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JANUARY/FEBRUARY 2021

Electronic Navigation Systems

Guidance for safe use on leisure vessels

GUIDANCE FOR SAFE USE ON LEISURE VESSELS


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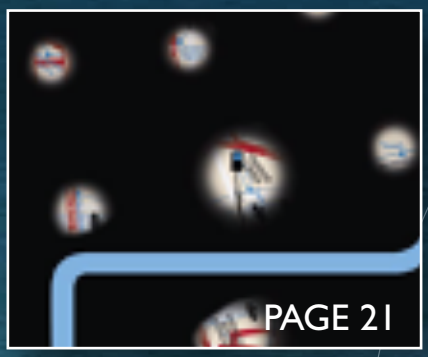
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GROUND-BASED NAVIGATION SYSTEMS

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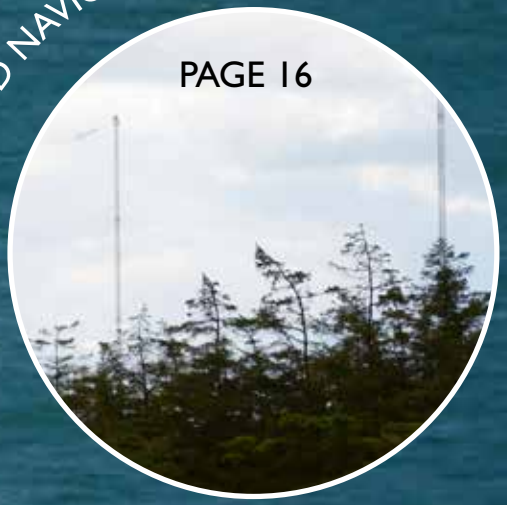
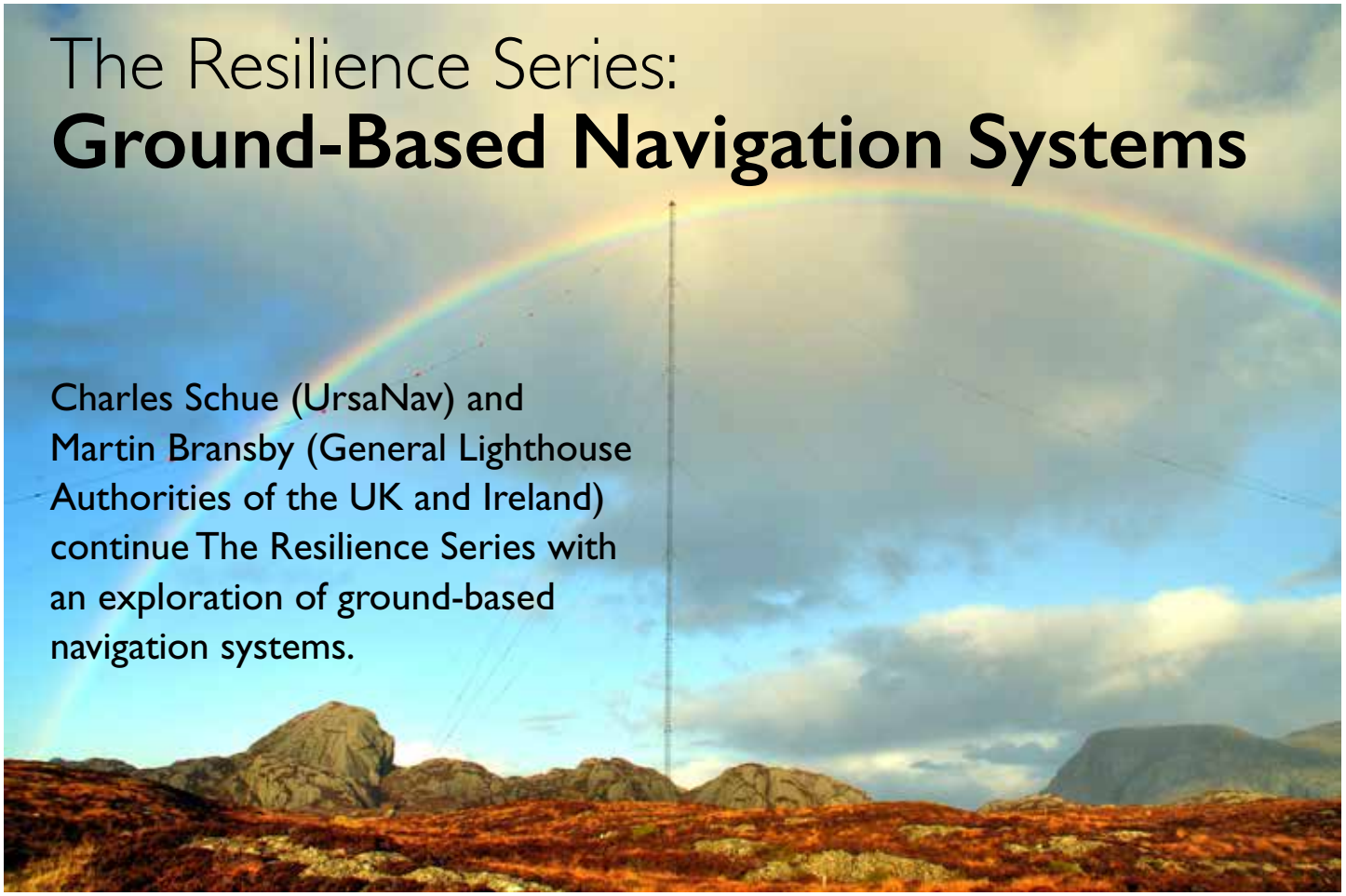


