Statement of Martin Faga

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Mr. Chairman, distinguished members of the committee, thank you for the opportunity to testify today about the critical importance of establishing a complementary system for our space-based system for Positioning, Navigation and Timing – the Global Positioning System (GPS). I am Martin Faga and I am testifying today as a private citizen. In the past, in various professional capacities, I have been extensively involved with the GPS system. I served as a congressional staff member in the late 70s and through the 80s, as Air Force Assistant Secretary for Space from 89-93 just as the GPS system was being completed, then as an executive at the MITRE Corporation, an engineering firm with extensive involvement in GPS and a wide range of national security and air traffic control systems. All of those are behind me. Today, I serve as a member of the administration's National Space-Based Positioning, Navigation, and Timing Advisory Board. However, I don't appear here on behalf of the Advisory Board.

As we know, GPS has become a world-wide public utility with countless users. We are all familiar with GPS for navigation, which is important for everyday applications; but also those where safety of life is involved such as maritime and aviation navigation. What is less well known is that GPS is very important for the distribution of precise timing. All networks, such as cellular telephones, financial networks, and the internet itself require that the network have access to timing information accurate to about 1/1,000,000 of a second. This is difficult to achieve over long distances and for long periods of time. GPS provides the best and least expensive way to achieve this; hence it has been widely adopted for such purposes. However, the result of GPS disruption would be the disruption of the many systems that depend on GPS timing for their operation. Most have local timing equipment that will work for minutes to hours, but GPS disruption longer than a few hours would result in the failure of many of the computer, communications and electronic services on which a modern society runs. In the extreme, the results could be catastrophic.

GPS is a wonderful system and it should be used whenever it is available. Its highly accurate signal is free for all to use and has been incorporated into virtually every technology. But it is a low-power space-based signal that can be disrupted. Such disruptions could result from many sources. These include:

> **Space weather.** Large solar flares can interrupt signals from space and in extreme cases, can damage or destroy satellites and sensitive ground equipment.
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> **Collisions.** Space has become crowded with both satellites and debris. Several collisions in space have occurred, and at least one was intentional. Fortunately, the GPS orbit is less susceptible to collision than many.

Error. The US Air Force has done a superb job of maintaining and operating our GPS system. It would be hard to be excessive in praise for 20 years of Air Force performance. But, human and software error is a threat to every complex system. The Russian navigation satellite system, GLONASS, twice went out of service last year (once for 13 hours) because bad information was accidentally loaded into the system. Europe's Galileo satellite navigation system has suffered from positioning and programming problems. GPS, GLONASS, and Galileo have all suffered from failed satellite launches. Simple, honest human mistakes are a real and unpredictable threat.

Intentional disruption. Senior members of the Administration have stated publicly that several nations have the ability to damage or destroy satellites in space, launch cyberattacks on control and communications systems, and jam signals over very wide areas.

GPS spoofing (providing false location information) and jamming are also within the reach of many non-state actors. While such incidents might not result in a national or multi-day disruption of GPS service, they could still have very serious military or societal consequences.

GPS disruption is of such great importance because it is a part of so much of our critical infrastructure. DHS describes the critical infrastructures of the United States in 16 categories, such as energy, transportation, financial services, agriculture, etc. DHS reports that GPS is important to all categories and critical to 13 of the 16.

Most other conceivable cyber-disruptions could cripple individual companies, agencies, or even an industry. But a major disruption of GPS would quickly and severely impact almost every sector, industry and citizen.

Every mode of transportation would immediately slow down, become more dangerous and accident prone. It would take more time and more fuel to deliver fewer people and less cargo, regardless of how they were being moved. Within several hours our telecommunications would begin to fail as cell towers and radio systems lost time synchronization. Then financial and other data systems would begin to shut down as it became impossible to certify the sequence of the millions of transactions that are normally processed each second. The internet would be affected.

Concern over our critical dependence on GPS was first officially recognized by President Clinton in 1998 in Presidential Decision Directive/NSC-63, on *Critical Infrastructure Protection.* It directed the Department of Transportation to look at the issue and make recommendations. Based on that work, in 2004 President Bush issued his National Space-Based Position, Navigation and Timing Policy, NSPD 39. It directed the Department of Transportation to work with the Department of Homeland Security and procure a backup capability for GPS.

