ENAV15 Input paper

Agenda item 12

Task Number

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Requirements for Resilient PNT

# Summary

Reliable positioning is fundamental to e-Navigation. Position is required for almost every e-Navigation application and if it cannot be relied upon, e-Navigation will not work. There is consensus in the maritime sector on the need for Resilient Positioning Navigation and Timing (PNT), but not on how it is to be achieved. The annex to this paper sets out an approach to defining the requirements and proposes a method of assessing the various alternative methods of achieving them.

## Purpose of the document

The Committee is invited to consider whether the method of assessing the Requirements for Resilient PNT set out in the Annex could be used as the basis for a submission to IMO NCSR2.

## Related documents

IMO e-navigation Strategy Implementation Plan.

ANNEX

**1 BACKGROUND**

At the 59th Session of the IMO Sub Committee on Safety of Navigation (NAV 59), there was consensus in the e-Navigation Working Group on the need for Resilient Positioning Navigation and Timing (PNT). It was also agreed that requirements for Resilient PNT should be prepared as part of the Strategy Implementation Plan for e-Navigation. This paper has been prepared for consideration by bodies such as IALA as a possible approach to the assessment of systems and combinations of systems. The results of such an assessment could form the basis for discussion and possible submission of a report to IMO.

**2 APPROACH**

IMO Resolution A.1046(27) does not distinguish between single systems that might meet the requirements by themselves and combinations of systems that might meet them together. The approach proposed here is that in addition to the parameters of availability, accuracy, integrity and continuity set out in A.1046, the limitations of each system should be assessed, such as vulnerability to interference, or restricted coverage. By this means complementary systems could be selected to ensure overall resiliency is provided. This approach of considering the WWRNS as a compendium of systems fits in with the planned development by IMO of a Multi-system Receiver Performance Standard, a generic standard that will cover different systems and combinations of systems – specifying what is required, not how it should be done.

**3 REQUIREMENTS**

The following table summarises the requirements set out in Resolution A.1046:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update rate |
| Ocean waters | 100 m 95% | 99.8 % | broadcast by MSI | - | 2 sec |
| Harbours, harbour approaches, coastal waters | 10 m 95% | 99.8 % | broadcast within 10 s | 99.97% in 15 minutes | 2 sec |

Table 1. WWRNS Requirements

**4 ASSESSMENTS**

It is proposed that the following table should be completed during system analysis and used to assess single systems and combinations of systems against the requirements, with the additional column recording limitations, so that these can be mitigated by combining with other systems:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update rate | Limitations |
| Ocean waters |  |  |  |  |  |  |
| Harbours, harbour approaches, coastal waters |  |  |  |  |  |  |

Table 2. Assessment of systems

**5 ALTERNATIVES**

It is generally accepted that GNSS (GPS in the short term) will be the primary position and timing sensor for maritime navigation. The increasing availability of more than one GNSS (GPS, GLONASS, Beidou, Galileo and others) will increase resilience and integrity. However, all these systems share the same failure modes, because they use the same frequency bands and have very low power signals. Therefore 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 onboard alternatives, such as inertial sensors.

Some of these alternatives can be made available in the short to medium term, in parallel with the expansion of GNSS. Some have been demonstrated to work, but would need lengthy regulatory measures to become generally applicable. Others are likely to require considerable technical development before they can be accepted as practical and economic options for maritime use.

For example, eLoran is a proven system, meeting the IMO requirements for harbour and harbour approach (Williams et al, 2013). However, it is not widely deployed at present. Studies have shown that ranging mode (R-mode) on DGPS beacons could provide a backup to GNSS, in areas where coverage of such beacons is good (Johnson et al, 2014). This system has still to undergo practical testing and the necessary regulatory measures have still to be put in place. Absolute positioning using solid-state radar and enhanced radar beacons has been shown to work technically, but the regulatory process needed to implement it would be lengthy (Ward et al, 2014). Options such as inertial sensors require considerable technical development before they have the necessary stability, at acceptable cost, to provide a maritime backup. Other autonomous alternatives such as quantum technologies are at a very early stage of development.

The various combinations of options for achieving resilience would need to take into account the different stages of development, as illustrated in Figure 1.

