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Leadership in Resilient PNT

The Need for Resilient PNT

Position, Navigation, and Timing, or PNT, is known as the hidden utility. Despite its widespread use in so many applications and its daily use by billions of people globally, PNT is little known and little understood outside a relatively small group of men and women who specialize in the subject. It is hard to imagine any other service, outside of food, water, and electricity, that is used by so many but understood by so few. It is a testament to those PNT specialists who have contributed to creating such a robust set of services that we can ignore it and yet still reap the benefits and rewards. The darker side of this success is that it allows us to ignore it at our peril.

Should there ever come a day, or days, when the principal source of PNT information is unavailable, that dark side would be revealed. We only need to see the results of hurricanes Harvey, Irma, and Maria to understand how severely our lives are impacted when food, water, and electricity are not available. As with the hurricanes, it is often too late to do anything about the situation after the fact. However, with proper planning and pre-deployment of resilient services, we can mitigate that impact and provide some level of continuity of operations and quality of life.

In the United States, and around the world, that principal source of PNT information is the Global Positioning System (GPS). Other Global Navigation Satellite Systems (GNSS) include GLONASS in Russia, BeiDou in China, and (expected in 2020) Galileo in Europe. Japan and India are also developing Regional Navigation Satellite Systems (RNSS). Irrespective of whether they are global or regional, they all work in roughly the same way and they are all subject to many of the same vulnerabilities. Fortunately, these systems are extremely robust and widespread anomalies are few, far between, and relatively short. On the other hand, several studies have shown that local anomalies are widespread and frequent and they generally result from the low cost and easy-to-acquire technology that can disrupt these weak space-based signals. In recent years, however, nation-states have raised the stakes by taking intentional disruption to the next level, including jamming over large areas of South Korea and spoofing in the Black Sea and in the Suez Canal.

A June 2017 UK government study concluded that the impact to the British economy of a five-day loss of GPS would be roughly £1B per day. Imagine how that would translate if the impact was in the US or worldwide. This would not be just in terms of a monetary impact. More significant losses could include our critical safety and security systems, as well as electrical delivery, telecommunications, and banking systems. Think again along the lines of natural disasters such as a hurricane or nor'easter. It would be a pretty bad time for most of us. It doesn't have to be this way, and many in government, including in the US Legislative Branch, are trying to proactively address the issue prior to a significant event, rather than waiting until after we've suffered the consequences of our complacency.

Although some solutions have been proposed to resolve this issue, study after study has shown that Enhanced Loran (or eLoran) is the only fully independent, complementary, multi-modal, and wide area solution to this lack of resiliency in PNT information. While eLoran provides similar PNT information as GPS (or more properly, GNSS), it has significantly different failure modes and operating characteristics that make it an ideal complement to GNSS. eLoran uses a very high power, Low Frequency signal that can travel over very long distances (i.e., approximately 1,000 miles over land and 1,500 miles over water), thereby making it a "continental" solution. eLoran is also a terrestrial system, thus much less costly to deploy and maintain than space-based systems. Most importantly, eLoran provides a completely independent source of PNT that is not tied to GNSS. eLoran is completely "sky-free".

The concept and operating principles of eLoran were first envisioned as part of the Loran Modernization and Recapitalization Projects undertaken by the U.S. Coast Guard's Loran Support Unit in the 1990's. See Figure 1 for a representative laydown of an eLoran service. The concept was matured in concert with academia and industry, and with other government organizations in the US and Europe. In particular, the government of the United Kingdom, under the auspices of the General Lighthouse Authorities, has been a leader in developing the eLoran concept and deploying an Initial Operating Capability maritime eLoran system along the east coast of England and Scotland. This system proved to be completely successful. However, once other countries in Europe terminated their Loran-C transmissions, the UK was left with a single transmitting site that, by itself, could not provide positioning. The UK government continues to provide eLoran service from their Anthorn site for wide-area UTC synchronization and data services.