In 2008, after much study and discussion, all of the concerned departments and agencies across the federal government identified a terrestrial system called Enhanced Loran as the best means to complement GPS. Loran stands for LOng RAnge Navigation and was first introduced during World War II. It uses a very low frequency radio signal transmitted from multiple locations on the ground. The Loran receiver triangulates among several towers and calculates its position to within about 10 meters and transmits accurate time to within 50/one-billionth of a second or better, more than sufficient for the critical timing applications I described earlier. It is not as accurate as GPS, isn'tglobal, and, unassisted, doesn't provide altitude information. On the other hand, it is very difficult to disrupt and has different failure modes than GPS, making the two together a great pairing. In addition, it offers service in mountainous terrain, urban canyons, and inside buildings which are sometimes difficult to do with GPS.

Several versions of Loran existed in the United States, and around the world, from World War II until 2010. The system was widely used for maritime applications and some air navigation applications but was too complicated and expensive for the widespread use we see with GPS. An updated version, called Enhanced Loran, or eLoran, has been developed which would make the high powered transmitters cheaper and would allow for very small, low cost receivers that could be used widely. I would expect that they would almost always be used in conjunction with GPS

A system for the Continental United States could be built out and operated for 20 years for several hundred million dollars. A very substantial sum indeed but bear in mind that we spend about $1 billion *annually* to maintain the GPS systems. This is not to imply that Loran could replace GPS at lower cost - it can't - but the cost of a complementary system should be weighed against the recognition of the vital role of Position, Navigation and Timing systems to the operation of our modern, high-tech society.

The government has never acted on the 2008 decision to build the eLoran system, and the risk to our nation grows because of increased foreign threat and increased dependence on GPS. Senior DHS officials have stated in recent months that "GPS is a single point of failure for critical infrastructure."

The government's 2008 decision on eLoran has since been confirmed as the only realistic path forward by numerous studies and analyses, including work done by the Administration's National PNT Advisory Board. In fact, the advisory board has repeatedly urged the government to move ahead with the project and protect the nation.

A very basic eLoran system would cost about $40M to establish, if we took advantage of existing, unused, government facilities, and could be operational in less than a year. It would provide a difficult to disrupt *time* signal to the Continental United States that could greatly reduce the risk to our critical infrastructure. It could also serve as the basis of an open-architecture system to which others could contribute to and expand upon by adding their own primary and differential transmitters.

The system could also be a source of revenue. If a service contract was properly structured, an eLoran system could generate enough income to pay for itself over its first ten years of operation while also offering a lower performance, free service. While not exact parallels, there are several examples in place today of federal service contracts, such as the FAA's Automatic Dependent Surveillance Broadcast system, where the government and industry cooperate to build a system that generates revenue, and both share the benefits of the income generated.

It would be exceptionally important, though, to properly structure the contract or agreement. At the end of this statement I have included some thoughts on provisions that should be included when the government drafts such a contract or agreement, and possible sources of revenue. These are not highly developed and are not intended as a specific proposal.

In the near term, however, the most important things for the nation, are that the Administration identify, empower, and task a single federal executive agent which can work with all stakeholders, including industry, to implement a solution. This is essential because, at present, the responsibility for addressing this issue is scattered across the federal government, as is ownership of the idle infrastructure that would need to be used if we are to put the system in place quickly and most economically.

Thank you again for the opportunity to appear today and discuss this important gap in our national security.

Salient Characteristics

Of a Successful Service-Level Contract

Or Cooperative Agreement

For eLoran

eLoran signals could effectively and efficiently be provided in the United States by the government establishing a service-level, performance based contract (or cooperative agreement) for construction and operation of the system. This is because eLoran is a mature technology, developed in the United States, but now in operation elsewhere in the world. It is therefore very low risk with no need for research before implementation. The government need only specify performance requirements and establish a small staff to monitor contractor/private partner performance.

The goal of establishing such a system is to improve our national and economic security by making our critical infrastructure and systems more resilient and deterring those who might consider jamming or spoofing satellite, and satellite-related, PNT services.

But building an eLoran system will not, by itself, make the nation and its critical infrastructure more secure. Governance and operation of the system must include provisions that will:

- Encourage PNT users to adopt the signal, along with GPS and other PNT sources,
- Ensure robust and reliable service, including reliable income streams, and
- Provide for continual evolution and improvement as new uses and users are discovered.

There is a broad spectrum of governance and business models for the government to choose from in establishing such a system in concert with the private sector. At one extreme, the government may want to limit its investment and involvement to simply allowing use of the infrastructure and frequency. In such a model, a private entity would bear all the responsibility for building the system, operating it, dealing with users, etc. At the other extreme, the government may want to fully fund a national system immediately, and have a more substantial role in its operation and interacting with users (similar to the current model for GPS).