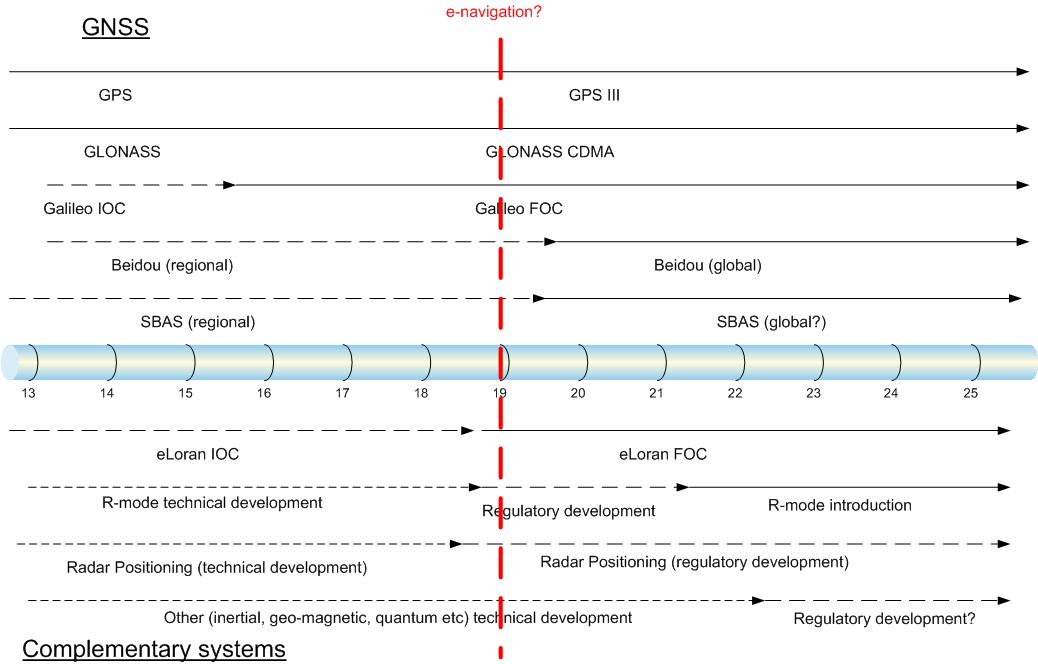
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Figure 1. Indicative timeline for Resilient PNT

**6 EXAMPLES**

**T**he following tables show assessment results for systems already deployed, near to deployment, or for which technical performance has been demonstrated – Green indicates that requirements can be met, Red that they cannot.

**6.1 GPS**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update rate | Limitations |
| Ocean waters | 9 m 95% | 99 % | broadcast by MSI or RAIM | N/A | 1-0.05 sec | Vulnerable to interference |
| Harbours, harbour approaches, coastal waters | 9 m 95% | 99 % | broadcast by MSI (>10s)  or RAIM | 1-1x10-5/hr  =99.99975% in15 mins | 1-0.05 sec | Vulnerable to interference |

Table 3. GPS. Source: FRP 2012

**6.2 GLONASS**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update | Limitations |
| Ocean waters | 6 m 95% | 99% | broadcast by MSI  or RAIM | N/A | 1-0.05 sec | Vulnerable to interference |
| Harbours, harbour approaches, coastal waters | 6 m 95% | 99% | broadcast by MSI (>10s)  or RAIM | ? | 1-0.05 sec | Vulnerable to interference |

Table 4. GLONASS. Source: Russian Federal Space Agency, IAC website

**6.3 GPS/GLONASS**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update | Limitations |
| Ocean waters | 2 m 95% | ̴ 100 % | broadcast by MSI  or RAIM | N/A | 1-0.05 sec | Vulnerable to interference |
| Harbours, harbour approaches, coastal waters | 2 m 95% | ̴ 100 % | broadcast by MSI (>10s)  or RAIM | 99.99975% in15 mins | 1-0.05 sec | Vulnerable to interference |

Table 5. GPS/GLONASS. Source: NSL (2013)

