Interview Guide: NIST Economic Impact Assessment of GPS
Evaluating the Uses and Benefits of GPS to the Telecom 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 telecom sector. For the purposes of this study, we are considering wireline networks, wireless networks, internet service providers, and cable television networks

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 telecom.

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

reducing this burden, to the National Institute of Standards and Technology, Attn: Kathleen McTigue (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 telecom sector?

SECTION II. How GPS Is Used in Telecom

3. Please describe the dependence of the telecom sector on GPS for the following:
   a. Wireline network performance
   b. Wireless network performance
   c. Internet service
   d. Cable television

4. When was GPS first used in each of these applications? How has adoption grown over time?

5. How would you characterize the impact of GPS on the telecom sector in the categories listed below? Are you aware of any studies that attempt to quantify the benefits?
   a. Reliability
   b. Security
   c. Bandwidth
   d. Scalability
   e. Other

6. Our preliminary research suggests that a GPS receiver, antenna array, and holdover device are the main pieces of equipment necessary to leverage a GPS signal. Are there any key components that are missing with respect to telecom?

7. Are there any key cost categories that we are missing?

8. At which points within the telecom network infrastructure is GPS equipment installed? Are different types of equipment required at different points within the infrastructure?

9. Can you estimate the cost of procuring each major component of GPS-related equipment?

SECTION III. If GPS Were Not Available

10. In the absence of GPS, what timing and frequency solution do you think the telecom industry would have used in the early 1990s when GPS was first adopted in the industry?

11. Would an eLoran network with national coverage provide sufficient performance for the telecom industry's needs today? What about a Loran-C network?

12. If you answered no in the previous question for either eLoran, Loran-C, or both, please consider the following:
    a. Which part of the telecom network requires more precision than what can be achieved under a Loran solution?
    b. At what point in time did the requirements of the telecom network exceed the capabilities of what Loran-C or eLoran could offer?
    c. In your opinion, what would a telecom network using a Loran system look like in terms of:
        i. Bandwidth (data traffic)
        ii. Capacity (number of devices)
        iii. Reliability
    (If possible, please quantify your estimate—e.g. 20% less bandwidth per device)

SECTION IV. Unanticipated 30-Day Failure of GPS System

13. If GPS failed unexpectedly please describe in a qualitative way how this would affect the telecom network over the timescales below. Please describe the impact in terms of how the outage would affect the different parts of the telecom network delineated in question 3 and in terms of the impact on service quality, network capacity, and service availability.

    a. Immediate impact (within 24 hours)

    b. Intermediate impact (1 day to 1 week)

    c. Beyond 1 week

14. Please review the second attachment, which details holdover estimates for the core and wireless networks. Do you agree or disagree with these estimates?

15. How does an outage in one part of the network affect other parts of the telecom network? For example, if the wireless network were to fail or be significantly affected before the core network, how does this impact the core network?

16. What parts of the network are most vulnerable to a GPS outage? What parts are most resilient?

SECTION VI. Technology Transfer

17. Are you familiar with the technology development history of GPS and devices that use GPS as they relate to the resource extraction sector?

18. Outside of launching and maintaining the GPS constellation itself, did federally funded research support the development and commercialization of any key GPS components that are used in the telecom sector today?

Section IV. Concluding Questions

19. Who else should we contact for this study?

20. Would you like to share any other comments?

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

ATTACHMENT 1: *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 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). Because of 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	10-50 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.

Justice, C., Mason, N., & Taggart, D. (1993). 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.

ATTACHMENT 2: *Telecom Network Holdover Capability (Adapted from Curry, 2010)*

Table 2. Telecom Core Network Traffic Timing—Holdover Capability

Telecom Network Traffic Timing	3 mins	3 hrs	3 days	3 wks	3 mos	3 yrs	>3 yrs
TCXO	X	X	X	X	X	X	X
Low spec OCXO	●	○	X	X	X	X	X
High spec OCXO	●	●	○	X	X	X	X
Low spec Rb	●	●	●	○	X	X	X
High spec Rb	●	●	●	●	○	X	X
1:1 System OCXO and Rb	●	●	●	●	○	X	X
1:1 system + backup timing	●	●	●	●	●	○	○
1:1 system + 24x365 support	●	●	●	●	●	●	●
1:1 system + backup + support	●	●	●	●	●	●	●

Source: Adapted from Curry (2010).

X   Failure of GPS would cause failure within the indicated time period.

○   Failure of GPS may cause degradation of service within the indicated time period.

●   Failure of GPS would not affect service within the indicated time period.

Table 3. Mobile Base Station Timing—Holdover Capability (FDD Systems)

Mobile Base Station Timing	3 min	3 hrs	3 days	3 wks	3 mos	3 yrs	>3 yrs
TCXO	X	X	X	X	X	X	X
Low spec OCXO	●	○	X	X	X	X	X
High spec OCXO	●	●	○	X	X	X	X
Low spec Rb	●	●	●	○	X	X	X
High spec Rb	●	●	●	●	○	X	X

Source: Adapted from Curry (2010).

X   Failure of GPS would cause failure within the indicated time period.

○   Failure of GPS may cause degradation of service within the indicated time period.

●   Failure of GPS would not affect service within indicated the time period.

Table 4. Mobile Base Station Timing—Holdover Capability (TDD Systems)

Mobile Base Station Timing	3 min	3 hrs	3 days	3 wks	3 mos	3 yrs	>3 yrs
TCXO	X	X	X	X	X	X	X
Low spec OCXO	●	X	X	X	X	X	X
High spec OCXO	●	○	X	X	X	X	X
Low spec Rb	●	○	X	X	X	X	X
High spec Rb	●	○	X	X	X	X	X
Lo spec OCXO with PTP backup	●	○	○	○	○	○	○
Hi spec OCXO with PTP backup	●	●	●	●	●	●	●

Source: Adapted from Curry (2010).

X   Failure of GPS would cause failure within the indicated time period.

○   Failure of GPS may cause degradation of service within the indicated time period.

●   Failure of GPS would not affect service within the indicated time period.