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Leaders in what's now. Innovators of what's next.

Indoor Enhanced Loran

Demonstrating Secure Accurate Time at the NYSE

Charles Schue
April 19, 2016

This demonstration was supported through a Cooperative Research and Development Agreement (CRADA) with the Department of Homeland Security (DHS) Science and Technology Directorate (S&T) and the U.S. Coast Guard.

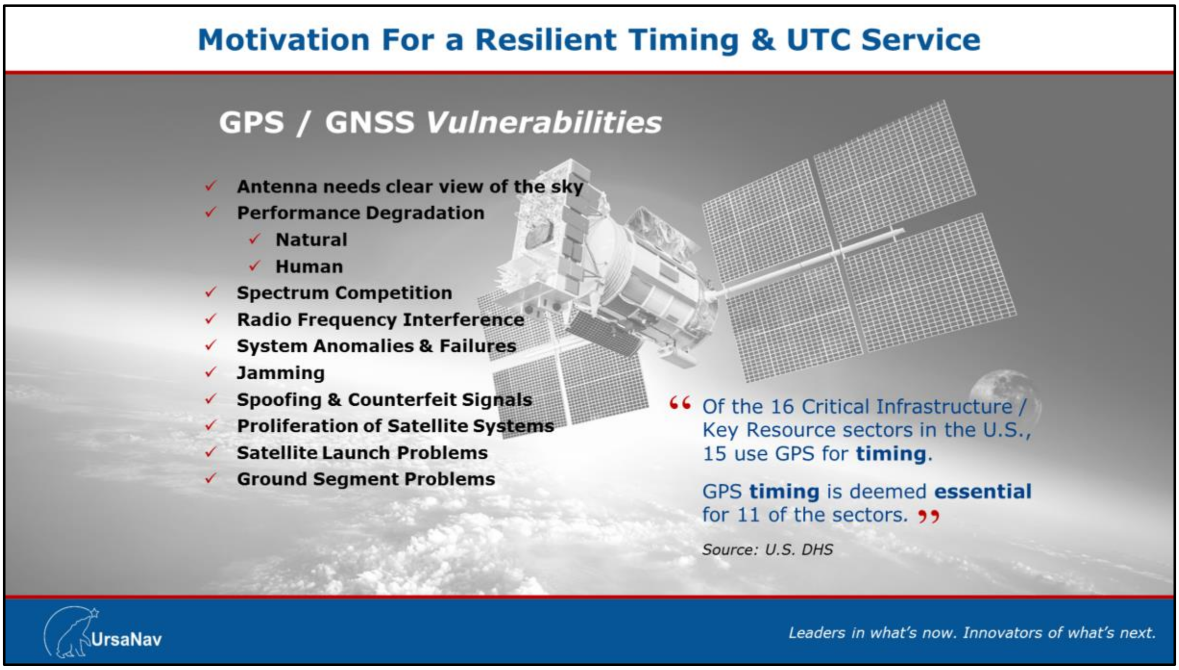
This document does not contain critical or sensitive information and there are no risks with the public release of the information.

April 19, 2016

Why should the ***Financial Sector*** care?

Note that MIFD II will also be influencing standards in the US.

The best contingency solutions is one that includes a "Resilience Triad": GPS/GNSS, eLoran, and one other PNT solution (i.e., oscillator/NTP/PTP for timing; INS for positioning).



The only completely equivalent PNT solution to GPS is another GNSS. It's not clear whether the USG or industry will or should rely on GNSS solutions supplied by other sovereign nations: GLONASS, BEIDOU, Galielo.

GPS is the gold standard for global PNT, and as purely an economic engine is incredibly hard to value.

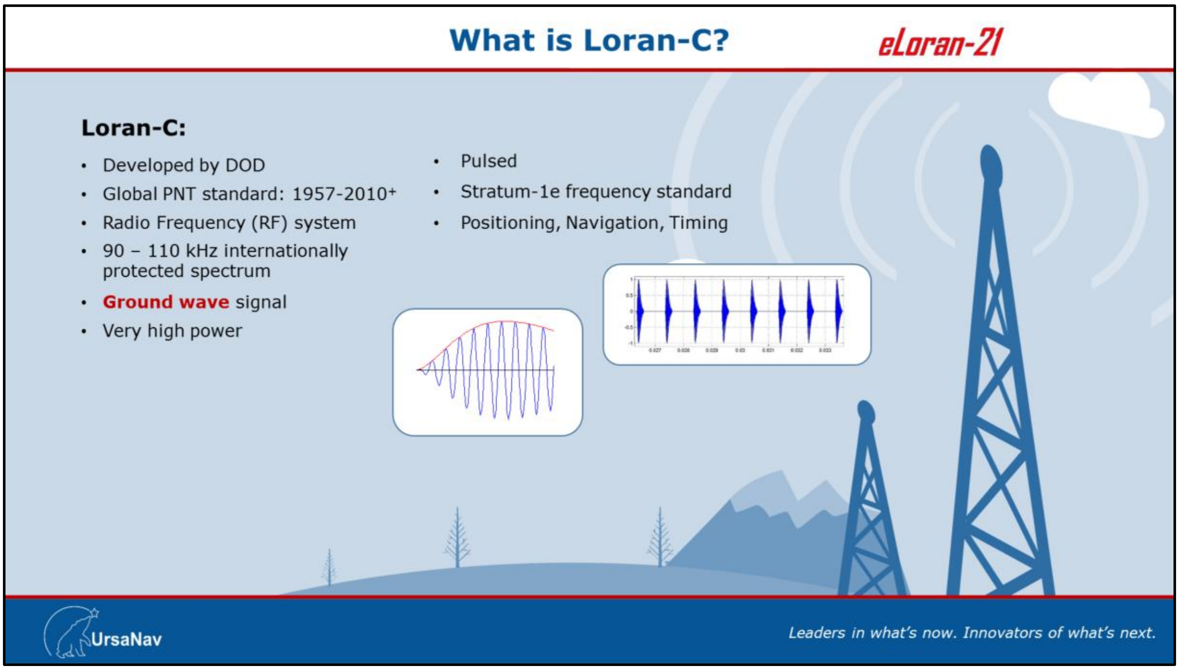
GPS should be fully funded, and receivers/antennas/signals should be continuously improved to better Protect, Toughen, and Augment its capabilities.

When GPS is available and trustworthy, it should be the first choice for PNT.

The very best "augmentation" that provides an alternative with diverse failure modes and that fully complements GPS is eLoran. It is the only wide-area, multi-modal source of PNT that is not satellite-based.

All systems are vulnerable, hence the need to have alternative/backup/complementary capabilities in place ***before*** there is an issue.

