Information Technology Sector

Use of Positioning, Navigation and Timing (PNT) Services

These comments are based upon public and private assertions made by representatives of this Critical Infrastructure/Key Resource (CI/KR) sector and PNT subject matter experts that have examined such issues. Some members of CI/KR sectors might not provide public comment out of a desire to avoid disclosing vulnerabilities and/or proprietary information. Therefore, the RNT Foundation is providing this response for the public record "on their behalf." See explanatory notes at the end of this document.

GPS PNT services have been integrated into virtually every technology and are a critical to nearly every facet of life in America. As such, their impact on one sector very much impacts another. For example, the transportation and communications sectors both rely heavily on GPS, and all sectors rely heavily on transportation and communications. The comments in this response try to address only the ways in which GPS/ PNT services are uniquely used by this sector.

These comments have been structured to respond as directly as possible to the questions posted in the Federal Register (***bold italics*** below).

(a) A brief description of your application(s) of positioning, navigation, and timing services;

A primary use of PNT by the IT sector is related to its dependence on wireless and fiber networks. These uses are addressed in another submission to the docket discussing the Communications Sector.

1. **Time stamps for Distributed (Cloud) Data –** Data storage in multiple dispersed physical locations requires that all versions of data be time stamped so that the latest refresh can be identified and previous versions be archived. Google's global Spanner data base, for example, uses GPS and atomic clocks for time stamping, but even then operations have to slow down temporarily in order to resolve time uncertainty.[1]

2. **Computing in Distributed Systems[2]** (footnoted reference quoted directly) –

   a. "Time can define order across a system (without communication) The order of events is important in distributed systems, because many properties of distributed systems are defined in terms of the order of operations/events:

      - where correctness depends on (agreement on) correct event ordering, for example serializability in a distributed database

      - order can be used as a tie breaker when resource contention occurs, for example if there are two orders for a widget, fulfill the first and cancel the second one

[1] http://static.googleusercontent.com/media/research.google.com/en/us/archive/spanner-osdi2012.pdf
[2] http://book.mixu.net/distsys/single-page.html#time

A global clock would allow operations on two different machines to be ordered without the two machines communicating directly. Without a global clock, we need to communicate to be able to determine order.

b. Time can also be used to define boundary conditions for algorithms - specifically, to distinguish between "high latency" and "server or network link is down". This is a very important use case; in most real-world systems timeouts are used to determine whether a remote machine has failed, or whether it is simply experiencing high network latency. Algorithms that make this determination are called failure detectors…"

3. **Location data to support services** – Location data is heavily used in numerous applications to better support services to individual and corporate users. People are corporal beings and exist in physical space. The places and things around them are of exceptional importance. Pushed information (advertisements, subscriptions, etc.) and pulled information (response to a user's requests) frequently require the user's location to be relevant.

4. **Orientation/compass in applications.** Most smartphones and vehicle navigation systems include a compass function. In many cases, this capability relies on GPS. Further, the user must be in motion for the compass to work.

5. **Geoencryption / Geofencing** – Geoencryption[3] is an enhancement to traditional encryption that makes use of **location or time** as a mean to produce additional security and security features. It denies decryption of information or use of a device to users who do not appear to be in an approved location and/or time. For example, an entertainment company may use location to enable or prevent a mobile device' ability to stream live video of a sporting event.

6. **Proof of time and location as part of identity** – Similar to geoencryption, location and time are used to help verify a user's identity for remote applications.

7. **General Comment excerpted from "National Institute of Standards and Technology Technical Note 1867 (February 2015)":** "A new economy built on the massive growth of endpoints on the internet will require precise and verifiable timing in ways that current systems do not support. Applications, computers, and communications systems have been developed with modules and layers that optimize data processing but degrade accurate timing. State-of-the-art systems now use timing only as a performance metric. Correctness of timing as a metric cannot currently be designed into systems independent of hardware and/or software implementations. To enable the massive growth predicted, accurate timing needs cross-disciplinary research to be integrated into these existing systems."