**6.4 GPS/WAAS**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update | Limitations |
| Ocean waters | 9 m 95% | 99 % | broadcast within 6s | N/A | 1-0.05 sec | Vulnerable to interference |
| Harbours, harbour approaches, coastal waters | 2 m 95% | 99 % | broadcast within 6s | 99.99975% in15 mins | 1-0.05 sec | Vulnerable to interference  No polar coverage |

Table 6. GPS/WAAS. Source: FRP 2012

**6.5 GPS/DGPS**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update | Limitations |
| Ocean waters | 9 m 95% | 99 % | broadcast within 6s | ̴N/A | 1-0.05 sec | Vulnerable to interference |
| Harbours, harbour approaches, coastal waters | 1-2 m 95% | 99 % | broadcast within 6s | 99.9875% | 1-0.05 sec | Vulnerable to interference |

Table 7. GPS/DGPS. Source: FRP 2012

**6.6 GPS/eLoran**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update | Limitations |
| Ocean waters | 9 m 95% | 99 % | broadcast within 10s | N/A- | 1-0.05 sec |  |
| Harbours, harbour approaches, coastal waters | 9 m 95% | 99.8 % | broadcast within 10s | 99.9875% | 1-0.05 sec | Within coverage of DLoran Ref.Station |

Table 8. GPS/eLoran. Source: Williams et al 2013

**6.7 Multi-GNSS/eLoran**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update | Limitations |
| Ocean waters | 8 m 95% | ̴100 % | broadcast within 10s | N/A | 1-0.05 sec |  |
| Harbours, harbour approaches, coastal waters | 8 m 95% | ̴100 % | broadcast within 10s | 99.9875% | 1-0.05 sec | Within coverage of DLoran Ref.Station |

Table 9. Multi-GNSS/eLoran. Source: Williams et al (2013)

**6.8 GPS/radar**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Region | Accuracy | Availability | Integrity | Continuity | Update | Limitations |
| Ocean waters | 9 m 95% | 99 % | broadcast by MSI  or RAIM | N/A | 1-0.05 sec | Vulnerable to interference |
| Harbours, harbour approaches, coastal waters | 7 m 95% | 99 % | broadcast by MSI (>10s)  or RAIM | 99.9875% | 1-0.05 sec | Range limited to 10 M from coast |

Table 10. GPS/radar. Source: Ward et al (2014)

**7 DISCUSSION**

e-Navigation and e-Maritime are totally dependent on reliable positioning. The present situation of reliance on a single system (GPS) is not acceptable for safety critical operations. Other GNSS are becoming available, but they share the same vulnerabilities as GPS, to accidental and deliberate interference. Augmentations, whether space-based or ground-based, increase integrity, but do not provide any protection against loss of the primary system. Complementary, dissimilar systems are needed to achieve real resilience.

The arguments for and against backup systems have been rather subjective, with advocates and opponents of particular systems dominating the discussion. This paper has attempted to provide an objective approach to the assessment of suitable combinations of systems against the recognised requirements.

It is clear that combinations of more than one GNSS will give significant advantages, particularly in availability. However, these combinations will not overcome the inherent vulnerability to interference. The addition of a dissimilar system, such as eLoran could achieve this in the short term and other options such as R-mode and radar could achieve it in the medium to long term, together with autonomous, onboard options such as inertial, if they meet performance and cost criteria.

The proposed assessment method might be considered for discussion in IALA and possible development into a submission to IMO.

The planned development in IMO of a multi-system receiver performance standard should make the approach of combining different systems a practicable proposition, depending only on which systems are available in any particular location. There would be no need to carry different receivers for different parts of the world, something that would almost certainly be opposed at IMO.

It would then be a matter for each administration, according to its obligations under the Safety Of Life At Sea Convention (SOLAS) Regulation V/13 ‘to provide, as it deems practical and necessary either individually or in co-operation with other contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires’.

**8 CONCLUSIONS**

Resilient Positioning, Navigation and Timing (PNT) is essential for e-Navigation. An approach has been proposed for the assessment of systems against the requirements for resilient PNT.

The proposed method can assess systems and combinations of systems, allowing the selection of complementary combinations.

Initial assessments indicate that a combination of multiple GNSS and eLoran in coastal waters could meet the requirements. Other candidates, such as radar and R-mode have the potential to provide a backup to GNSS, but still need technical and/or regulatory development.

**REFERENCES**

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