southwold lighthouses. These stations are about 10 M apart on a relatively low-lying coastline, these being the criteria for their selection.

The trials were carried out at distances up to 10 M off the coast.

**5 Trials Plan**

The trials took place over four days, the first day being taken up with equipment installation and testing and the last day with the removal of equipment. The second day was used for ‘static’ tests, with the vessel holding station at a number of points, at different distances from the racon locations. The third day was intended to be used for dynamic tests, sailing parallel with the coast through the trials area. In addition several ‘static’ tests were carried out, with the vessel rotating through 360° at a fixed location.

The processing used both range and bearing from the racons, to calculate position, combined with the latitude and longitude encoded using FSK modulation on the dash of the Morse D character.

**6 Environmental Conditions**

Conditions throughout the trial period were warm (25°C), dry, with light winds (5 knots) and moderate visibility (5 M). Sea conditions were calm.

**7 Installations**

The experimental X Band radar scanner and frequency down-convertor were installed on the starboard side of the monkey island. The intermediate frequency signals were fed down to a digitiser in the wheel-house for onward processing and recording. The scanner location meant that there was superstructure on its port side. This location was chosen after consultation between Furuno, R&RNAV and TH Marine Section. It was not ideal, but the best position available without interfering with (or removing) the vessel’s operational radars.

The racons were installed on the gallery rails of the lighthouses on the side oriented towards the trials area. Again the locations were not optimal, as there was some degree of masking and risk of reflections from the structure of the lanterns. However, these positions were considered the best available without providing a mounting point on top of the lantern roof. This would have involved scaffolding and access ladders, with unavoidable masking of the light. The racon positions were surveyed using a dual frequency GNSS receiver to an accuracy of better than 1 m and these positions were encoded by FSK modulation on the leading dash of the Morse ‘D’ character.

**8 Results**

The summary of results given here is derived from notes taken by the R&RNAV observers on board the vessel. The Furuno technical personnel were recording data continuously and will be analysing it on their return to Japan, with the intention of providing a brief report in early August and a more comprehensive report later in the year.

During the trials the consequences of the sub-optimal installations were evident. Responses with the racons on the port side were limited because of the position of the radar. There were also sectors in which no racon responses were received because of blockage by buildings on the shore, South of Lowestoft.

The calm conditions resulted in distinct nulls in the responses due to cancellation between the direct and reflected signals. This accords with conventional radar theory.

The appearance of the racon paints on the experimental radar was similar to that on the vessel’s conventional radar. The first dash of the Morse ‘D’ character showed striations from the modulation, but was clearly distinguishable. There was considerable spoking when the vessel was close to a racon, because of triggering by side-lobes, probably caused by reflections from local obstructions.

The maximum ranges at which the racons could be seen was about 20 M, however, responses at these ranges were sporadic and inconsistent. The maximum ranges at which consistent responses were received varied between 8 and 12 M depending on location and time. Therefore a usable range of 10 M is probably to be expected.

The accuracies also varied considerably, depending on the number of racons being received, their geometry, relative to the vessel and the consistency of response.

During static tests ‘ideal’ locations were found at which both racons were almost continuously available, with ranges of less than 10 M and the geometry was good – the two Lines of Position (LOP) crossing at right angles. Combined position accuracies at these points were 5-10 m. When geometry was poor or only one racon could be received, accuracy was in the region of 50-100 m.

In the dynamic tests, similar performance was seen, but definite figures for accuracy were difficult to obtain. Such figures are expected to emerge from the post-trial analysis.

**9 Trials Conclusions**

The installations of the radar and racons were not optimal, but some conclusions can be drawn about the potential performance of the system:

1. Effective range of the experimental radar used with the modified racons was about 10 M.

2. Accuracy achievable with two LOPs and good geometry was 5-10 m.

3. Accuracy with a single LOP was 50-100 m.

**10 Feasibility analysis**

There is still a lack of recognition in the maritime industry that GPS alone cannot provide robust positioning. The view that multiple GNSS will provide the resilience required is also expressed, in spite of the common vulnerabilities. The World Wide Radio Navigation System has yet to be appreciated as a compendium of systems, which need to be dissimilar in order to provide redundancy. Once this concept is grasped there will need to be a consensus behind one or more alternatives to GNSS, for example a wide-area terrestrial system, such as eLoran, a short range backup using radar, or a non-radio option such as inertial systems.

