The steady reduction of the Arctic ice means that all types of navigation in Arctic waters are substantially increasing, writes Fernando del Pozo:

• Trans-Arctic traffic, which some shipowners are already trying to convert into regular services, even building specialized ships, such as TeeKay which has commissioned the first LNG carrier with icebreaker capabilities, the Eduard Toll; also Russia's Rosatom group is actively planning to operate a container shipping line along the Northern Sea Route, to compete with the Suez Canal;

• Intra-Arctic, already very active, although almost exclusively between Russian ports, such as Dudinka in the Yenisey, serving the mining complex in Noril'sk; Yamburg, Noviy Port and Sabetta in the Ob, also in Siberia; and in European Russia Varandey serving the facilities in the Pechora. One exception to this Russian-only network is the Murmansk-Churchill Arctic bridge, which exports the wheat production of Manitoba, Canada, bringing in exchange Russian fertilizers; and

• Destinational (eco-tourism, scientific, research, fishing...), probably the type of shipping showing the biggest growth.

All this increased navigation activity needs support in the form of: reliable charts; aids to navigation (lighthouses, buoys, beacons, markers, etc.); Search and Rescue bases and assets; a working Automatic Information System; weather and ice forecast; communications; and electronic position, navigation and timing (PNT). However, all those support means are deficient in high latitudes in different degrees and for a variety of reasons: not enough hydrographic surveys to produce quality charts; no aids to navigation (AtoN) except in the Russian rivers; immense distances and lack of bases for SAR operations; AIS not working because of the scarcity of the traffic, which does not trigger responses to allow SOTDMA to work; weather and ice forecast unreliable because of poor satellite coverage and few shore stations, etc. In this paper we will focus on the electronic navigation systems and related communications.

Global Navigation Satellite Systems (GNSS)

Over the past few years, in particular since the US Presidential order of 2000 to abandon the Selective Availability Feature of the Global Positioning System (GPS), ships' positioning has come to rely exclusively on satellite-based systems, (GNSS), first and foremost GPS, but also on the Russian Globalnaya Navigatsionnaya Sputnikovaya Sistema (GLONASS), the Chinese BeiDou, initially covering the area of Chinese immediate interest, but due to reach a global coverage by 2021; the Indian Navigation Indian Constellation (NavIC); the Japanese Quasi-Zenith Satellite System (QZSS), the last three with just local coverage for the time being; and the European Galileo which is poised to take global prominence once the whole complement of satellites is deployed, due sometime in 2020.
From the point of view of Arctic navigation there are a few important differences between those systems. The GPS' orbits are at 25 000 Km altitude, equivalent to 14 hrs orbital period, with an orbital inclination of 55º. As a result, their coverage of high latitudes is poor, as no satellite reaches the zenith beyond latitude 55º N . This does not affect horizontal accuracy very much, at least until 75º N, for maritime and air regular navigation purposes, but altitude determination becomes poor, which might be a problem for air navigation, and in any case does not reach the horizontal accuracy required for scientific and industrial research, precision navigation, and charting purposes.
This is improved by GLONASS, which uses a slightly lower altitude, but the orbital inclination is 64,8º, which allows it to cover substantially farther North; and by Galileo, which has an orbital inclination just slightly superior to GPS' at 56º, but a higher altitude, 30 000 Km, with which it will also perform better than GPS in the High North.
Nevertheless, neither anyone of the GNSS individually, nor the combination of two or more of them (which most receivers can handle today), are able to ensure accurate navigation beyond about 75ºN. This, combined with absence of AtoN, makes determination of PNT in the Arctic something uncertain and risky.
It is to be regretted that some global navigation systems that preceded GPS were decommissioned in disregard of their usefulness in the Arctic: Transit, the first satellite system and predecessor of GPS, which used low polar orbits (1100 km), which ensured full Arctic (and Antarctic) coverage, disappeared in 1996; Omega, a very low frequency hyperbolic system that with just eight stations gave full global coverage, was switched off in 1997.

Augmentation Systems

Both the EU and the US support their respective GNSS with transmission of the local measured errors, the so-called differential technique, with which corrections can be applied to the positions obtained, improving the accuracy in a wide area surrounding each of the stations. These systems are the Wide Area Augmentation System (WAAS) for the GPS, and the European Geostationary Navigation Overlay Service (EGNOS) for Galileo. Their stations in the Arctic area are located in Cape North (71°N) in Norway, Ny Alesund (79°N) in Svalbard Islands, Peary Land (83°N) in Greenland, Ellesmere (82.5°N) and Queen Elizabeth Islands (77°N) in Canada, and Alaska (70ºN), but their coverage in the wider Arctic is comparatively small and unreliable as a time source. The main problem, however, is that both systems broadcast through geostationary satellites, of which the footprint is geometrically limited to 81,5º latitude, beyond which they are below the horizon. In practice, owing to terrain irregularities, scintillation and other propagation problems caused by ionospheric variability, communication with satellites in geostationary orbit is limited to latitudes generally not higher than 75º.

