Loran – Past, Present and Future

by
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Abstract

Loran is perhaps best remembered as a World War II development that had a major impact on the outcome of that conflict. The "A" version embodiment operating at 2Mhz was significantly improved in the later "C" version that incorporated spread spectrum pulse technology transmitted at 100kHz where the stability of the groundwave uncontaminated by skywaves could be realized. This paper reviews the author's involvement with Loran-C from the early 1960s until the present day and provides the evidence of a system whose potential has yet to be realized. The technological limitations that have precluded capitalizing on past successes using the system for timing. positioning and navigation are described, punctuated with some untold anecdotes. The current status of Loran-C is presented from both a technological and political standpoint stressing the need to abandon the perception that the system is outdated and of questionable value. The future of Loran-C incorporating state-of-the-art digital components and software technology is projected in the context of the system being an indispensable complement to satellite technology to achieve acceptable availability, integrity and continuity of service. The paper concludes with recommendations for structuring the provision of Loran-C/Satellite services worldwide to overcome the tendency towards dependency upon a single system.

Loran Dichotomy

The editor of *GPS World* and the new magazine *Galileo's World* describes those who caution against dependence upon the United States Global Positioning System (GPS) as "zealots supporting non-GPS radionavigation systems." Agencies under the Department of Transportation have been heard to describe the loran community as the "Loran Mafia." Within the loran[1] community those who actively support a complementary mix of satellite and terrestrial systems are known as "The Usual Suspects." Moreover the vast majority of those in the GPS industry regard loran as an outdated, old fashioned system that has no place in the modern world of radionavigation. To add fuel to this decidedly negative attitude towards loran, the United States Coast Guard has no stated requirement for loran and the Federal Aviation Administration, while investigating the possible use of loran in the National Airspace System, has no requirement for loran. On the other side of the ledger, Congress has seen fit to appropriate funds for the continued operation of loran and, more importantly, provide the funding for upgrading the entire United States

[1] Throughout this paper loran refers to the current system Loran-C (or the Russian equivalent Chayka) that operates at 100kHz with a pulsed transmission unlike its predecessor, Loran-A, that was a continuous wave transmission at 2MHz. Users of Loran-C receive a stable ground wave that is unaffected by the ionosphere.

system. What lies behind this dichotomy and why are the supporters of loran so maligned? From a personal standpoint why, after all these years, do I remain a staunch supporter of loran, yet, at the same time, strongly endorse satellite navigation and timing technology? Certainly not for monetary gain!

Myths Dispelled

Let's immediately dispense with two common myths. First, concerning loran being an old fashioned and obsolete technology. Loran is no more old fashioned than GPS, both systems are literally as old as the hills. They transmit radio waves obeying Maxwell's equations while propagating by different modes; GPS by line of sight through the ionosphere; loran by direct terrestrial path over the surface of the earth. It is the loran receiving equipment and some of the loran transmitters that are "old fashioned" and "outdated" and understandably so. There has been no long-term commitment to loran while its death has been sought after for 25 years, resulting in virtually no investment for nearly two decades.

The second myth is that the loran community believes loran is on a par with GPS and competes with GPS and augmented GPS – WAAS for example. There may be individuals who hold this opinion but the International Loran Association's official radionavigation policy clearly states that a mix of satellite and terrestrial systems is necessary and sole dependence on a single system violates the fundamental rules of navigating with safety.

History Recounted

It was 24 years ago that I was elected the third President of the ILA. Now with almost 40 years of experience with loran I feel qualified to recount some history. Bear with me, this is not a boring reminiscence of the past by one of the old boys, there are some fun stories mixed in with the irony of the past 30 years.

The weather initiative: My introduction to Loran-C came shortly after starting Beukers Laboratories in the early 60s and was a result of what was considered at the time to be a way out proposal to the then Weather Bureau. We suggested that the best way to overcome the difficulty of determining upper-air winds at sea was to abandon the classic radar or radiotheodolite requiring a stabilized platform and instead retransmit loran signals from a meteorological probe thereby obtaining its position and course. With only two loran stations, Nantucket and Cape Fear, on the air and with jury-rigged manual tracking equipment we nevertheless demonstrated an economically viable method of determining winds of the upper atmosphere. The Weather Bureau project engineer, Chris Harmantis, was elated with the initial results and we really believed we had a technology in the bag. Soon thereafter Booze Allen & Hamilton came into the picture to do an analysis. To our chagrin the conclusion was that although the technique was viable there was no guarantee that loran would be around in the long term to warrant an investment in the technology. By then it was the late 60s – over 30 years ago and loran is still going strong!