The feasibility of such complementary alternatives to GNSS depends on technical performance, regulatory acceptance and cost. These trials have shown that the required performance can be achieved with radar positioning, within certain range limitations. However, since the system will not work with conventional radars, it would be necessary for all existing radars to be replaced. This would require some form of regulation, commercial incentive, performance advantage, or a combination of these. A supporting infrastructure would be needed: either a complete system of radar AtoNs, a complete set of radar charts, or a combination of these. These two aspects are considered in more detail in the following sub-sections.

**10.1 Radar replacement**

If the radar option is chosen then a transition plan would need to be agreed for the move from conventional (magnetron) radars to solid-state, with the advantages that brings, in terms of higher performance, versatility and low maintenance. Accepting these benefits and assuming a price advantage conferred by the large market opened up, such a transition could still take at least 20 years, using the introduction of ECDIS as a guide.

**10.2 Infrastructure**

In contrast, the installation of radar AtoNs to provide a position-fixing infrastructure would require no regulatory changes, other than agreement on standards, through ITU and IALA, which could be accomplished in a few years. However, the cost could be substantial. Several different scenarios can be envisaged: a complete network of enhanced racons at 10 M spacing round the coasts; a sparser network covering the critical areas of dense traffic or high risk; a complete set of radar charts to a level of detail and accuracy sufficient to support navigation and positioning by radar alone; a combination of more basic radar charts with a sparse network of racons as reference points. Finally there is the possibility of providing radar AtoNs of lower cost and functionality than racons, but retaining the essential feature of encoded identity and/or position.

Initial assessments of two of these scenarios for the UK and Ireland have been made below. The options involving radar charts and lower-cost radar AtoNs involve too many assumptions to provide useful information at this stage. The evaluations carried out here should be supported by simulations to ensure that the answers are realistic.

**10.2.1 Dense network**

Providing enhanced racons at 10 M intervals round the coasts of the UK and Ireland would involve about 350-360 racons, compared with approximately 50 installed on fixed stations at present. This would provide the potential for 5-10 m accuracy all round UK and Irish coasts, including islands. The cost of such a scheme would be in the order of £6m, assuming £15k per racon and allowing £5k for power supplies and supporting structure. This does not include purchase of land. Wherever possible existing GLA sites could be used, otherwise sites belonging to other government agencies, such as the coast guard might be an option.

**10.2.2 Sparse network**

In this scenario racons would be provided at 10 M intervals to give 5-10 m accuracy in critical areas, such as the Dover Strait, North Channel, Minch, Pentland Firth etc. In other areas the interval would be extended to 20 M, providing a potential 50-100 m accuracy. This would reduce the number of additional racons needed to about 150, at a cost of about £3m.

**10.2.3 Limitations of the analysis**

These projections only apply to the UK and Ireland and would need to be extended to cover the North Sea Region as a whole, for the ACCSEAS Project. The costings do not include installation and maintenance and these would have to be added to produce a whole-life costing for comparison with other options. The costs are indicative, intended only to show whether these options are within realistic bounds. They would represent somewhere between 5 & 10 % of the annual costs of providing the whole lighthouse service, therefore they could be managed if spread over a sufficient period, given that the planning and installation work would probably take two to three years.

**11 Overall Conclusions**

1. NT Radar with an enhanced radar AtoN infrastructure is technically feasible as an option for providing resilient positioning within about 10 M of the coast.

2. The cost to lighthouse authorities in the UK and Ireland would be within realistic limits, if planned over a reasonable time.

3. These estimates need to be further developed, verified by simulation and extended to the whole North Sea Region.

4. The regulatory and policy process for the international adoption and installation of suitable radars could take at least 20 years, assuming an international consensus could be reached on this way forward.

**12 Recommendations**

1. The performance estimates should be checked when the results of the processed data have been received.

2. The assumptions made about numbers of racons needed should be tested by simulation and extended to the North Sea Region as a whole.

3. The projections about the policy and regulatory process should be confirmed by consultation with experts in that field.

**13 References**

1. IMO 2008. Report of the Maritime Safety Committee on its 85th Session, MSC 85/26, Annex 20.

2. GLA 2010. Business Case informing eLoran decision, Project reference: M021/2010-B.

3. IALA 2011. e-NAV 10/8/3, Enhanced Radar Positioning.

4. IALA 2011. e-NAV 10/8/5, NT Radar and enhanced radar AtoN as an alternative means of absolute positioning.

5. GLA R&RNAV 2012. The Potential Use of Advanced Marine Radar for the Absolute Positioning of Vessels in Coastal Waters. Report No: RPT-17-NW-12.