The Resilience Series:
Ground-Based Navigation Systems



Charles Schue (UrsaNav) and Martin Bransby (General Lighthouse Authorities of the UK and Ireland) continue The Resilience Series with an exploration of ground-based navigation systems.

Photo courtesy of UrsaNav

Introduction

First off, let us go on the record as absolutely in favour of GNSS, and fully supporting that their spectrum should be protected, they be fully funded, and that all three segments of each GNSS (space, control, and user) be continually improved. We are certain that every analysis of GNSS economic benefits has fallen short of their actual essential contributions: critical infrastructure, business, trade, military, security, first responders, transportation, and everyday life.

Then, we might ask: "If we are so confident in GNSS, why are there still so many ground-based navigation and timing aids: VOR, DVOR, DME, NDB, TACAN, ILS, MLS, TLS, DGPS, Locata, (e)Loran, etc.?" Almost three decades after the first GNSS constellations were declared operational, these alternatives are still operating, along with space- and ground-based augmentations.

Finally, why is the fastest growing segment of space PNT that associated with the "anti-jam" market?

"The global GPS anti-jamming market was valued at US$ 4,036.9 million in 2019 and is projected to reach US$ 6,523.7 million by 2027; it is expected to grow at a CAGR of 6.4% during 2020–2027."

Report Linker – October 21, 2020

Everything in the natural world is part of a "System-of-Systems" (SoS). Therefore, it makes perfect sense that Ground-Based navigation systems be included in any approach to a resilient SoS. A well-designed resilient PNT solution will include one or more ground-based components. In our case, the wide-area, wireless, ground-based component is Enhanced Loran (eLoran).

VOR:	Very High Frequency Omni-Directional Range	**TACAN:**	Tactical Air Navigation System
DVOR:	Doppler Very High Frequency Omni Directional Range	**ILS:**	Instrument Landing System
		MLS:	Microwave Landing System
DME:	Distance Measuring Equipment	**TLS:**	Transponder Landing System
NDB:	Non-Directional (Radio) Beacon	**DGPS:**	Differential Global Positioning System

Enhanced Loran

eLoran, like its predecessor system, Loran, is very well described and documented in countless national and international government, academic, and industry publications, papers, and presentations. Loran is a proven architecture, with proven performance for commercial and military uses. For over 60 years, Loran was the global gold standard for PNT. It had intercontinental range in the Northern Hemisphere and single-station reliabilities consistently exceeded 99.9%. Its successor, eLoran, has been globally accepted as the best terrestrial, wide-area wireless PNT solution.

"Not your Father's Loran, eLoran seems to be the perfect solution for PNT resiliency"

GPS World, 5th December 2017

But eLoran is not just another iteration of the Loran concept: it has been taken into the digital age and belongs well and truly as part of the fourth industrial revolution. eLoran meets the accuracy, availability, integrity, and continuity performance requirements for aviation en-route and non-precision instrument approaches, maritime harbour entrance and approach manoeuvres, land-mobile vehicle navigation, and location-based services, and is a precise source of time and frequency for applications such as telecommunications. Additionally, eLoran provides one or more low data rate "short message service" channels as part of its signal. eLoran is an independent, dissimilar, complement to GNSS. It allows GNSS users to retain the safety, security, and economic benefits of GNSS, even when their satellite services are disrupted.