Loran-C Wins: During the early 1970s there was the great radionavigation debate – to what radionavigation system should the US Coast Guard commit for the Coastal Confluence Zone (CCZ)? Omega, differential Omega, Decca, Hastings Raydist and other systems were thoroughly analyzed for their suitability[2]. A highly emotional battle raged for many months but in the end, as we all know, loran was the winner. A sigh of relief was heard within the loran community and we felt that it would be smooth sailing for several decades. Wishful thinking perhaps, but more of that later.

Cloak & Dagger Stuff: Then for us at Beukers Labs. on Long Island, New York, all hell broke loose. Word had got out that we could track remote objects with an expendable device costing a few dollars. A rotund gentleman in Air Force blue from "the company" knocked on our front door with a blank check in hand and demanded that we stand on our heads to satisfy a bizarre list of requirements. Locate the prisoners in Vietnam; track vehicles carrying people being smuggled out of foreign lands and even develop loran transmitters that could be installed in motel rooms in foreign cities. Together with the advanced semiconductor labs at Texas Instruments and the black magic battery department at Honeywell we came up with a smoking pipe with a loran retransmitter in its bowl powered by lithium batteries located in the lid of a peanut butter jar – the only commodities permitted to be sent to the Vietnam prisoners.

Another challenge was to determine the room that a cooperative individual was going to in a high rise building in a major city in the Far East. With a loran retransmitter incorporating a pressure cell concealed in a paper bag our test engineer attempted to use the elevator only to discover that the transmission interfered with the automatic door closing mechanism. He and the project never got off the ground!

Secret Service Stuff: Then the secret service jumped in, and we found that we were being given the responsibility of tracking VIP's going abroad. We were loaned the Air Force One helicopter together with its pilot to conduct some way out scenarios from an instantaneously installed helicopter pad just outside the lab. To track the President and Vice President we came up with shoe motion

[2] A complete record of the debate was documented in the Hearings before the Subcommittee on Coast Guard and Navigation in the ninety-third Congress for the Coast Guard Authorization Bill HR 13595

generators, heel mounted H-field antennas and a retransmitter the size of a silver dollar. One amusing story I must relate. On one test we ordered the AF1 helicopter pilot to fly down to Montauk Point at the end of Long Island and proceed back along the southern coast of Fire Island. The pilot proceeded with all speed outward bound and we followed his progress on a large flat top Calcomp plotter. The track was perfect. On the way back every few miles the trace developed a series of perturbing loops. At the following debriefing we asked the pilot to confirm his route and we questioned the inbound track departure from normal. A rather red-faced pilot had to admit that the scantily clad scenery on the beach provided light relief from a monotonous trip.

The Coast Guard Steps Up: At the same time as executing the cloak and dagger stuff we were working with the US Coast Guard on a system know as DALS – Distress Alerting and Locating System. A remote hand held unit containing a loran receiver and transmitter that was to be located by a base station performing the calculations to determine the position of the remote unit. So successful was the system that the Coast Guard brass wanted to see a first hand demonstration without waiting for reports. On the appointed day the Coast Guard Gulfstream landed at McArthur airport, and, I'm not exaggerating, it must have carried every Admiral and high-ranking officer in the Coast Guard Service all out for a jaunt in the country. We spent the day providing a dramatic and impressive demonstration with a lunch break followed by interactive participation by the brass. We returned the Admirals to their aircraft on time - exactly to the minute. As the last of the Admirals was piped aboard, I asked how he felt the demonstration went. His reply, "I am thoroughly impressed, you got us back to our plane on time!"

Americas Cup Race: The Admirals' visit led to my last story in which Bill Roland played a major role. It was 1974, the Secretary of the Department of Transportation, Claude Stout Brinegar, had signed the authorization for the use of loran in the CCZ. We wanted a big publicity stunt to make the decision known to the public. Bill Roland came up with the idea of tracking the yachts in the final race of the America's cup and getting Walter Cronkite to do a commentary on the race from the Calcomp plotter track located in the Newport, Rhode Island Coast Guard Station. This involved Ted Turner with his yacht the Courageous and the Australian team, together, with the New York Yacht Club boat. We had retransmitters on all three boats and immediately ran into trouble with the NY Yacht Club because we claimed that they were setting the race marker buoys at the wrong locations. After several hours of heated arguments the technician on the Yacht Club boat admitted that he had forgotten to include the delay in the radar transponder. The tracks obtained during the trials preceding the race were accurate and impressive, so much so, that the Australian captain believed that the United States was using the information to enhance its race performance. We were summarily thrown off both boats.