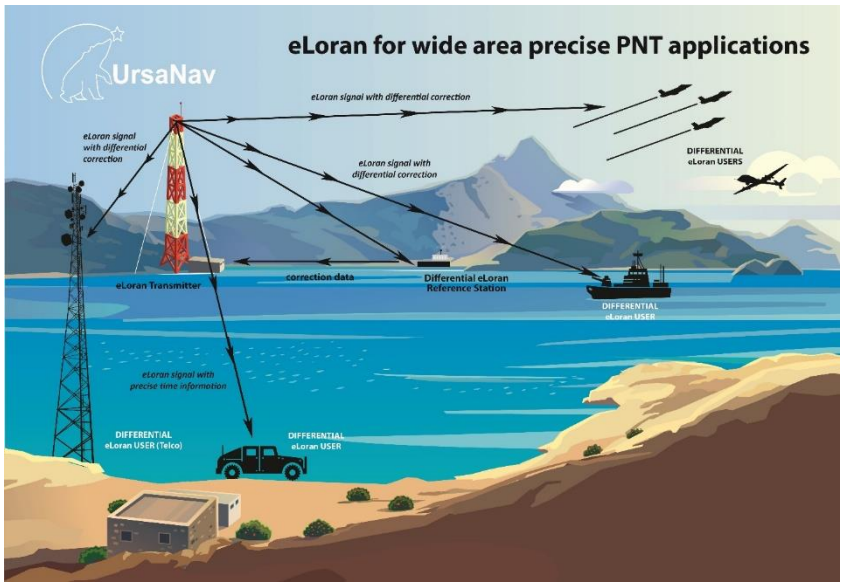

Figure 1: Wide Area Resilient PNT with eLoran

Technology Strength and Leadership Through Partnership

UrsaNav, with headquarters in N. Billerica, MA, is the acknowledged leader in Loran-C, eLoran, and Low Frequency PNT solutions. UrsaNav has significant technical expertise and a staff with decades of experience in Loran-C and eLoran. UrsaNav has developed most of the latest technology for worldwide eLoran systems, including transmitting, control, monitoring, and reference site equipment. In 2007, UrsaNav entered into a deep partnership with Nautel to design and develop a 21st century eLoran transmitter. UrsaNav partnered with Nautel to develop the first

transmitter designed specifically for eLoran. UrsaNav also provides the timing and control suite, control and monitoring suite, differential reference site and monitor site equipment, and signal provider and user eLoran receivers, as well as the deployment expertise that makes our customers successful. The partnership combines Nautel's 48 years of experience developing high-power, solid-state transmitters for broadcast and navigation, including DGPS and beacon transmitters, with UrsaNav's 47-year history of developing solid-state Loran transmitters and associated technologies for governments around the world. This combination of experience and expertise resulted in the world's first purpose-built eLoran transmitter with adaptive pulse-shape pre-equalization and variable reactive tuning capabilities. Nautel was the ideal partner in the development and commercialization of a modern eLoran transmitter because of their deep experience with digital radio technology. This technology has subsequently been proven during thousands of hours of in-plant, deployable, and fixed-site operations, beginning in 2007. The first production transmitter was delivered in 2013. The most recent operations were completed in June 2017 using a Nautel NL-40 eLoran transmitter installed at the former Loran-C site in Fallon, NV.

Advances in clock ensemble technology, ease of maintenance, and ease of operation are at the forefront of this new eLoran technology. This allows for completely unmanned and, should the provider choose, completely autonomous, operational transmission sites, thereby providing significant cost savings for the eLoran service provider. The technical innovations also allow for tiered levels of service, a key component of a subscription-based business model for service providers. These advancements also provide the impetus for a Public-Private Partnership (P3) where the public sector would provide the spectrum, any former Loran assets, and an annual subscription, and the private sector would provide financing, technology, operations, and maintenance. The public sector then becomes a consumer of a service rather than a provider, and they might even share in any profits that the private sector provider generates. This model allows for competition, which will lead to commercial operating efficiencies and expansion as the market grows. It also avoids a cumbersome government acquisition program that can add years to the timeline and reduces the flexibility in reacting to the market.

Investments by UrsaNav and Nautel have led to the design of cost-effective, highly reliable, scalable, and easily managed eLoran systems for deployment by domestic and international organizations for PNT, data, and azimuth applications. Nautel's NL Series transmitters use patent-pending amplification technology to enable the efficient transmission of a signal with bandwidth considerably larger than that of the narrow-band antenna of a Loran-C or eLoran system. The modified amplitude modulated amplifier in the NL Series transmitter is designed to accommodate and essentially capture energy flowing from a narrow-band antenna during the negative power flow phase of a signal, such as in a Loran pulse. This capability translates into superior system efficiency, reduced AC power consumption, and dramatically reduced cooling requirements. The NL Series sets a new standard of Low Frequency, data capable PNT transmitters with outstanding performance, rugged design, and operational simplicity in the industry's most compact enclosure.

