Interview Guide: NIST Economic Impact Assessment of GPS

Evaluating the Uses and Benefits of GPS to the Electricity Sector

RTI International is working with the National Institute of Standards and Technology (NIST) to conduct an economic impact assessment of the nation's precision, navigation, and timing (PNT) services provided through the Global Positioning System (GPS).

The study has two objectives:

- Quantify the economic impact of GPS.
- Quantify the economic impact of an unexpected 30-day failure of the current GPS system.

As part of this study, RTI identified an alternative scenario, or counterfactual, to describe what we expect might have happened in the absence of GPS being developed and leveraged for commercial applications. Preliminary research and expert interviews suggest that in the absence of GPS the terrestrial PNT system known as Loran-C would have likely evolved over time to meet some of the needs filled by GPS. Some background on the Loran-C and Enhanced Loran (eLoran) systems are provided in an attachment.

Your perspective will help us quantify the benefits of GPS to the electricity. For example, we are interested in the economic impact (benefits) the electricity services sector gains from the high level of precision timing provided by GPS.

Your participation is voluntary and confidential; only aggregated information will be included in any deliverables or communications. Additionally, we do not wish to discuss any proprietary or confidential business information, but rather your professional opinion about the role of GPS in electricity sector.

Our research products will be an economic analysis, final report, and presentation materials. All deliverables will be publicly available in early 2019 and these will be shared with you as soon as they are released.

If you have questions, please contact:

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- Kathleen McTigue, Technology Partnerships Office, NIST, kathleen.mctigue@nist.gov

Interview Questions

SECTION I. Respondent Background

1. Please give a brief description of your background.

2. How familiar are you with the use of GPS in the electricity sector?

SECTION II. How GPS is Used by Electric Utilities

3. Where and how is GPS used in the electricity system and what level of timing precision is needed to support each function?
    a. (Y/N) Phasor measurement units (PMUs): _____ milli/micro/nanoseconds
    b. (Y/N) SCADA Networks: __ __ milli/micro/nanoseconds
    c. (Y/N) Fault detection: __ __ milli/micro/nanoseconds
    d. (Y/N) Protective Relays: _____ milli/micro/nanoseconds
    e. (Y/N) Substation control: _____ milli/micro/nanoseconds
    f. (Y/N) Billing and power quality incentives: _____ milli/micro/nanoseconds

4. When was GPS first used in each of these system components/functions and how long did it take for full adoption throughout the system?
    a. What drove the adoption?
    b. What was the influence of government initiatives such as the American Reinvestment and Recovery Act (ARRA).

5. What was used for frequency and precision timing needs prior to GPS?

6. It is our understanding that PMUs have been instrumental in transforming the electricity grid. Do you agree or disagree?
    a. What was the history of the technology development?
    b. Was the R&D conducted by private-sector companies, government laboratories, a combination?
    c. Were there collaborations and/or consortiums?

7. What other GPS-enabled technologies have been important in transforming the electricity grid and what was their history of the technology development?

SECTION III. If GPS Were Not Available

8. If GPS had not become available, how would the electricity system have evolved/adapted?
    a. Would utilities have relied on existing SCADA systems?
    b. Would utilities have supported their own system of quartz or atomic clocks?
    c. Would Loran-C or eLoran (as described in the attachment) been a viable alternative if GPS had not been made available?
    d. Other ____

9. What would have been the technical impact on the electricity system if GPS had never been made available and no alternative system had been deployed?
    a. No significant impact on operation or efficiency

   b. Transmission and distribution (T&D) losses would be ____ % greater.
   c. The probability of blackout or brownout events would increase by ____%.
   d. Fault detection and correction would take ____% longer.
   e. Other ____

10. What would have been the cost system implication from not having GPS?
    a. Negligible – little to no cost increase in providing today's quality of service to customers.
    b. Increased fuel costs associated with T&D losses - ____ %
    c. Increased generation capital costs associated with decreased capacity utilization - _____%
    d. Increased cost associated with location and correction of faults - _____%
    e. Increased costs associated with meeting precision timing and frequency using alternative methods
        i. For example, purchase and installation of atomic clocks and/or fiber systems for synchronization.
        ii. Ongoing operating costs associated with alternative system.
    f. Other increased operation costs? ____

SECTION IV. Unanticipated 30-Day Failure of GPS System

11. If GPS failed unexpectedly, what precision timing and frequency equipment/systems are in place for holdover?
    a. How long could the required frequency and precise time be maintained? ____hours, _____days?