Gathering Storm

These and many other projects were the fun side. But the clouds were gathering. In 1977, just three years after loran had been selected for the radionavigation for the CCZ, the General Accounting Office was asked by Congress to look into Radionavigation Planning and in a report published in 1978 it called for the termination of loran, chastising the Department of Transport for not putting more funds into the Global Positioning System. This was followed up in 1981 with a report entitled "DOT Should Terminate Further Loran-C Development and Modernization and Exploit the Potential of the NAVSTAR/Global Positioning System." The report called for the termination of Loran-C by the early 1990s. Then in 1992 the Federal Radionavigation Plan stated that Loran-C would remain in service until 2015, but this was rescinded two years later and replaced with a termination date of 2000. That date we know has passed and the latest language says Loran-C will remain in operation "in the short term." It is no wonder that industry has been less than enthusiastic about investing in loran with this on-again, off-again U.S. Government policy that has been going on for a quarter of a century.

Realizing Loran's Potential

I have probably spent far too much of my time talking about the past, but it pays to bear the history in mind when considering loran today and for the future. I can say without reservation that while we had the embryo of a technology that had great promise we were never able to achieve the full potential of the system because we lacked the computer processing power and chip technology that are available today. It is quite remarkable what the loran industry was able to achieve in the past without the benefit of today's technology. Since then, except for a very few small isolated pockets of R&D and manufacturing, loran receiver development and mass production has not progressed for nearly two decades. Today we are witnessing a resurgence of loran activities and, with the use of the technologies available today, the full potential of the system will be realized.

Why Loran?

So what, you might say, and who needs loran anyway? The answer to this question gets us to the crux of the matter. As a complement to GPS[3] loran has all the desirable non similar features that make it an indispensable, independent system to support GPS for positioning, navigation, integrity, continuity of service and time dissemination. The debate as to whether an

[3] Although GPS has been used throughout this paper, the concepts apply equally to the current GLONASS and future Galileo constellations.

alternative, complement or backup to GPS is necessary has been raging for a decade. Today the vulnerability of GPS to natural and manmade interference, intentional and unintentional, is well known and the concept of sole means GPS for all forms of transportation and time dissemination is no longer considered viable. The change in policy in the United States is reflected in the 1999 Federal Radionavigation Plan that defers termination of terrestrial systems for many years. Even then their demise is predicated on GPS providing the integrity and continuity of service to satisfy the most stringent safety-of-life requirements leaving the sole means issue unresolved.

Sole Means and Vulnerability: On the basis that one can accept that there must be complementary systems to GPS, for both positioning and timing, loran is the only current system that can possibly fulfill this role. GPS augmentations offer no more security than GPS since these services are dependent upon an operational GPS constellation. Other satellite systems fall into the same category of vulnerability and, in any case, there is no evidence of a solid operational constellation being available for several years. Further, as far as the United States is concerned, there appears to be no movement towards accepting use of a system not under its control.

Communications Dependency: The aviation community, although a minority GPS user, is a critically important segment of the user community because of the priority given to safety. Aviation's use of GPS is a special case in that there are aviation-specific alternative terrestrial systems for navigation and landing. However, aviation users rely upon precise time for communications and the dissemination of precise time is becoming increasingly dependent upon GPS.

The Zealots' Issue: There is another worrisome aspect of total dependence on GPS and this is the scenario that our *GPS World* editor calls us zealots for raising. By tying an entire national infrastructure to GPS[4] interruption of the service would become an economic disaster with devastating consequences. Other than disruption through natural causes there are some very smart hackers and crackers, terrorists and even cranks with a chip on their shoulders that may find a way to deny GPS service. What is the probability of GPS being unavailable for an extended period of time? Very low, but not dismissible, so why tempt providence with this possibility when the means to avoid the consequences are already available at very modest cost? This is akin to pedaling insurance, it's a hard sell; the premiums may be low, but the cash has to come out of the current account and the return on investment is indefinable.

The Potentials

Coverage and Technology: We are fortunate in having extensive loran coverage in the Northern hemisphere. North America, Europe, the Far East and parts of the Commonwealth of Independent States enjoy loran service and have the option of benefiting from the complementary use of loran and GPS. The potential of loran alone using current processing technology is only just being realized and the many benefits of combining the two systems have yet to be seen.