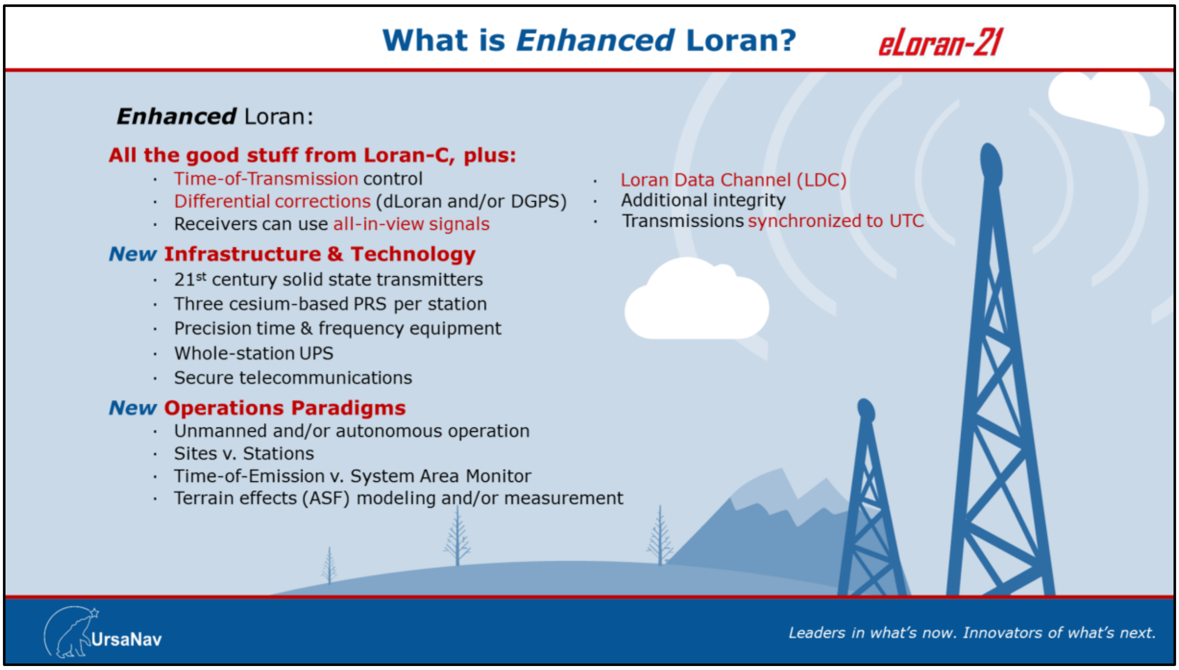
We know the DOD is working diligently to improve receivers, antennas, and signals to harden GPS. However, we don't expect any of these solutions to be made available to the public anytime soon, if ever. The USG must look to protect our Critical National Infrastructure / Key Resources by providing a resilient PNT ecosystem that consists of multiple layers of protection. GPS/GNSS should be at the top; then a wide-area, multi-modal complementary solution, like eLoran; and then single-mode or purpose-built solutions, like VOR/DME/INS/OSC/ILS, etc. Augmentations, like SBAS, GBAS, and differential eLoran should also be put in place to fill gaps in coverage or capability.



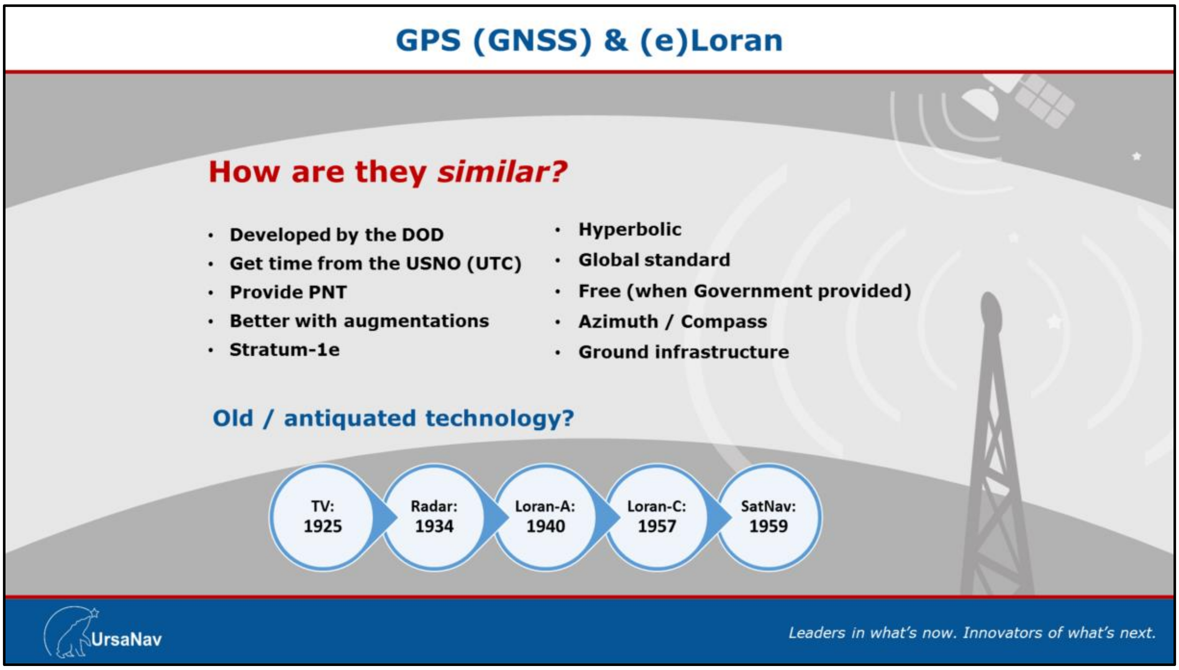
Loran-C was the global PNT standard before GPS.

It is an evolutionary solution, with its roots in Loran-A and Loran-B (both developed by the US DOD and UK MOD).

The DOD also developed a tactical, precision bombing variant, called Loran-D, and a fully deployable version known as the Air Transportable Loran System (ATLS).