[3] http://scpnt.stanford.edu/downloads/3.%20Qiu_Poster_PNT_Symposium.pdf

(b) the positioning, navigation, and/or timing performance required for a complementary PNT capability to support operations during a disruption of GPS that could last for longer than a day,

To qualify as a "complementary" system, a new PNT capability would need to:

1. **Provide very wide area, precise, wireless location and timing services.** The timing signal would need to be synchronized with UTC (and therefore GPS, when in it is in operation) and location information would have to correspond to that obtained from GPS as closely as possible.
2. **Have features and/or capabilities not available with GPS.** Without such it would be a "duplicate" or "redundant" service, vice "complementary." Desired features for special-purpose users, such as First Responders and the military, include a signal that is usable under foliage, underground (i.e., garages), indoors and that has a robust, security-capable, data channel for differential corrections and other information.
3. **Likely remain functioning in situations when GPS is disrupted.** The complementary system should have different signal characteristics, and therefore different failure modes, than GPS. These include a signal that is terrestrial based, high power and in a frequency band far distant from that of GPS.

Material published in 2012 about Google's Spanner data base shows a need to limit time uncertainty to 10 milliseconds.[4] The requirement now may be much greater.

(c) availability and coverage area required for a complementary PNT capability,

Availability. Any system intended to complement GPS should have the same availability as the GPS system.

Coverage. As illustrated in the graphic a the end of these comments, a multi-layer model provides the best PNT resiliency. eLoran complements GPS/GNSS' global coverage, provides continental PNT coverage, and complements or enables local PNT coverage.

The system should be as ubiquitous as possible as information technology is becoming increasingly mobile.

(d) willingness to equip with an eLoran receiver to reduce or prevent operational and/or economic consequences from a GPS disruption,

Note: Our interaction with receiver manufacturers causes us to believe this question to be irrelevant except for the first few years of an eLoran system's operation. Once an eLoran system is in operation and receivers are in wide production, the size, weight, power, and cost (SWAP-C) of the receivers will decrease dramatically. We expect most commercial grade navigation receivers to be "multi-mode", having the capability to receive GPS/GNSS and Loran/eLoran. Many receivers might also include inertial, gyro, CSAC, and/or barometric altimeters. Thus it will not be a matter of a user's "willingness to equip," but rather that the market will be automatically

[4] http://static.googleusercontent.com/media/research.google.com/en/us/archive/spanner-osdi2012.pdf

equipping the user. As one manufacturer expressed it: "Except for niche applications, building GPS-only receivers wouldn't make sense."

(e) current and planned availability of e-Loran capable user equipment,

Loran-C and/or Chayka user equipment is now produced by the governments of China and Russia for internal consumption and use with their national systems. Outside of those countries, Loran-C and eLoran receivers are produced in limited quantities, on demand. RNT Foundation discussions with several large receiver manufacturers have indicated that they would readily pursue development of integrated receivers that include eLoran capability if there were Government support for the provision of eLoran service. The estimated economic order quantity for these vendors is approximately 100,000, although the number of units depends upon the market sector served. Also, once this level of production has been achieved, the size of receivers will undoubtedly be reduced to be compatible with many mobile devices, and the price per unit will drop dramatically (as was the case with GPS technology).

The US Army has extensive information on this as a result of a recent RFI for 50,000 eLoran receivers.

(f) other non-eLoran PNT technologies or operational procedures, currently available or planned, that could be used during a disruption of GPS for longer than a day.

Sidebar: In 2011, Mr. James Caverly, at that time working for the DHS Office of Infrastructure Protection, reported on the department's "**GPS Critical Infrastructure Timing Study: Usage/Loss Impacts/Backups/Mitigation."** This report has never been made public, to our knowledge. A publicly released presentation based on the report provides information about requirements and backup systems for all critical infrastructure sectors and cites the situation generally as worsening.[5]

The information technology industry uses a variety of atomic clocks and network timing to supplement GPS time.

Most GPS location services on mobile devices are supplement by a variety of ranging and other signals to improve accuracy, especially for indoors locations. These supplemental signals will not likely be available during an extended GPS outage lasting a day or more.