12. What would happen to the electricity system under a 30-day failure of GPS?
    a. No significant impact on operation or efficiency
    b. Transmission and distribution losses would be ____ % greater.
    c. The probability of blackout or brownout events would increase by ____%.
    d. Fault detection and correction would take ____% longer and cost _____% more to correct.
    e. Increased power quality issues (please describe)
    f. Other ____

13. Can you approximate the changes in system costs over the course of a 30-day blackout?
    a. ____% increase in fuel costs?
    b. ____% increase in operating costs (non-fuel)?
    c. Other ____

14. Is there potential for damage to the existing infrastructure that would need to be repaired/replaced in the event of a 30-day failure of GPS? If so, what would be the cost in terms of damage to assets?
    a. Negligible probability of damage to system assets.
    b. ____% loss in generation assets resulting from damage.
    c. ____% loss in T&D assets resulting from damage.
    d. Other ____

Section IV. Concluding Questions

15. Would you like to share any other comments?

16. Would you be willing to participate in a brief follow-up discussion of your responses to this survey?

THANK YOU for contributing your time and insight to the study.

ATTACHMENT: *Loran as a Counterfactual in the Absence of GPS*

We hypothesize that in the absence of GPS a Loran-based system could have been used by the electricity industry to provide some of the frequency and precision timing needs currently being provided by GPS. The following is a brief background on Loran.

The legacy Loran system, known as Loran-C, was introduced in 1957 and operates similarly to GPS in that its primary signal is a timing and frequency message. In the late 1980s and early 1990s, investments were made to expand the coverage of Loran-C to cover the continental United States and improve the precision and accuracy. However, progress on further upgrades to Loran-C stalled as the costs exceeded available funds and as GPS was more widely adopted, eliminating the need for Loran-C in some applications.

In 1994, the U.S. Coast Guard ceased operating the international Loran-C chains, and the 1994 Federal Radionavigation Plan stated that by 2000 support for the remaining domestic Loran-C network would end (Narins, 2004). However, in the late 1990s, interest in maintaining and modernizing Loran-C rekindled because GPS was recognized as a single point of failure for much of the nation's critical infrastructure. An evaluation conducted by the Federal Aviation Administration determined that with some investment in upgrades the Loran-C system could indeed function as a suitable backup in the event of a GPS outage (Narins, 2004). Additionally, some research and development was being conducted to standardize an enhanced Loran (eLoran) system, which would have more capabilities and better precision and accuracy.

While eLoran would not be able to achieve the levels of precision and accuracy available from GPS, proponents claim it could perform sufficiently to support many critical applications. Table 1 provides a comparison of the frequency, timing, and positioning capabilities of the different systems.

Table 1. Precision and Accuracy Performance

	Loran-C	***eLoran***	***GPS***
Frequency	1 x 10^{-11} frequency stability	1 x 10^{-11} frequency stability	1 x 10^{-13} frequency stability
Timing	100 ns	10-50 ns	10 ns
Positioning (meters)	18–90 meters	8–20 meters	1.6–4 meters[a]

Sources: Narins et al. (2004); Curry (2014); FAA (2008)
[a] GPS positioning accuracy varies widely by type of receiver and augmentations being applied. The accuracy quoted here is from the GPS Wide Area Augmentation System (WAAS) 2008 Performance Standard.

References

Curry, C. (2014). *Delivering a national timescale using eLoran.* Lydbrook, UK: Chronos Technology.

Federal Aviation Administration [FAA]. (2008). GPS Wide Area Augmentation System (WAAS) 2008 Performance Standard. Retrieved from https://www.gps.gov/technical/ps/2008-WAAS-performance-standard.pdf

Narins, M. (2004). *Loran's capability to mitigate the impact of a GPS outage on GPS position, navigation, and time applications*. Prepared for the Federal Aviation Administration Vice President for Technical Operations Navigation Services Directorate.