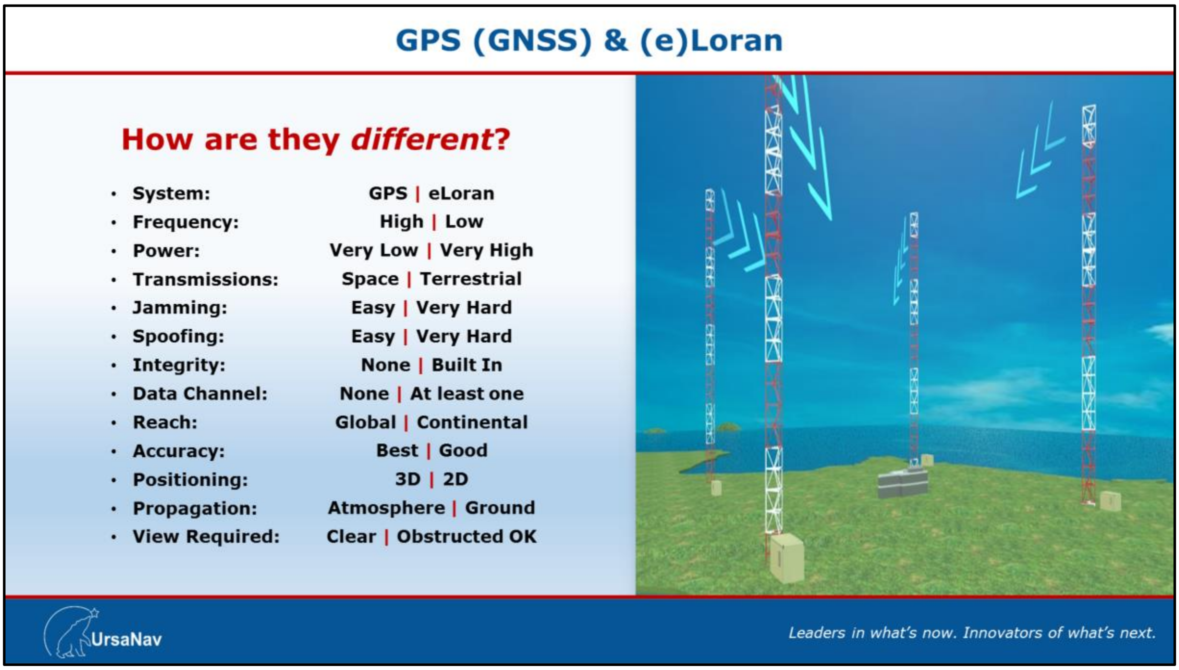
eLoran was the product of years of R&D and testing led by the USCG and FAA, in collaboration with academia (e.g., Ohio University, the USCG Academy, the University of Rhode Island, the University of Alaska, the University of Bangor, and Stanford University), industry (e.g., BAH, MITRE, Northrop-Grumman, Peterson Integrated Geopositioning, and Rockwell Collins), OGA (e.g., the VOLPE Center, the DOD Range Commanders Council), the international community, and 160+M Congressional funding.



GPS receivers require an almanac and ephemeris information for best accuracy. If this information is not already available and current in the receiver, it can take additional time to download and thereby improve performance.

eLoran receivers use previously stored Additional Secondary Factor (ASF) information to improve accuracy. Updates provided via the Loran Data Channel (LDC) produce the best accuracy.

Other technologies, such as TV, Radar, and SatNav have continually evolved; Loran has as well.

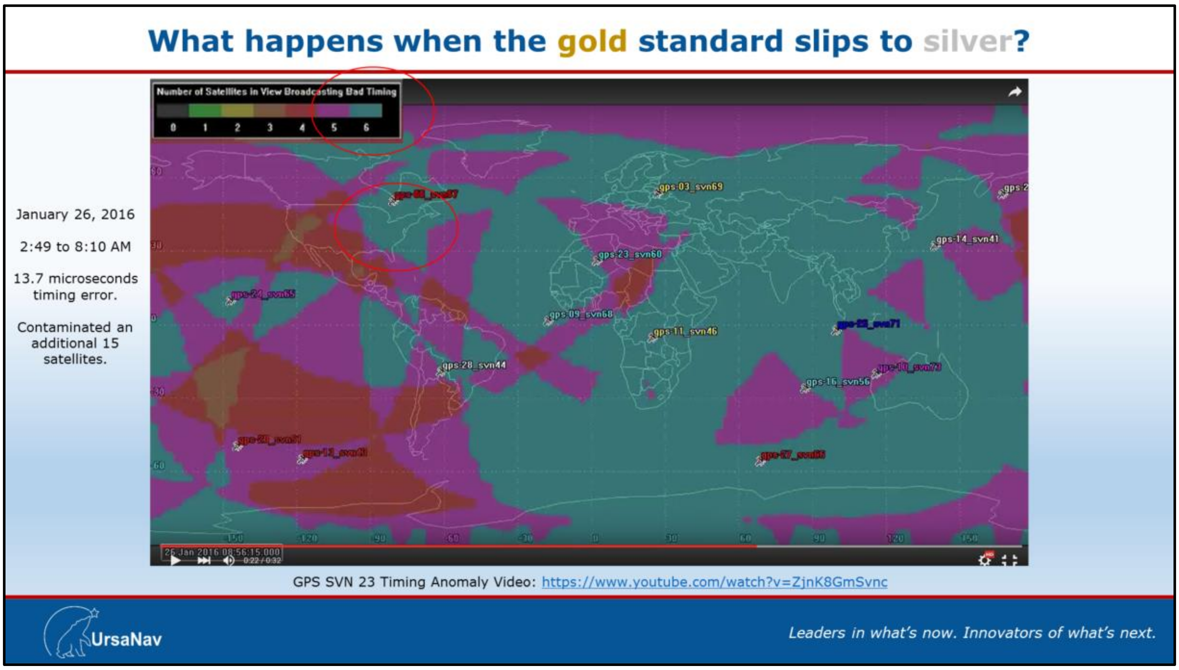


Four GPS satellites are required to get a 3D position and time.

With three GPS satellites, a 2D position is available, but it is presumed to be at sea level. No time is available.

eLoran signals from at least three stations are required to get a 2D position. 3D is available using an altimeter. Only a single eLoran signal is required to get time at a fixed location. Time is available while in motion if at least three eLoran signals are available (to provide positioning).

The most likely scenario for users is that GPS/GNSS and eLoran be integrated into a single receiver. The best solution is a "resilience triad" of technology, such as GPS/GNSS, eLoran and an OSC/NTP/PTP for timing and/or GPS/GNSS, eLoran, and INS for positioning. Anything that can be integrated with a GPS receiver can also be integrated with an eLoran receiver: INS, SAG, CSAC, etc.



Bad things happen to even the best systems/technologies.

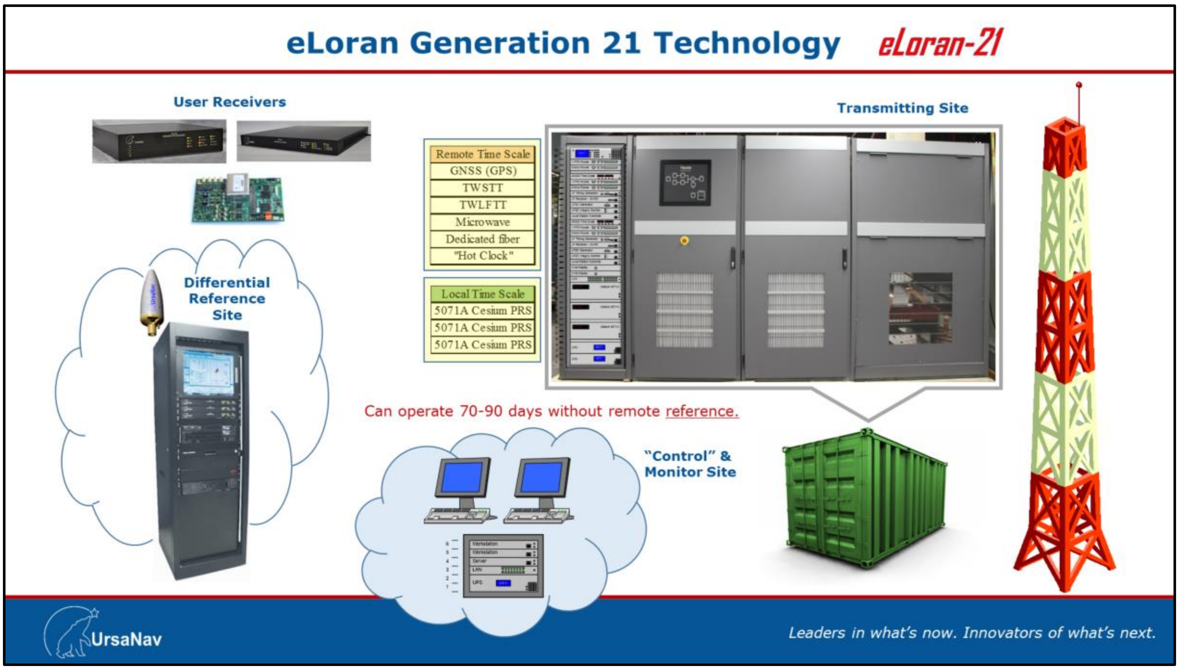
The entire Russian GLONASS constellation was unavailable for eleven hours during April 2014.

The European Galileo GNSS has suffered continual setbacks from funding delays, and in August 2014, two satellites were launched into the wrong orbits.

Even GPS has had its moments – see January 26 SVN 23 timing anomaly.

Because GNSS all operate in the same frequency bands, jammers are particularly effective. Modern jammers target not only GNSS, but also WiFi, Bluetooth, and telecommunications simultaneously.

The most insidious vulnerabilities to GNSS are spoofing, or "counterfeiting" of the signals. In most cases, the user doesn't know their PNT information is bad. This is known as Hazardous Misleading Information (HMI).



eLoran technology exists today, and is proven in operational use. The system consists of four major components: the transmitting site, the monitor & control and/or Quality of Service site, the Differential Reference site (as required), and the user receivers.

The technology is based on almost 60 years of operational experience in military and civilian use around the world. The design philosophies originally implemented for DOD use of the equipment is carried forward in all new versions. The technology is designed to be fully redundant and hot-swappable to maximize operational availability and reduce the logistics tail (i.e., maintenance).

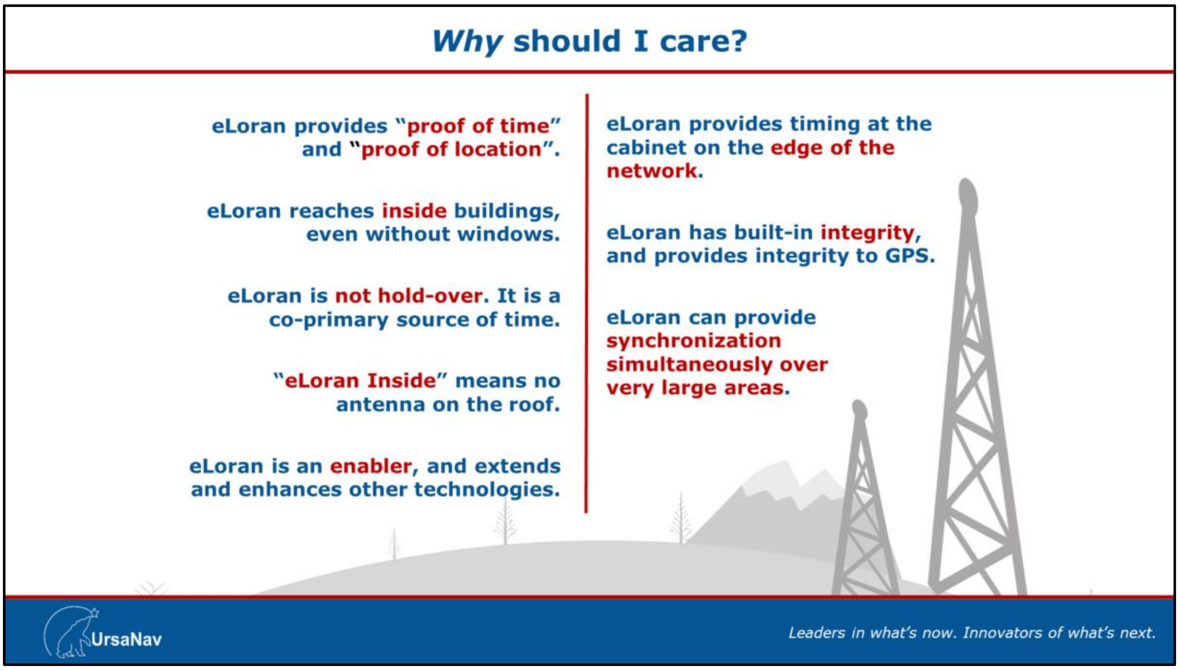
eLoran transmitting sites include a Local Time Scale that consists of an ensemble of three cesium-based Primary Reference Standards (PRS), and a Remote Time Scale that can have one or more reference UTC inputs: GPS/GNSS, TWSTT, TWLFTT, microwave, dedicated fiber, or "hot clock". The Local Time Scale monitors all of the Remote Time Scale reference inputs, but is not directly coupled to, or dependent upon, them. An eLoran transmitting station can operate fully autonomously without a remote timing reference input for 70-90 days using three 5071A cesium-based PRS, or possibly longer using other PRS: hydrogen maser or quantum clock.

Where required for improved PNT accuracy, a Differential Reference Station can be installed. These sites can provide differential corrections for positioning, timing, or both over an area of approximately 35 miles radius.

Before GPS was declared the primary source for PNT in the US in 1994, there were many Loran-C receiver manufacturers around the world. Receivers were available for maritime, aviation, land-mobile, handheld, and timing/frequency purposes. Because of the unavailability of a full GPS constellation during the first Gulf War, more Loran-C receivers were sold/used than GPS receivers. Industry will begin development of eLoran receivers, either integrated with GPS/GNSS or as standalone units, as soon as there are signals in space and some guarantee that those signals will remain available for 20 or more years. An eLoran receiver "on a chip" simply requires an investment; it is not a technology problem. Small footprint eLoran antennas are also achievable, with appropriate investment. At present, eLoran E-Field and H-Field antennas are available in approximately the same SWaP-C as GPS antennas, except for the mobile and hand-held markets.

Global standards exist for Loran-C signals in space and receivers, including maritime, aviation, and timing/frequency. These standards could easily be repurposed and/or upgraded for eLoran.

For less than the cost of a single GPS Block III satellite, a complete eLoran PNT system for the lower 48 states could be fully capitalized and operationally funded for 20 years.

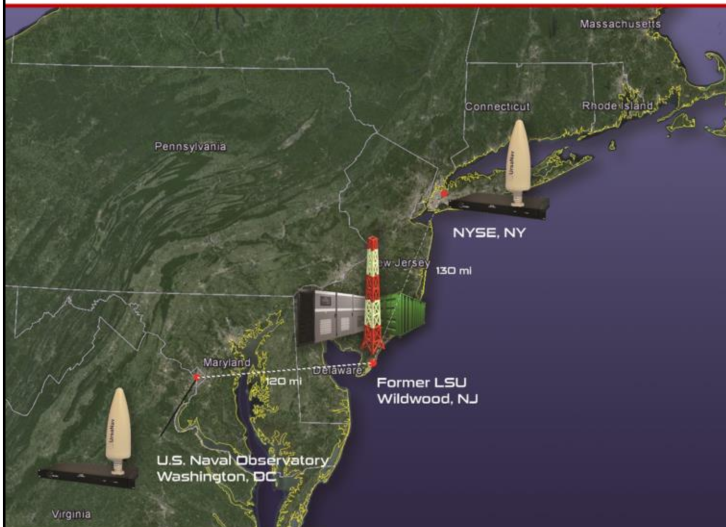


Why should all Sectors care?

eLoran also reaches to some extent underground and under water.

The Loran Data Channel (LDC) alone (i.e., not as part of a PNT solution) can be used to provide one-way, secure, and "guaranteed" data into areas where other signals may not reach: inside buildings, underground, under water, under triple canopy, etc. Note that GPS does not include any data channel capability. The LDC is part of the eLoran signal and, therefore, does not require a separate receiver. In fact, a standalone LDC receiver is very easy to develop.

eLoran Timing Evaluation Technology Laydown



eLoran Transmissions from former USCG Loran Support Unit Wildwood, NJ

- Synchronized to UTC via Two Way Satellite Time Transfer **(TWSTT)** provided by US Naval Observatory
- **360 kW** of Effective Radiated Power
- Broadcasting dual rated as 8970 Master and Secondary
- Data sent via **LDC** only on Secondary rate at raw data rate of 56 bps and effective data rate of 21 bps

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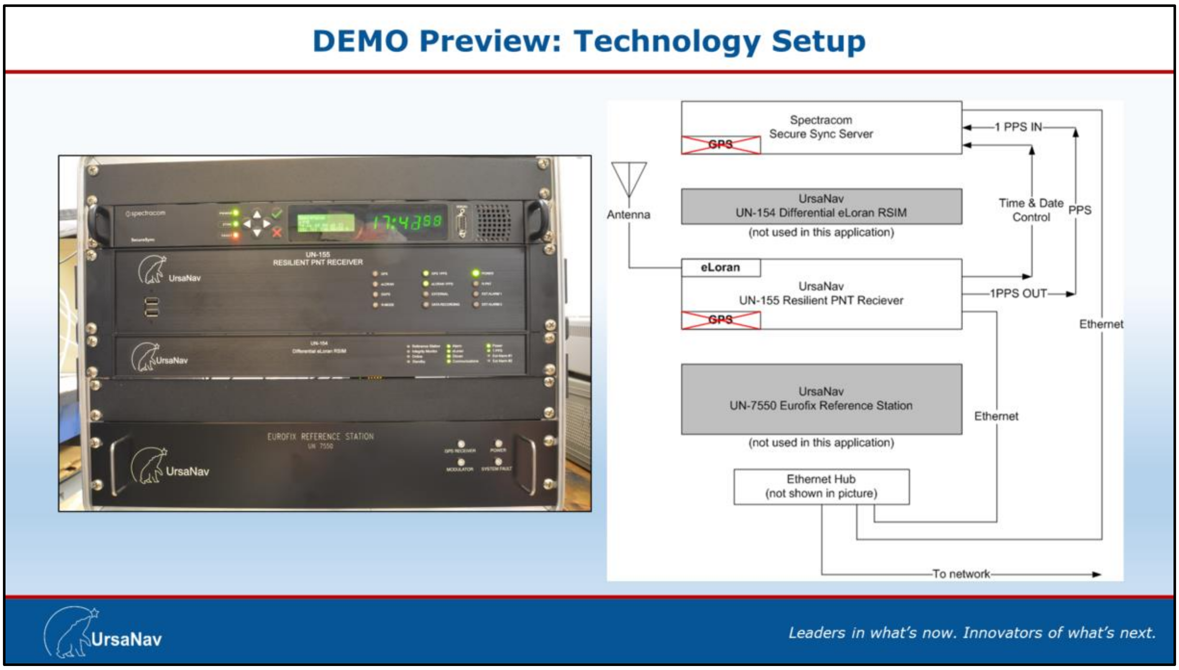
The TWSTT link between the USNO and the former LSU is provided as a UTC reference for testing. It is NOT used as a direct input to the Local Time Scale.

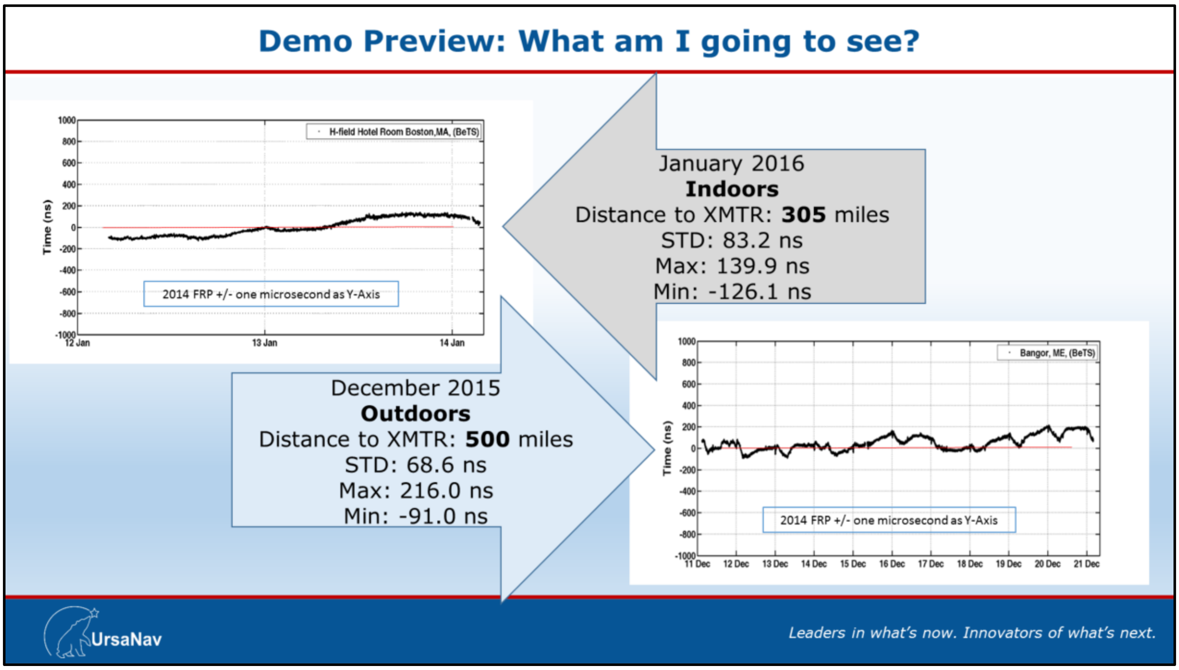


This rack includes equipment which we use for other demonstrations, and that is not being used today at the NYSE.

Spectracom provided the Sync Server that takes in 1 PPS and 10 MHz from an external source (i.e., GPS or eLoran) and provides a PTP output to a network. eLoran receivers provide the same outputs as GPS/GNSS receivers: 1 PPS, 10 MHz, and NMEA strings.

UrsaNav's UN-155 Resilient PNT Receiver is being used for today's demonstration. It includes GPS, DGPS, radio beacon, and eLoran receivers inside. Because GPS cannot be received inside the NYSE (hence, the red alarms), only the eLoran receiver can be used. The output of the eLoran receiver is fed into the Sync Server, which is then providing PTP to the network.

Because GPS is not available as a timing ***reference***, we brought along a 5071A cesium-based Primary Reference Standard (PRS – not shown) that was previously synchronized to within a few nanoseconds of UTC in our laboratory. The PRS is used simply as a ***reference*** against which to compare the eLoran timing signal.

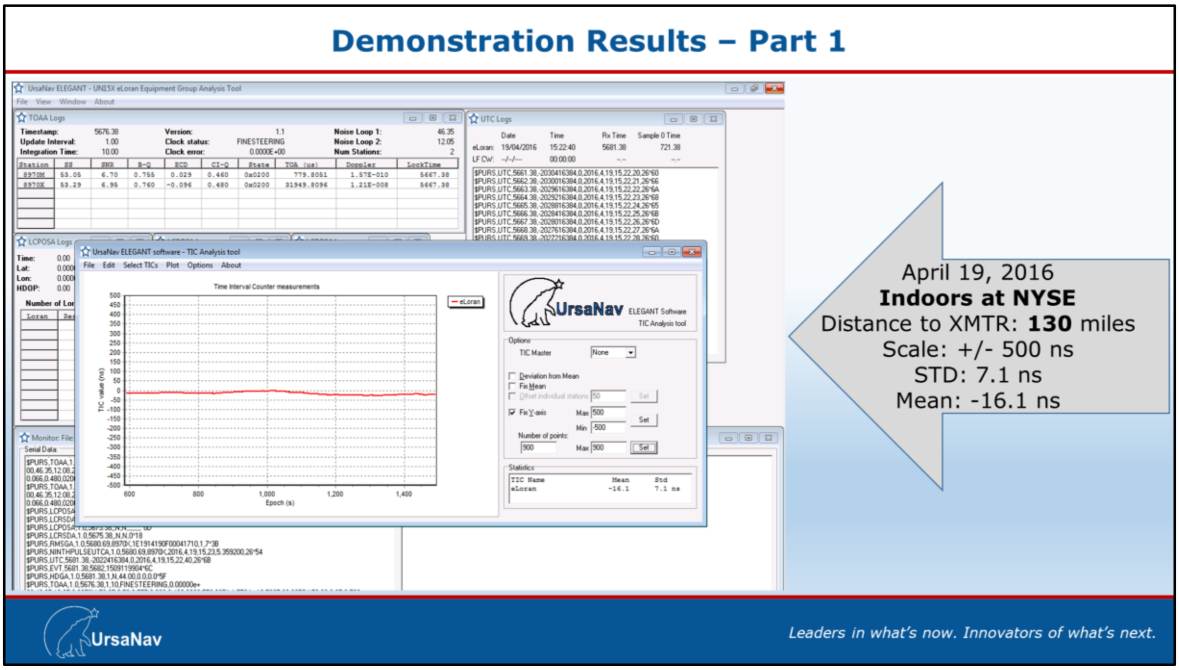


These charts provide you with a precursor to what you will see in the live demonstration.

The left chart shows an eLoran timing signal as received indoors in a hotel in downtown Boston, MA in January 2016. The distance to the transmitting site was 305 miles, and NO differential corrections were applied.

The right chart shows an eLoran timing signal as received outdoors in Bangor, ME in December 2015. The distance to the transmitting site was 500 miles, and NO differential corrections were applied.

The performance of the timing solution depends on the distance, terrain, weather effects, and receiver location (as it does with any RF solution). Actual performance, without differential corrections, may not always be this good, but within the lower 48 states will always be better than one microsecond to UTC, and typically less than 500 nanoseconds. Preliminary testing and modeling indicates the actual performance can be better than 350 nanoseconds over the entire lower 48 states. Performance is much better, and more consistent, when within range of a differential reference station site.



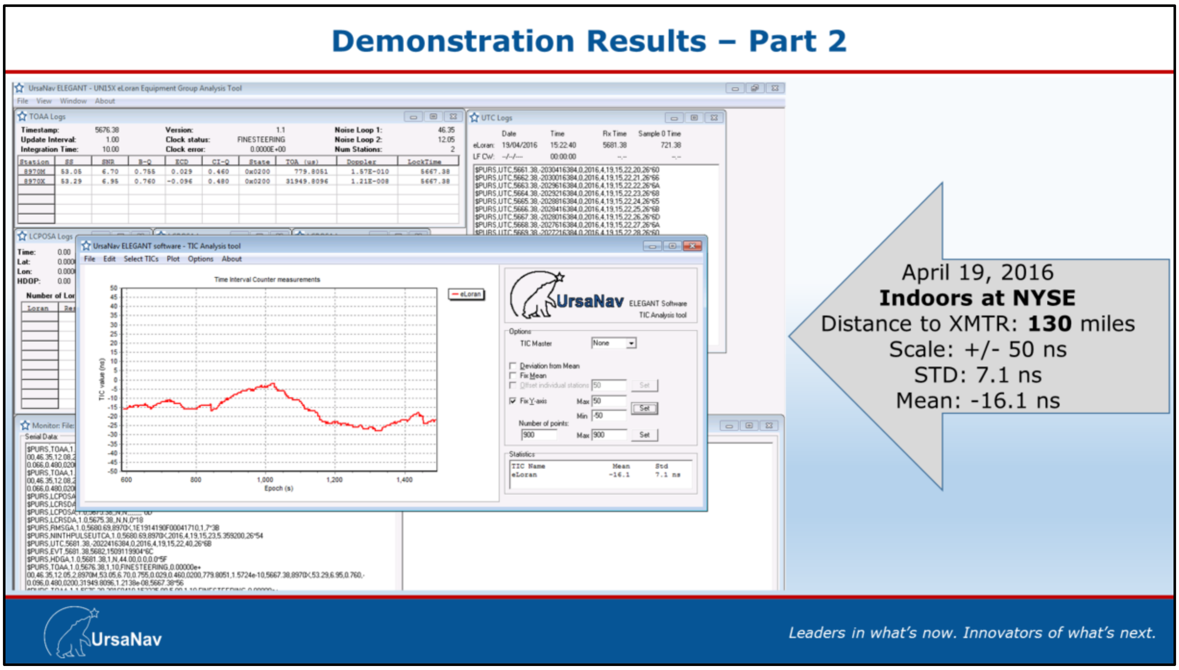
Dual rated transmissions from the Former USCG Loran Support Unit located in Wildwood, NJ: 8970-M and 8970-X.

