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Interview Guide: NIST Economic Impact Assessment of GPS

Evaluating GPS's Impacts on the Surveying 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:

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

Accomplishing these objectives relies on the input from sector stakeholders. This interview guide was developed to capture input from stakeholders from each sector.

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 surveying sector. 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 surveying.

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

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Interview Questions

SECTION I. Respondent Background

1. Please give a brief description of your background.

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

SECTION II. How GPS is Used in the Surveying Sector

3. Where and how is GPS used in the surveying sector?

4. Please give a brief background of the surveying industry in general:
    a. What are the main categories of surveying? (e.g. boundary, cadastral, topographic, hydrological, mapping, construction)
    b. What level of accuracy is required for a location technology like GPS to be useful in surveying?

5. What are the primary benefits of using GPS in surveying? (try to link to categories in 4a)

6. What are the tradeoffs between GPS and more traditional technologies such as total stations?

7. How do the benefits of GPS vary by type of surveying or geography?

SECTION III. Timeline of GPS Rollout

8. When did GPS in surveying really take off? What were the breakthroughs? What were the important dates for when GPS was adopted in surveying?

9. How have the enhancements to GPS changed its usefulness to surveying over time (e.g. conventional to differential, differential to real time kinematic, etc.)? When did they occur?

10. Are there any co-technologies that have changed the usefulness of GPS for surveying over time? When did they occur?

11. How did adoption of GPS for surveying change for the changes discussed in questions 8 – 10?

SECTION IV. Counterfactual Questions (please refer to the attachment) and 30-day outage

12. Given the precision and accuracy information in Table 1 of the attachment, would Loran-C or eLoran have provided any benefit to the surveying industry? If not, what level of accuracy would have been required?

13. Loran-C and eLoran, the technologies considered in the counterfactual, are incapable of vertical measurement. How would this impact their usefulness in the surveying industry?

14. What would happen to the surveying industry if GPS failed for 30 days?

15. What percentage of surveyors would be able to continue work and how would their productivity be impacted?

SECTION V. Technology Transfer (depending on specialized knowledge of the interviewee)

16. How did government laboratories influence or support the development of GPS technologies for the surveying sector?

17. What government developed/supported technologies are embedded in private sector products and services?

18. How has industry directly collaborated or interacted with government laboratories as part of their R&D process?

Section VI. Concluding Questions

19. Do you have any other contacts that you recommend we reach out to?

20. Are there any other comments you would like to share?

21. 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 would have been available and would have evolved over time in performance. The following is a brief background on Loran.

The legacy Loran system, known as Loran-C, was introduced in 1957, 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 U.S and improve the precision and accuracy. However, progress on further upgrades 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 (USCG) 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). Due to the higher performance capabilities of GPS, it was generally preferred over Loran-C for most applications, which was a key reason for Loran-C gradually falling out of use (Justice et al., 1993).

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 FAA 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	1×10^{-11} frequency stability	1×10^{-11} frequency stability	1×10^{-13} frequency stability
Timing	100 ns	10-40 ns	10 ns
Positioning (meters)	18-90 meters	8-20 meters	1.6-4 meters*

Sources: Narins et al (2012); Curry (2014); FAA (2008)
*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. (2010). Dependency of communications systems on PNT technology. Lydbrook, UK: Chronos Technology.

Justice, C., Mason, N., & Taggart, D. (1994). Loran-C time management.

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, March*.

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.