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News & Highlights

What if the Global Positioning System Didn't Work?

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Cargo ships unable to unload would form traffic jams outside of US ports, dramatically slowing the delivery of goods. First responders would take longer to reach fires, accidents, and crime scenes. Cell phone users would notice more dropped calls and deteriorating service—and then telecommunications networks might crash. Farmers would need more time to plant their crops. These are just some of the problems that could occur in the United States if the global positioning system (GPS) went down for 30 d, according to a new report commissioned by the US National Institute of Standards and Technology (NIST). The report estimates such a 30-day outage would cost the US economy between $30 billion and $45 billion USD [1].

The precise location and navigation information supplied by the roughly 30 GPS satellites (Fig. 1)—at least 24 are needed for GPS to function—is indispensable not just for lost drivers, but also for users such as farmers, mining companies, surveyors, and delivery companies. The satellites are also important, however, because they transmit the exact time, accurate to within 40 ns, allowing synchronization of clocks and computer networks that are vital for financial transactions, telecommunications, weather monitoring, and numerous other applications [2]. "GPS is taken for granted—it's like electricity," said Bradford Parkinson, an emeritus professor of aeronautics and astronautics at Stanford University in California who led the development of GPS and now co-directs the Stanford Center for Position, Navigation and Time. "The value is enormous—and it's increasing."

But even as developers create more and more GPS-enabled applications, "many people are overconfident about GPS," said Fabio Dovis, an assistant professor in the Department of Electronics and Telecommunications at the Politecnico di Torino in Italy who studies GPS and similar systems. "They are not aware of the vulnerabilities embedded in satellite navigation."

Such vulnerabilities include terrorist or military attacks that could destroy the GPS satellites or jam their transmissions [3]. GPS signals can also be spoofed, or faked, to supply inaccurate guidance [4]. Solar flares, jets of electromagnetic radiation erupting from the Sun, occasionally interfere with the signals [5], briefly causing devices to lose their satellite connection or to provide inaccurate navigation information. But a massive solar flare like the one that occurred in 1859, which was so powerful it set some telegraph offices on fire [6], could have a much more serious impact. "It's easy for GPS to go away," said Dana Goward, former director of Marine Transportation Systems for the US Coast Guard who heads the Resilient Navigation and Timing Foundation in Alexandria, Virginia. "All the Sun has to do is burp in the wrong direction, and it will fry the satellites," he said. "If we rely on GPS without alternative plans, we do so at great peril."

Fig. 1. Shown here in an artist's rendering, this GPS IIR-M satellite is one of a series launched between 2005 and 2009. Along with about 30 other GPS satellites in the US GPS satellite network, it circles the Earth twice daily and broadcasts time and orbit data that receivers can use to precisely determine their location. Credit: United States government (public domain).

GPS has never stopped transmitting signals for an extended period. However, an incident in January 2016 showed that even a temporary disruption can unleash widespread problems. When the US Air Force, which runs GPS, retired an old satellite, the shutdown triggered a software error that caused some of the other satellites to send out timing signals that were off by 13.7 ms [7]. The glitch caused problems around the world, such as halting some radio broadcasts in the United Kingdom and disabling first responders' navigation devices in parts of the United States [7,8]. These problems only lasted a few hours because technicians who monitor GPS quickly identified and corrected the error.

For the NIST report, published in June 2019, researchers at the nonprofit Research Triangle Institute (RTI International) in North Carolina consulted almost 200 experts to determine the value of GPS for ten key sectors of the US economy. Overall, the report estimates that GPS added more than $1.4 trillion USD to the US economy between 1984 and 2017. The report also details the potential

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effects of a 30-day outage. The authors did not specify the cause, but they assumed it would disable other navigation satellite systems that some GPS-enabled devices might also be able to access: Russia's GLONASS, