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13 – INTERNATIONAL

13.1 – Resilient PNT Forum

13.7.1 – Update on Resilient PNT

Note by the Secretariat
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1. INTRODUTION

Global Navigation Satellite Systems have become the primary means of maritime navigation. In fact, most onboard systems requiring position or time input are dependent on GPS, the GNSS provided by the US. This means effective dependence on a single system.

Developments such as e-navigation, sea traffic management and particularly autonomous vessels are heavily dependent on electronic position inputs. Therefore resilience is essential for these developments to succeed. Resilience is defined here as the ability to continue functioning during disruption or recover rapidly from disruption.

This update draws on the proceedings of 'Innovations in Maritime Navigation' a seminar held at Trinity House on 2nd March 2016.

2. GNSS VULNERABILITY

All GNSS are susceptible to disruption from natural and man-made causes, because of their extremely low signal strengths and shared frequency bands. This may be acceptable for conventional navigation, where reversion to conventional methods is possible, given adequate training and awareness, but increasing automation limits this option.

The vulnerability of GNSS to disruption has been known since its inception. Interference from natural causes, such as solar activity, accidental interference from faulty equipment and intentional and unintentional jamming have all been recorded many times over the last two decades. It is in the nature of satellite systems, using solar power, that signals at the Earth's surface at a range of 20,000 km are extremely weak and the fact that all GNSS share the same bands means that they are all susceptible to disruption from the same sources.

Well-documented incidents of disruption over the last two years include false information from GLONASS over a period of several hours on two occasions, interruptions to GPS from a solar flare, loss of timing services from GPS when decommissioning a satellite, local loss of GPS believed to be caused by jamming, and the ongoing situation with only five out of ten Galileo satellites available, believed to be a result of clock problems. Jamming and space weather will affect all GNSS; system problems such as those that affected GLONASS and GPS timing can also degrade combined GNSS solutions. So it is clear that GNSS outages are a real problem and that multiple GNSS do not provide resilience.

The aware and well-trained navigator can appreciate this problem and should know how to deal with it, reverting to radar positioning, dead-reckoning or visual bearings, if GNSS is lost. However, the increasing dependence on automated systems onboard and ashore, combined with a decline in traditional skills gives rise to concern about the continued ability of today's mariners to cope with such disruption. Therefore interest remains in providing complementary alternatives that will allow the vessel to continue navigating without interruption.