Although we always recommend using GNSS as the primary source of PNT if they are available and trustworthy, we also recommend one or more alternative solutions be seamlessly available during outages or anomalies, so continuity of operations is preserved. Note that interference detection and mitigation are great tools, but continuity of operations must be the prevailing consideration for everyday users. We are confident that any prudent mariner or aviator will agree that even a slightly degraded PNT service is better than no service, or indeed a service which "tells lies." eLoran provides very wide-area, multi-modal PNT services with very dissimilar failure modes from GNSS. Incidentally, but importantly for operators, eLoran requires the lowest capital investment and operational expenditures per million square miles of coverage from a terrestrial solution.

Although eLoran is fully capable of delivering co-primary PNT services, it is equally at ease when cast as a key component in a holistic system approach where global, very wide-area, and local technologies are combined into a SoS. On the other hand, eLoran is the only non-space-based service that can deliver absolute time (and frequency) wirelessly and simultaneously to unlimited users over very wide areas. As far back as 2008, the US Coast Guard demonstrated eLoran's ability to deliver absolute time at levels below 50 nanoseconds (as referenced to UTC) for over 70 days without any external timing reference. Using today's newer transmission and clock technology, eLoran can deliver even better results over a longer period. In 2016, UrsaNav demonstrated, indoors at the New York Stock Exchange, eLoran's ability to deliver sub-ten nanosecond timing, as referenced to UTC, from a transmission site 130 miles away. See Figure 1.

For a very relevant example of eLoran's fundamental usefulness in a resilient PNT solution, we need look no further than the recent MarRINav report, funded by the European Space Agency.

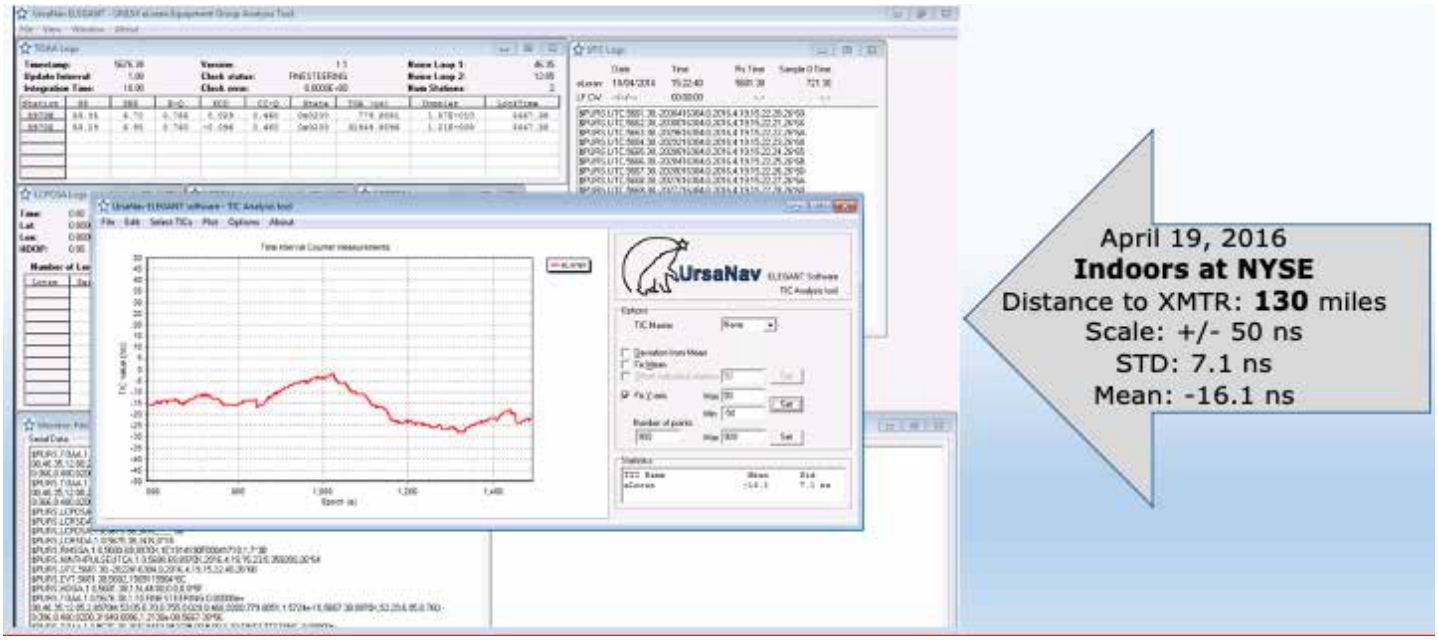


Figure 1: Indoor precise time delivery at the NYSE in 2016. (Courtesy of UrsaNav.)