Regardless of the model selected, the service level contract, agreement, or other governing document should incorporate the following salient characteristics:

- **A single, empowered government executive agent.** A single and empowered agent is essential for the system to be cost-effectively built and operated.
    - Government infrastructure and equipment that could be used is owned by at least seven different agencies/departments.
    - Governmental equities, interest and use of the system span all agencies and departments.

- **Provisions for maintaining a signal on air for at least 20 years** beginning when the precise time signal is first available. This is necessary to:
    - Stimulate industry investment in integrated technology products and services,
    - Encourage users to incorporate the signal, along with GPS, in their enterprise systems to increase resilience, and
    - Enable return on investment for private entities that contribute to establishment or enhancement of the system.

- **Allow, but not require, use of legacy government-owned Loran-C sites, along with in-situ and other equipment**
    - This will provide the quickest path to establishing the system and reducing risk to our critical infrastructure by minimizing the time needed for site acquisition and permitting.
    - The government should also make a search for, and make available, any unused relevant equipment that is not in-situ.
    - The private entity should be explicitly held harmless for any pre-existing environmental damage and/or contamination from hazardous materials, petrochemicals or other sources, and not be required to remove or dispose of any hazardous materials or petrochemicals on any site.

- **Day-to-Day Operation and Management by an Empowered Non-Government Entity**
    - eLoran will be a new national PNT utility. Its greatest benefits may be realized by unanticipated users and unanticipated uses. The operator/manager of the system should be able to adapt/modify the system to increase its utility to the nation, as long as the baseline required performance parameters are unaffected.
    - A governmental management entity would probably be unable to be as responsive to innovative users.

- **Ability of the Private Party to use the allotted frequency band and facilities to provide additional revenue generating services.**
    - Responsibilities for any additional costs and disposition of any revenues should also be addressed.

    - This would, of course, be absent the objection of the government executive agent.

- **Maximized automation and autonomous operation**
    - The government should mandate performance, not staffing nor equipage levels. The system should be highly automated to minimize cost and maximize performance.
    - Each of the transmitting sites should be fully autonomous using triply redundant, hot-swappable, and/or soft-fail technology. This will require no more than a part time, on-call technician.
    - Transmitting sites should be well secured as they are not staffed and many are in remote locations. Note: More than one of the deactivated Loran-C sites has been vandalized or stripped of scrap metal.

- **An open architecture that other entities can supplement**.
    - Other governmental and private entities may wish to improve/augment service in a particular area by establishing additional primary and/or differential transmitters. System architecture and governance should anticipate this. It should provide a mechanism to coordinate such efforts to ensure they improve, and not conflict with, existing services, both nationally and internationally.

- **Harmonization of the US system with that of other nations.**
    - This will be key for receiver manufacturers and enthusiastic adoption by users.
    - This will require US government agencies and their contractors/ partners to actively engage with international standards bodies such as IALA, IMO, IEC, RTCM and RTCA.

- **Phased implementation, beginning with provision of CONUS precise time**
    - Provision and adoption of eLoran’ s difficult-to-disrupt, precise, synchronized time signal will have the greatest and most immediate impact to reduce the risk to critical infrastructure from reliance on GPS as a sole or primary PNT source.
    - A minimum of four transmitting sites are needed to provide an eLoran accurate time signal to the entire Continental United States (CONUS). Eight to ten transmitting sites would ensure that CONUS users would have access to signals from at least two sites. When paired with GPS, this would provide users three independent, but synchronized, sources of time, frequency, and phase, and two sources for data via eLoran.
    - Ten CONUS transmitting sites could be on the air in approximately one year (after the contract was sufficiently funded and execution begun), if existing infrastructure and equipment were used.

  - Several additional sites per year could be easily built in CONUS, funding permitting. These would enable location-based services and provide addition resiliency for critical time, frequency, phase and data applications.
  - It could be mutually beneficial for Canada and/or Mexico to host eLoran sites that support the first CONUS phase of the project. This could improve the geometry for the US, and help those nations begin to develop their own systems to complement GPS.
  - Providing eLoran services in Alaska, Hawaii, Guam, and Puerto Rico will be in the nation's best interests for both infrastructure and transportation. This should be the second major phase of the project. While the logistics may be more complex and costly, establishing the service will not be a technological challenge. In fact, these areas were served by earlier versions of Loran (Loran-A, -C, and -D).

- **Government encouraging use of the signal,** especially integration into critical infrastructure and systems. As mentioned earlier, constructing an eLoran system will be for naught, if the signal is not used.
  - Government has a leadership role to encourage resilience, particularly for critical infrastructure and systems. Once the eLoran signal is available, due diligence, economic, and legal liability should compel widespread use, alongside GPS and other sources. Appropriate government agencies and department should also encourage and facilitate adoption of eLoran and/or other PNT resilience measures through establishment of best practices, regulations (not preferred, but if needed) and other mechanisms.