LDC information was provided on only one rate.

Transmitting at approximately 360 kW ERP.

NO differential corrections were available or applied.

5071A PRS, synchronized to within nanoseconds of UTC, used as the timing reference against which to measure the eLoran timing.



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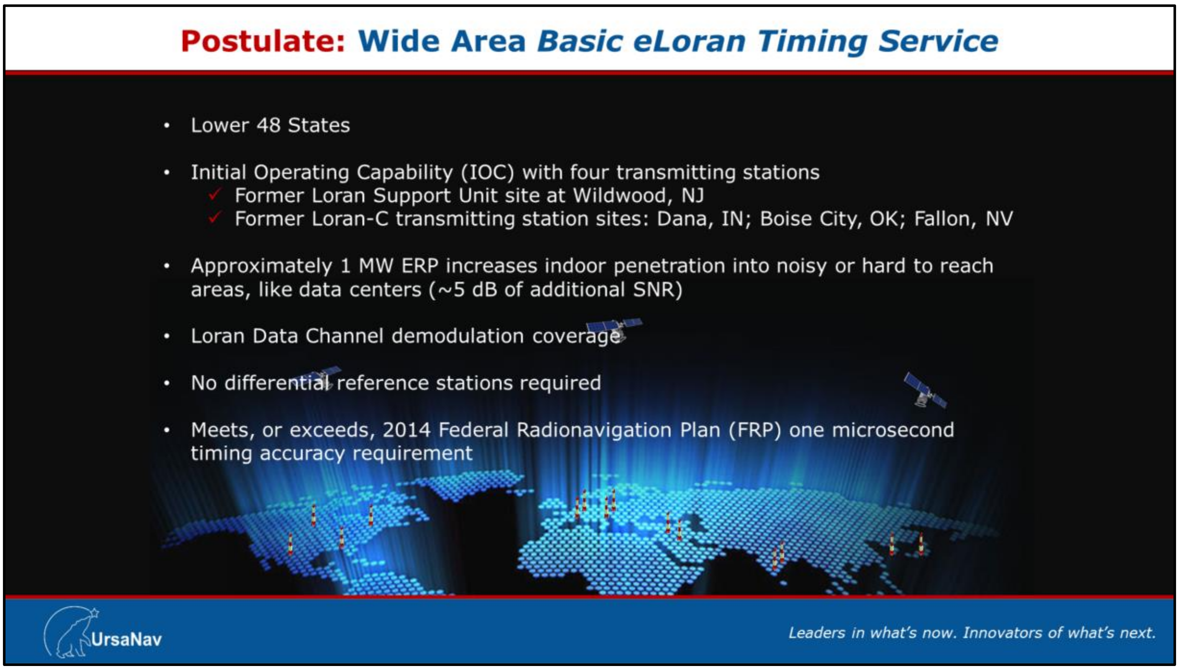
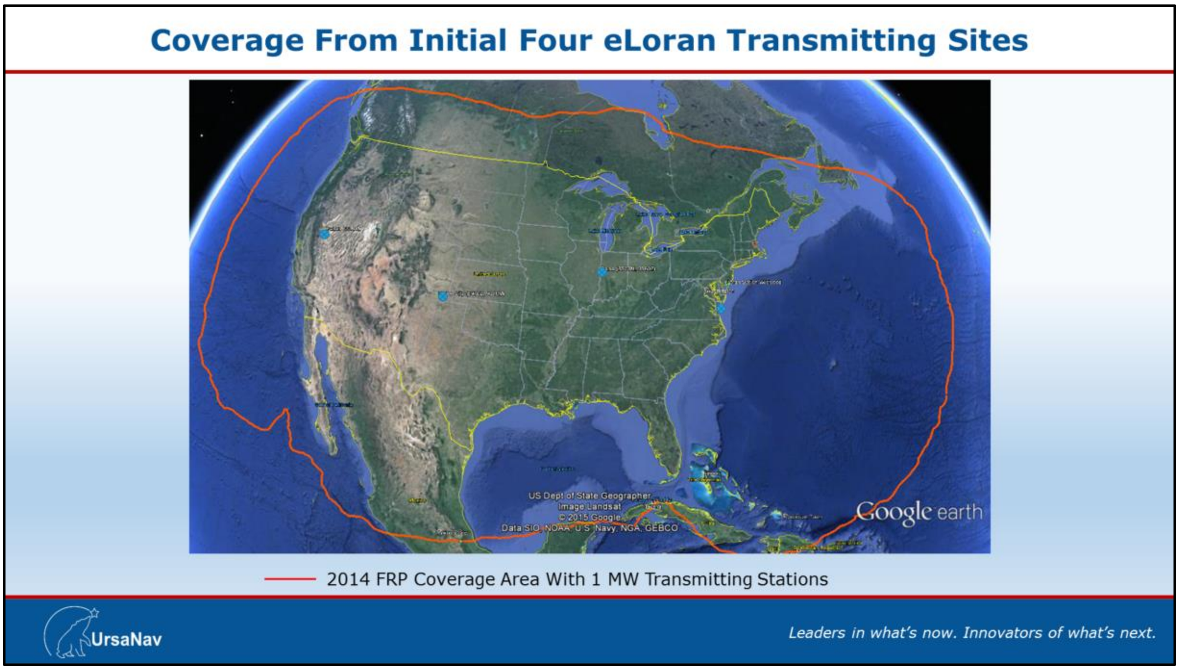


What you just saw in the demonstration was the capability of eLoran to provide accurate timing WRT UTC over a very long distance (hence, wide-area), and indoors. No differential corrections were applied.