Compared to legacy Loran transmitter technology, the NL transmitter's Class D amplifier has several key advantages:

- Efficiency - The building block of the NL Series is a Class D RF amplifier, which when used with Nautel's patent pending pulse power recovery technique, recaptures power that is normally dissipated in the antenna when using legacy technology. This results in an overall improvement in system efficiency, including reduced input power and cooling requirements.

- Flexibility - The transmitter acts as a voltage source that operates continuously throughout the duration of the Loran pulse and can be adjusted on every RF cycle, allowing the transmitter to deliver any pulse shape within the limits of its peak voltage and current capabilities.
- Scalability - The NL system's power capacity can be increased by adding more amplifier modules.
- Accuracy – The NL platform produces very low pulse-to-pulse jitter and tight pulse-to-pulse amplitude variations producing the most accurate signal ever.
- Future Proof - Advanced Digital Signal Processing (DSP) techniques are used to generate a very precise, software definable pulse, and modulation control. The ability to configure the pulse shape via software allows current and future modulation techniques to be easily implemented, "future-proofing" the NL Series.
- Reliability – Nautel's Class D RF amplifiers have a proven reliability record during 40 years in high power RF applications.
- Redundancy - The NL Series features fully parallel and redundant architecture with no single point of failure on all active components. The NL Series can experience significant RF power amplifier failure with no change in pulse shape, timing, or data. Further losses reduce amplitude while maintaining the integrity of pulse shape and timing.
- Maintainability – The NL Series combines hot-swappable power modules and power supplies in each power cabinet. Module replacement, if necessary, can be conducted without the need of any special tools or lifting assemblies, and without interrupting the signal transmission. Service is as easy as removing and replacing a module.

The innovation and investment by UrsaNav and Nautel has resulted in proven technology leadership and has advanced the state-of-the-art in resilient PNT for nearly a decade. UrsaNav and Nautel are committed to eLoran and Low Frequency PNT technology and UrsaNav's experience and focus continues to advance the state of the technology and operations, with many patents in the field, including patent-pending subscription service options.

The complexity involved in designing Low Frequency, pulsed systems such as Loran and eLoran is often underestimated. Loran antennas are low bandwidth and electrically short radiators. The challenge of putting a large amount of current into such an antenna efficiently is very challenging, but is not new or novel. UrsaNav's staff has almost 50 years of experience operating five generations of tube-type and solid-state transmitting technology into a considerable variety of purpose-built and repurposed antennae, both fixed and deployable, around the world.

As seen in Figure 2, UrsaNav and Nautel have developed proven, production ready, eLoran technology that works today and has been demonstrated to interested parties. Together, they provide a complete, turn-key solution, including eLoran transmitters, timing and control equipment, monitor and control systems, differential reference stations, end-user equipment, as well as a full set of services that help service providers effectively design, develop, deploy, document, train on, and maintain their systems.

Figure 2: Proven Technology – Ready to Go Today

Real Results Today

UrsaNav has proven the effectiveness of eLoran for wide-area timing, specifically, as well as general purpose PNT, through a Cooperative Research and Development Agreement with the US Department of Homeland Security and the US Coast Guard. For example, Figure 3 shows the exceptional timing accuracy and stability of eLoran. The data was recorded in N. Billerica, MA which is approximately 300 miles from the transmitting site in Wildwood, NJ. The plot shows Coordinated Universal Time (UTC) from an eLoran receiver compared to UTC from a commercial grade GPS timing receiver. The black line shows this comparison without eLoran differential corrections applied. The blue line shows the comparison of differentially corrected eLoran UTC versus UTC from GPS. The results thus far have demonstrated that UrsaNav and Nautel eLoran technology easily exceeds the timing requirements for many current and future applications, including telecommunications, financial systems, and electrical grid management.