Explanatory Notes:

1. The Resilient Navigation and Timing Foundation (RNTF):

RNTF is a scientific and educational 501(c)3 non-profit dedicated to helping protect critical infrastructure through (a) stronger laws and better enforcement against jamming and spoofing of GNSS signals, and (b) encouraging strong, difficult-to-disrupt terrestrial systems to complement and provide additional resilience for GNSS.

[5] http://rntfnd.org/wp-content/uploads/James-Caverly-DHS-GPS-PNTTimingStudy-SpaceWeather4-27-111.pdf

Our corporate membership includes providers of a broad spectrum of PNT services from development of GPS satellites, to local and indoor positioning systems, and wide area low frequency systems, and some of the world's leading navigation associations. Individual members are concerned citizens and PNT professionals from academia, industry and government.

2. The Reason We Are Providing These Comments:

Our nation's increasing reliance on GPS location and timing information for a very broad spectrum of technologies represents, in the words of Dr. Brad Parkinson, "… a single point of failure for much of America…" We believe that national effort to provide and encourage adoption of diverse sources of location and timing information, provided by both federal and private entities, are essential to our national and economic security.

We believe responses to this request for comment may be limited by individual companies' reluctance to air their vulnerabilities or the perception that they would be revealing proprietary information.

3. How These Comments Were Developed:

The information provided was developed in coordination with our members who have had extensive interaction with the critical infrastructure sector being addressed. Information available in the media, professional discussion sites and other "open sources" has also been included.

4. eLoran:

The request for comment mentions in several places a possible "eLoran" system. Such technology is not generally known in the United States, even though it was developed here.

For purposes of this response, we presume that the eLoran system mentioned is similar to the one in operation in the United Kingdom as recently described in a paper presented to the Institute of Navigation[6]. With appropriate ASF corrections, this system's accuracy has been measured at less than 25 feet for location and less than 50 nanoseconds for timing. While we understand that the Dutch have improved on these results, the underlying system is still eLoran. While most technologists agree that much better performance is possible with further system development, our presumption is that the system the government refers to is the one described in the referenced paper.

5. The Importance of Quickly Implementing a Complementary System for GPS

We are unable to improve upon the 2004 Presidential National Security Directive 39 issued by President Bush and affirmed by President Obama that identified GPS as essential to our national economy and national security, and mandated acquisition of a "back-up" system – though we agree that a more appropriate descriptor would be "complementary" system.

Since 2004 threats to GPS have increased, as have the number of disruptive incidents per day. The threats range from fleeting local disruptions such as might be caused by a private citizen passing

[6] http://rntfnd.org/wp-content/uploads/2015-ION-ITM-Offermans-eLoran-IOC-in-UK-final-4Feb.pdf