- **Minimizing cost barriers to adoption.** The needs of national and economic security would be best served if the eLoran system followed the GPS model and the signal was provided without direct cost to end users. However, the government may decide that generating revenue and making the system fiscally self-sustaining is a higher priority. In such a case, the governance and business models should minimize end-users' perceived costs and other barriers to adoption.
  - Slight marginal increases to existing service fees, embedding fees upstream of the consumer and other methods to not directly impose fees on end-users should be strongly considered.
  - As an example, end-users may be <u>more</u> likely to adopt the signal if they can receive it without additional charge by purchasing a $50 receiver, but <u>less</u> likely to adopt it if they must purchase a $30 receiver and pay an additional $15 one-time license fee.

Commercial and/or Fee-Supported eLoran

Possible Revenue Streams

An eLoran system could generate multiple sources of revenue. Depending upon the type of business model(s) selected, the system could pay back government and/or private entity initial investments and operating costs within ten years. These possible revenue sources include:

- **Guaranteed delivery data transmission** –eLoran' s high power and low frequency mean that the data signal penetrates where few others will. This includes most indoors, underground and underwater locations. Data speeds of 1,000 BPS are achievable. While this is considerably slower than broadband or "internet" speeds, it is adequate for high-priority, critical, one-way texting, machine control, and other applications. The system could therefore generate revenue as telecommunications provider charging by message or time on the network. Applications could include:
    - Assured wireless control of remote equipment and vehicles, including areas indoors and underground, and to certain depths underwater.
    - Information delivery to first responders and other crews regardless of location. This would be especially good for pre-programmed emergency and operational commands to evacuate, use another procedure, etc.
    - Immediate, but low data rate, device updates and reprogramming. The ability to reach all of the enabled devices on a given network at the speed of light and virtually simultaneously has unlimited potential.

- **PNT Interference Detection and Monitoring** – One of the biggest challenges to countering jamming satellite navigation and timing signals is the lack of a detection network. The eLoran transmitter and receiver network will continuously synchronize with GPS/GNSS signals and instantly detect when differences between the two dissimilar systems occur. Instant reports could be generated to inform federal, state, and local authorities of the anomalies and assist in finding their locations. Mobile disruptors could even be tracked as they drove down the highway, sailed through the port, or flew across the sky. The system could generate revenue by contracting to provide such information to private parties and government agencies concerned about interference incidents.

- Proof of Position and Proof of Time. – Relying on a single source of PNT, such as GPS, provides no ability to ensure your position or time are correct. Using complementary PNT solutions can provide a warning when one is providing information that is different than the other.

- **Licensing Receivers** – Over 20 million navigation receivers are sold in the United States each year. Including a small fee as part of the price of on every receiver that had the ability to receive eLoran could generate a substantial amount of revenue. Such a fee could be discontinued as other sources of revenue from the system made it unnecessary.

- **Licensing the Signal** – The signal could be encrypted such that purchase of a decryption key or service (cable box model) at some periodic intervals was required.

- **Licensing a Data Channel** – This concept is currently being used in the international community, and is referred to as a "Third-Party Data Channel" license. Given that the basic performance and integrity of an eLoran service must be preserved and protected, any available bandwidth could be leased to Public or Private users to pass secure information to select users.

- **Licensing a Portion of the Signal** - More than 90% of the users of precise time in the United States require it at the microsecond (1,000 nanoseconds) level of accuracy. eLoran can provide a signal accurate to 30 nanoseconds. To achieve that level of precision, the eLoran network transmits data that compensates for small differences in the received signal due to the terrain in a given area. This correction data could be encrypted. Most users would access the signal at the microsecond level of accuracy for free. Revenue could be generated by charging those who desire the higher level of precision a fee for the encrypted portion of the signal. For example, evolving FCC e911 service requirements for telecommunications providers will require precise time to within 100 nanoseconds.

- **Broad-based User Fees** – Since navigation and timing signals are essential to so much US critical infrastructure, a case could be made that the cost to endow eLoran should be spread as broadly as possible across the technologies it supports. For example, a temporary – for just one year - eight (8) cent fee on every monthly US cell phone and electric bill could provide enough funding to endow the system in perpetuity.

  This method could be in the best long term interests of industry users, individual consumers and the nation. In one stroke it would minimize cost barriers to adoption and ensure that system construction and continued operation was well funded. Other sources of revenue from value-added services such as data transmission, could even be used to begin to "pay-back" the endowment.