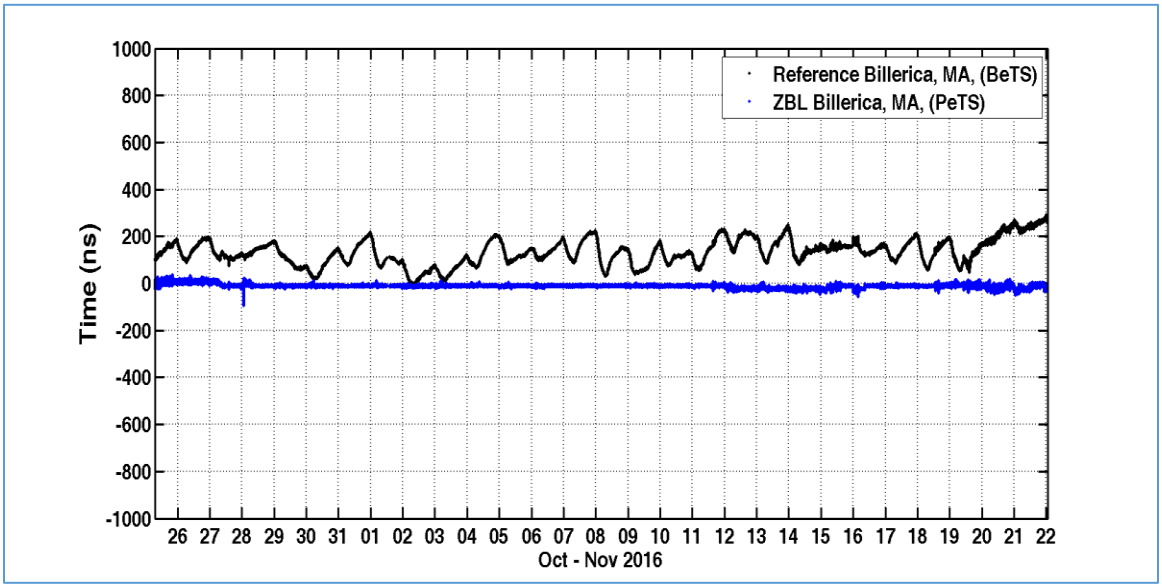

Figure 3: Representative eLoran Timing Performance

Additionally, as part of our support of the General Lighthouse Authorities of the United Kingdom and Ireland, positioning performance was shown to meet requirements for harbor entrance and approach and coastal en route navigation. Figure 4 shows the positioning performance of eLoran at Humber, UK. The eLoran signal from Anthorn, UK (160 miles) was used, along with Loran-C signals from Lessay, FR (300 miles); Sylt, GE (360 miles); Vaerlandet, NO; (575 miles) and Ejde; DE (650 miles).

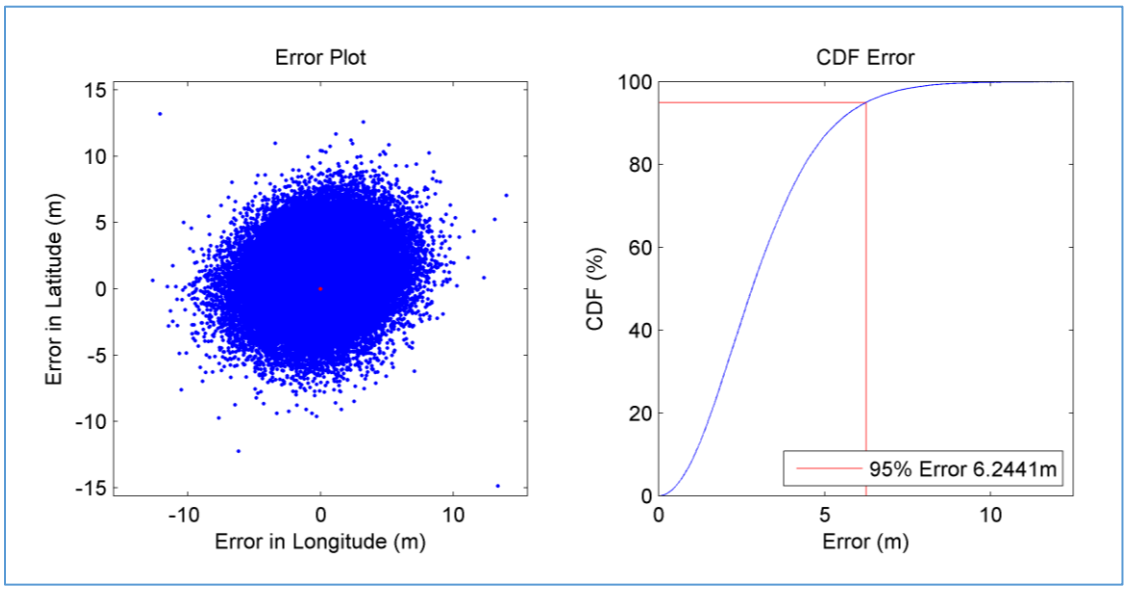

Figure 4: Representative eLoran Positioning Performance in Humber, UK.
[Graphic from the General Lighthouse Authorities of the UK and Ireland]

UrsaNav continues to showcase what has already been proven time and time again in the US, UK, and elsewhere in the world: eLoran is proven and available for deployment today! Let's hope that resilient PNT can be put in place before our complacency and procrastination show what a "day without space" feels like.