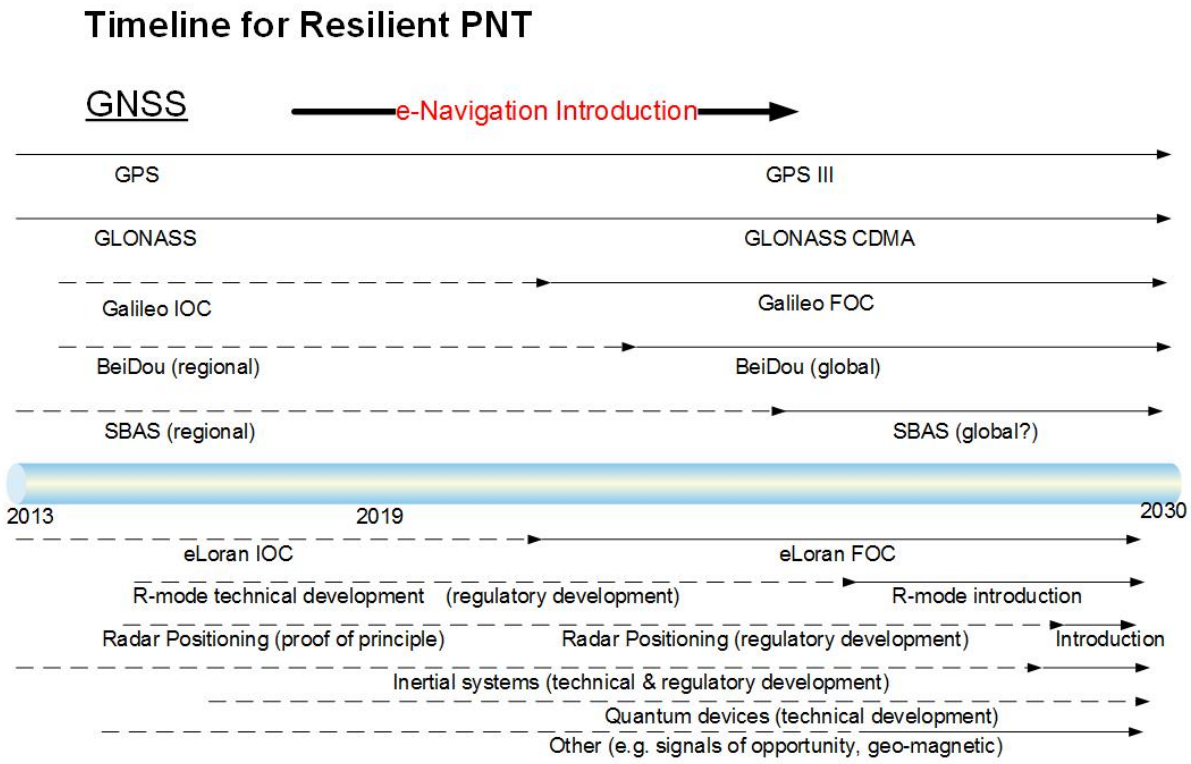
3. COMPLEMENTARY TECHNOLOGIES

There are several alternative backup technologies that could be considered complementary to GNSS for future introduction into ships' Integrated Navigation Systems. They have varying capabilities, different limitations and levels of maturity, which are summarised in Table 1.

Technology	Capability	Status
eLoran	Can provide resilient PNT and data cross-sector over large geographic areas. Proven as a technical solution.	Future subject to cross-sector support from governments, regional agreements and/or viability of commercial operation.
R-mode	Maritime-only PNT and data within areas of cooperating infrastructure.	Feasibility of 24/7 capability to be established. Requires modified infrastructure, new standards and regulatory agreements.
Radar Absolute Positioning	Littoral coverage for 5nm to 10nm possible, depending on options (shore infrastructure of active responders or passive coastal feature mapping).	Basic feasibility demonstrated with active modified racons. Agreement needed for modification or replacement of existing radars and racons.
Signals of Opportunity	Digital television (DVB-T) with 8MHz bandwidth offers capability for positioning independent of GNSS (with similar accuracy) but range is limited to littoral navigation. AM broadcast is ideal with 100s km range, if available.	Opportunistic radio positioning feasible within a Software Defined Radio (SDR) incorporating other capabilities (e.g. R mode) AM is being switched off across Europe.
Bathymetric Navigation	Bathymetric profile from multi-beam sonar is matched to a database to determine position.	Used by naval applications. Reliable positioning requires up-to date database and is limited for shifting or less contoured seabed profiles.
Low Earth Orbit (LEO) Communication Satellites	Ranging and Doppler measurements available for all phases of voyage. Few details on capability.	Many LEO satellites available. Boeing established positioning system with its Iridium satellites Recent interest has been reported from Apple.
Onboard systems	Inertial system Bathymetric Quantum, geo-magnetic,	Available, but limited duration backup Military use, needs detailed surveys Long-term development

Table 1: Capability and status of complementary positioning technologies

The estimated timescales for development and implementation of these options are indicated in Figure 1 below.



4. CONCLUSIONS

1. eLoran is the only complementary backup system that can be implemented within the timescale envisaged for the introduction of e-navigation, however, there are political obstacles to its implementation, at least in Europe.
2. R mode and possibly radar positioning could be introduced by about 2030, however, both have inherent coverage limitations. Feasibility studies are needed to assess their economic viability.
3. Other options, such as inertial systems and signals of opportunity might emerge as viable alternatives by 2030, but there are large uncertainties about technical and regulatory matters.
4. Quantum devices and options such as bathymetric and geo-magnetic positioning can only be considered as longer term possibilities.

A multi-system solution may offer the best approach. The IMO concept of the Integrated Navigation System aboard vessels, incorporating a Multi System Receiver, provides flexibility for the inclusion of the above positioning technologies if and when they become available, at an affordable cost.

5. THE COUNCIL IS INVITED TO

Note this information.