The solution

The problem of PNT in the Arctic is therefore obvious and with no solution with the state-of-the-art means available, as even the most advanced technology is constrained by geometry and other unsurmountable obstacles.
Focused experiments by the UK, off Tynemouth on the NW English coast, real-life experiences in waters close to the two Koreas, and more recently off the Northern Norwegian coast during the Russian military exercises Zapad-2017, have demonstrated the GNSS' vulnerability to deliberate jamming, owing to the very low power those systems use. This alarming fact, plus the traffic congestion in some areas such as the Channel, and the remote but measurable probability of a systemic failure, have prompted at least the UK and ROK Governments, as well as the USCG, the main Loran operator, to seek continued support for land-based systems independent of satellites.
Despite that and general advice against, in 2009 a US Presidential Directive terminated Loran-C (the latest operational generation of Loran). However, by then studies on an enhanced Loran (eLoran) with integrated differential techniques for improved accuracy were well advanced, and this was not included in the termination directive. On the other hand, a new eLoran must rely on the existing Loran-C infrastructure, therefore, the eventual success in deploying an eLoran is not assured.
The features that make eLoran a suitable complement and backup to GNSS (and simultaneously a valuable alternative to the same in the Arctic) are: a powerful and structurally robust signal, which makes it far less vulnerable to jamming and spoofing than GNSS; higher reliability, as stations are accessible and can be repaired or replaced on site if necessary (there is also a mobile/air transportable version of Loran station); less susceptibility to atmospheric disturbances because of the lower frequency used; enough accuracy for harbour entrance (typically, the 95% CEP of "raw" Loran is 20m and of differential eLoran less than 10m, against GPS' 3m, and Galileo's 30cm). But while differential techniques improve the accuracy of both GNSS and eLoran, the eLoran differential broadcast does not require geostationary satellites,

one of the main problems of differential GNSS in the High North, as noted above. Additionally, its signal structure allows for the transmission of, besides its own differential corrections, the same for any GNSS, navigation safety messages, Virtual Aids to Navigation (see below), etc. As a summary, and using words from a publication specialised in GNSS "[eLoran] meets the accuracy, availability, integrity and continuity performance requirements for maritime harbour entrance and approach manoeuvres, aviation non-precision instrument approaches, land-mobile vehicle navigation and location-based services. It's a precise source of time (phase) and frequency. Additionally, eLoran provides user bearing (azimuth) and has built-in integrity". Its only drawback is that it does not provide altitude, which nevertheless can be solved by integrating the receivers with an altimeter.

But the big bonus that eLoran brings to the Arctic scene is the ability to embed in its transmission Virtual Aids to Navigation (VAtoN). This has already been regulated by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), as well as for other potential vehicles for VAtoN, such as AIS and communication protocols, WiMAX, GPRS, etc. It has been mentioned above that lack of AtoN in the Arctic is a deficiency with enormous impact on safety, and while VAtoN "are not intended to replace physical aids to navigation" they certainly "can provide early notification to the mariner of urgent, temporary or dynamic information", and are recommended for, among other circumstances "new hazards (fixed or dynamic); temporary areas to be avoided; changed hydrography; temporary replacement of off-station physical AtoN; polar navigation; ice conditions and navigation" . It is easy to recognize in this list how well VAtoN apply to the Arctic, and that it is a valuable addition brought by a system, eLoran, already well suited to the Arctic PTN problem.

Currently nine nations are operating Loran-C or eLoran, including the UK, Russia and China, and it seems that Republic of Korea, India and Saudi Arabia are contemplating to upgrade Loran-C to eLoran. All this means that we are still in time to rescue the remains of Loran-C and the experimental eLoran with a view to implement the latter in the Arctic.

Conclusion

It is clear that the new Arctic routes require navigation systems that replace, complement or improve the GNSS' unsatisfactory performance there. The EU, with five Member States (MS) in the Arctic Council and Nordic Council, seven more as permanent observers, additional memberships in other Arctic organisations, and even the EU Commission itself as member of Barents Euro-Atlantic Council and the Council of the Baltic Sea States, is very well placed to take initiatives to improve navigation safety in the Arctic.

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