Loran Communications: Data communication by means of loran is now operational in Europe. Over the past decade a dedicated team of engineers at Delft University in The Netherlands under the direction of Professor Durk van Willigen has developed and have now perfected a method of using the loran transmissions for communication. The concept known as Eurofix is being used to transmit differential GPS but can additionally transmit a GPS integrity message and be used for inter-station communications. The relatively slow data channel has benefited from the cessation of GPS Selective Availability that required constant real time updating to remove the effects of the deliberate degradation of GPS accuracy.[5]

Data Rate: Even without the need to correct for SA the Eurofix data requires additional capacity to provide an equivalent performance to the satellite Wide Area Augmentation System. This has stimulated the FAA and Coast Guard to investigate alternative modulation schemes seen to have the potential of increasing the data throughput to that of the WAAS. The object of this work is not to replace WAAS but to enable loran to provide an alternative where or when WAAS is unavailable.

In a Nut Shell – Features and Limitations

Features:

- Loran is the only independent terrestrial service that can provide both radio positioning and a precision time reference on a regional worldwide basis.
- Loran is a regional system under the control of national managements.
- Loran is compatible with and complementary to GPS.
- Loran and GPS signals are propagated in distinctly different modes.

[4] GPS is not only a positioning service but is now widely used to disseminate precise time. Digital communications and power distribution and, any service dependent upon precise time, would be affected by any prolonged outage of GPS.

[5] Although SA has be turned down to zero (off?) transmission of differential information is still required to improve the basic GPS accuracy from a 10-20 meter system to under 5 meters.

- Loran and GPS have no failure modes common to both systems.
- Loran signals are strong, penetrate buildings and are not shielded by buildings and trees.
- Loran signals can provide continuity of service at times when GPS is unavailable.
- Loran offset[6] can be removed by GPS and Loran-DGPS (Eurofix).
- Loran with the offset removed has a repeatable accuracy on par with uncorrected GPS.
- Loran communications can provide GPS integrity.
- Loran transmitters offer additional signal sources for the GPS constellation.
- Loran transmitter failures are rare but, when they occur, being terrestrial, they can be rapidly corrected.

But:

- Loran is not a substitute for GPS or any other satellite system.
- Loran is not a substitute for WAAS, EGNOS or MSAS.
- Loran is a regional not a global system.
- Loran cannot achieve the 5 meter accuracy of differential GPS.
- Loran is not immune to local and atmospheric interference.

Structuring a Worldwide Service

Accept Concept: First and foremost there has to be a universal acceptance that to become totally dependent upon space for all modes of transportation and communications is an unacceptable policy. From thereon implementation of a worldwide regional loran service will be straightforward with operational models to imitate. Relative to satellite technology the cost to implement and operate regional coverage is insignificant.

National and Regional: National systems will cover the larger landmasses with coverage spilling over to adjacent states and coastal waters. States with smaller landmasses can take advantage of coverage extending beyond state boundaries by cooperative agreements to install one or more transmitters to provide full national coverage. Substantial oceanic areas will receive coverage as land implementation progresses.

The Models: There are currently two active models to imitate. The Northwest Europe Loran-C System – NELS (Denmark; France; Germany; Ireland; Norway; The Netherlands.) and the Far East Radionavigation System FERNS (China; Korea: Japan: Russia.) These consortia together with the US and Russia provide coverage over much of the Northern Hemisphere.

Consolidation of Coverage: To maximize worldwide loran coverage at minimum cost requires that the current coverage be extended by strategic site planning of additional transmitters. With state cooperation and using well understood modeling techniques a plan for transmitter locations can be generated. This is a project that needs to be put high on the priority of action items.

Coordination of Rates: All loran stations transmit a spread spectrum signal centered on 100kHz. Individual stations are identified by the precise time of signal transmission within groups. The high power of the transmitters and the ability of loran groundwave transmissions to travel 1000km or more require that there is world coordination of Group Repetition Intervals (GRI). The administrative procedure for implementing GRIs on a worldwide basis is already in place and is being coordinated by the International Association of Maritime Aids to Navigation and Lighthouse Authorities, headquartered in St. Germain-en-Lay, France.

Epilogue

The unquestionable and inumerable benefits of loran as a complement to satellite technology far outweigh the system's limitations. It follows that we should continue to support loran, not just as a stand-alone service, but as one that complements satellite technology to provide a robust worldwide service with outstanding integrity and continuity.

[6] Variation in the velocity of propagation over the surface of the earth gives rise to a static offset of the loran position. This offset can be removed using constants derived from measurements or models. Alternatively the GPS or Loran-DGPS can be used in real time for a one-time calibration of the loran position.