MarRINav

The 'MarRINav' (Maritime Resilience and Integrity of Navigation) project developed the concept of a UK maritime critical national infrastructure (CNI) to provide resilient and high-integrity PNT for ships and ports. The project identified candidate technologies (space-based and terrestrial) to be integrated into a SoS architecture for maritime operations and across the whole logistics chain. The MarRINav solution covers the Exclusive Economic Zones (EEZs) of the UK and Ireland, but focuses on navigationally critical and difficult areas such as the Dover Straits and the approaches to some of the UK's busiest ports. The architecture uses terrestrial elements located on UK sovereign territory, under national control as much as possible.

Long knowing that a backup to unavailable GNSS was essential to meeting the accuracy, availability, integrity, and continuity performance requirements set out for maritime navigation systems by the International Maritime Organization (IMO), the General Lighthouse Authorities of the UK and Ireland (GLA) provided Initial Operational Capability (IOC) eLoran services for maritime in the UK during the mid-teens (2013-2015). eLoran IOC in the UK provided sub-10m position accuracy with integrity in seven ports and harbours on the east and south coasts of the UK using transmissions from the GLA funded eLoran transmitter at Anthorn (Cumbria), as well as transmissions from continental transmitters in Norway, Germany, France, and the Faroe Isles. Small, newly designed, differential reference stations provided corrections to signal path delays between the transmitters and the user's receiver. Uniquely in the eLoran system, these corrections are gathered at the transmitter and broadcast over the main transmission signal using a data channel designed for the purpose.

Figure 2 - UK Baseline plot based on 6 UK-based eLoran transmitters. Three coloured contours are shown that represent 10 m (blue), 20 m (green) and 100 m (dark red) 95%ile accuracy (Courtesy of the General Lighthouse Authorities).

The GLAs IOC provided the knowledge and expertise to ensure that eLoran was a central component of the MarRINav SoS architecture. GLA experience of other key component technologies ensures that MarRINav provides a truly hybrid SoS approach using both space-based and, importantly, terrestrial components.

This SoS solution embraces the principle of primarily using the eLoran system for maximum overall geographic coverage. This is then supplemented with shorter-range solutions at a local level, such as R-Mode, RADAR Absolute positioning, pseudolites, and LEO satellite systems. MarRINav proposed that six eLoran transmitters are used to provide a baseline system, a backbone if you like. The layout of these, with the coverage contours, is shown in Figure 2, which also shows the major UK ports within the eLoran coverage area.

Much interest has been shown in the MarRINav SoS approach in the UK, Europe, Asia, and the US where it is being lauded as an exemplar of how resilient PNT systems should be specified and built using space-based and terrestrial systems to provide a hybrid resilient PNT SoS. As stated above in our introduction, GNSS will provide PNT in most circumstances, but when you need to provide that PNT with resilience and integrity, MarRINav has shown that eLoran should be central to any SoS approach serving critical maritime infrastructure.

Conclusion

There are always new technologies on the horizon, some of which survive crossing the chasm from laboratory to operations. eLoran is here today, is proven, and is evolutionary. The GPS of today is considerably more advanced and capable than that of 1995, when it first became operational. Similarly, Loran has advanced from Loran-A, -B, -C, and -D, and now eLoran, but there is more to come as this extremely capable system continues to evolve, both as a co-primary PNT solution and as part of a SoS approach to providing PNT with resilience and integrity.

Reference:

[1] "Satellite-derived Time and Position: A Study of Critical Dependencies", UK Government Office for Science, 2018. "The economic impact on the UK of a disruption to GNSS", London Economics, 2017. "Global Navigation Space Systems: reliance and vulnerabilities", The Royal Academy of Engineering, 2011. "Independent Assessment Team Summary of Initial Findings on eLoran", US Institute for Defense Analysis, 2009. "Loran's Capability to Mitigate the Impact of a GPS Outage on GPS Position, Navigation, and Time Applications", US Federal Aviation Administration, 2004.