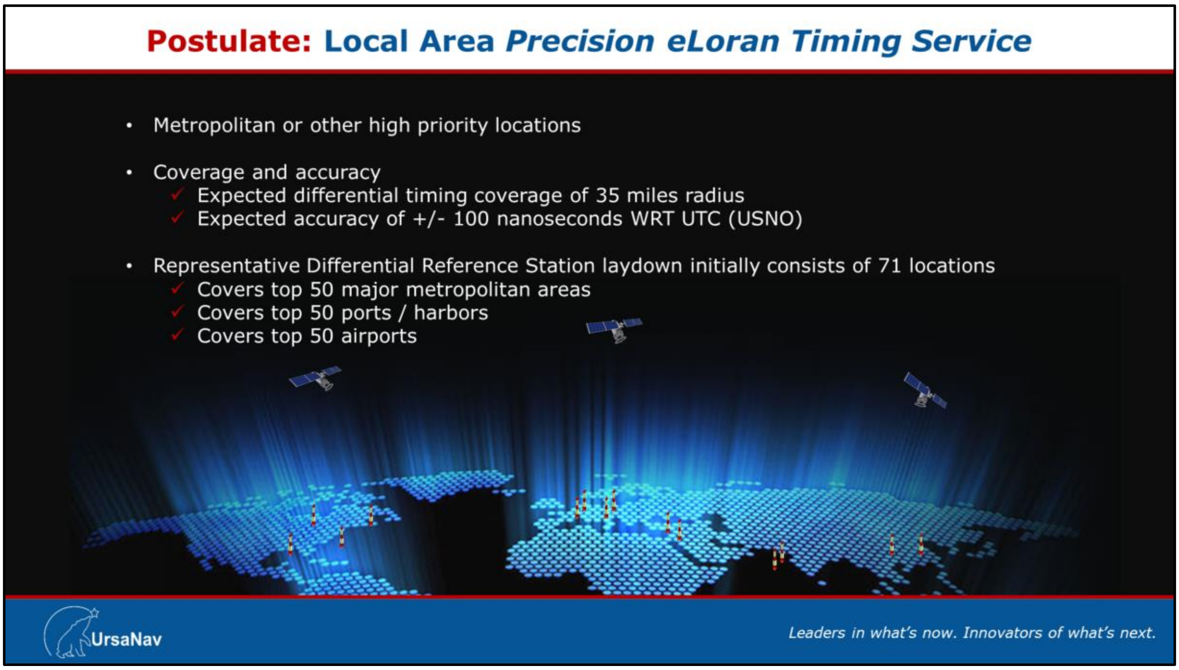
To provide this capability over the lower 48 states, in an IOC mode, would require at least four transmitting sites. Ten transmitting sites would provide better coverage and improved redundancy.



Four IOC sites are shown. Ten IOC sites are recommended, with three to the north and three to the south of the four shown. Existing Loran-C infrastructure could be repurposed for all ten sites.

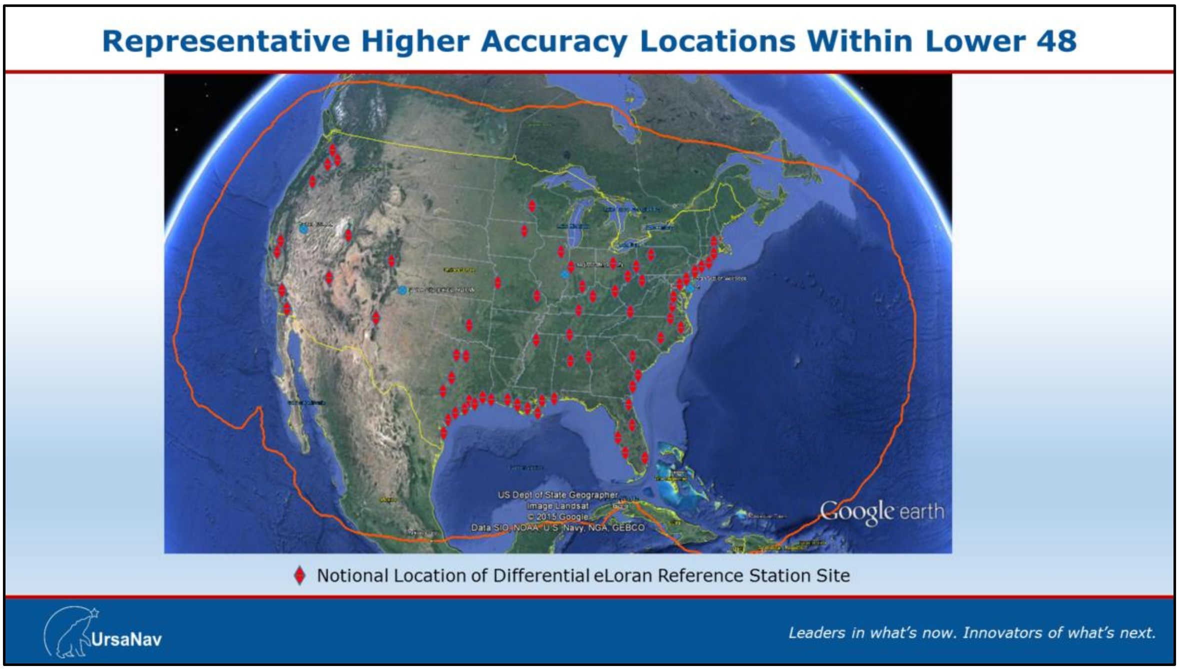
Sites can be brought on line as they are completed, and would be useable immediately.

With ten sites, some positioning capability can also be provided, along with the ability to get timing while mobile.



For more coverage and improved penetration into buildings, etc., additional transmitting sites are required. Additionally, PNT accuracy is greatly improved through the use of differential reference sites.

A notional 71 differential reference sites would provide improved accuracy at the top 50 major metropolitan areas, top 50 ports/harbors, and top 50 airports. Note that positioning accuracy can only be improved when there is an adequate number of transmitting sites to provide at least three signals with good geometry at the differential reference site. Timing can be improved using the four or ten proposed IOC transmitting sites.



These are notional locations for differential reference station sites. Because they are key to improved accuracy within their respective coverage area, the differential reference stations have triple redundancy built in.

There is no reason, other than financial, that two reference stations could not be installed for especially critical/key locations.

eLoran signals propagate along the surface of the earth, and are mostly affected by changes in terrain and seasonal and daily weather. These "Additional Secondary Factor (ASF)" effects can be measured and/or modeled and calibrated out of the system. ASFs are virtually constant over long periods of time, so their impact on the typical user is minimum.

However, for the user who requires higher accuracies, the LDC is used to provide differential corrections that mitigate the impact of localized weather effects.

The capabilities of the Differential Reference Station site is improved when it has access to localized weather information (e.g., temperature, dew point) from NWS, NOAA, NEA, NGA, WIMS, CORS, or other data bases.

Take Aways

- ✓ eLoran ***is*** a stable, wide area source of PNT for redundancy and resiliency in critical infrastructure and key resource sectors.
- ✓ It works in many locations where GPS is not available.
- ✓ It works when GPS may be untrustworthy.
- ✓ ***Without*** differential corrections, eLoran is capable of meeting 2014 FRP timing user requirements of +/- 1 microsecond over very wide areas.
- ✓ ***With*** the application of differential corrections, eLoran is capable of meeting the needs of higher accuracy timing users of +/- 100 nanoseconds over a local area.
- ✓ With an initial four transmitting stations, eLoran can provide resilient and complimentary timing, frequency, and data over the Lower 48 United States.
- ✓ With additional transmitting stations, eLoran can provide additional resilience and complimentary positioning over the Lower 48 United States.
- ✓ eLoran is efficient, economical, and can be provided expeditiously.

Contact Steve Bartlett at UrsaNav for opportunities to collaborate under our CRADA with the DHS/USCG.

Because CRADAs are not a contract, there is no USG funding provided. However, with appropriate approvals, industry days can be arranged to allow for USG, academic, or commercial testing.

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