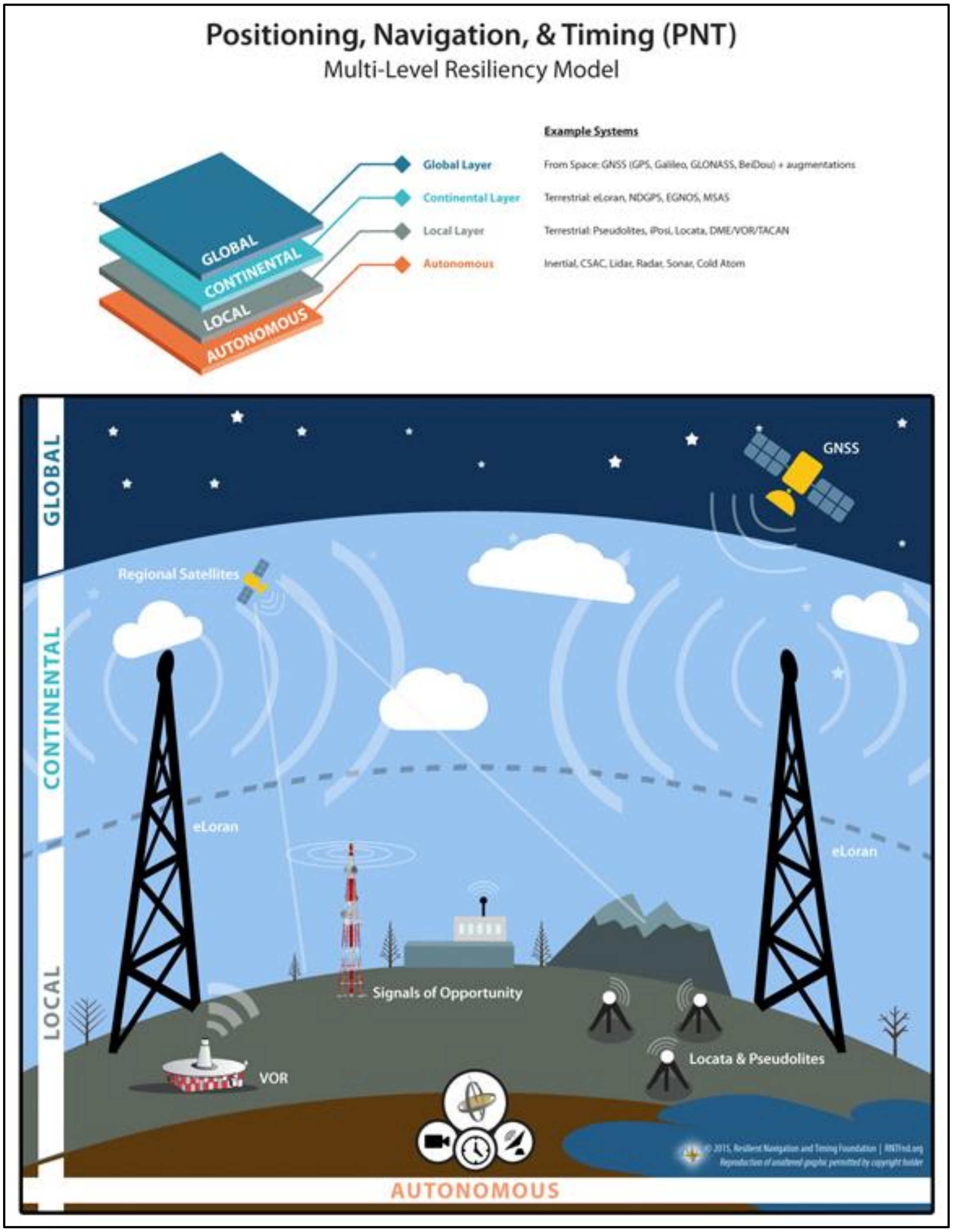
by with an illegal "Personal Privacy Device," to a global outage resulting from malicious intervention or simple human error.

GPS is currently being modernized and made more resilient. It is also being joined by other modern systems, including Galileo (Europe), Beidou (China), QZSS (Japan), INRNSS (India). GLONASS (Russia) is being upgraded over a longer time period to include digitally modulated signals. These have certain resilience features for GPS. These are all positive developments that should be continued in order to improve the overall resilience of our global PNT architecture.

In April of last year, GLONASS, the Russian satellite navigation and timing system, experienced two unannounced outages, one of which lasted for eleven hours. If this were to happen to the GPS constellation, unless there were complementary systems, such as other GNSS or eLoran, that users had adopted and which would prevent PNT service disruption, the impact to our critical infrastructure and economy would be widespread and serious.

The larger question, beyond those that the Department of Transportation has posed in the Federal Register, is:

What would happen to our CI/KR, to our nation, and to the daily lives of its citizens, should there be a 24-hour disruption of GPS for any reason?


Positioning, Navigation, & Timing (PNT)
Multi-Level Resiliency Model
Example Systems
Global Layer
From Space: GNSS (GPS, Galileo, GLONASS, BeiDou) + augmentations
Continental Layer
Terrestrial: eLoran, NDGPS, EGNOS, MSAS
Local Layer
Terrestrial: Pseudolites, iPosi, Locata, DME/VOR/TACAN
Autonomous
Inertial, CSAC, Lidar, Radar, Sonar, Cold Atom
GLOBAL
CONTINENTAL
LOCAL
AUTONOMOUS
GLOBAL
GNSS
Regional Satellites
CONTINENTAL
eLoran
eLoran
LOCAL
Signals of Opportunity
VOR
Locata & Pseudolites
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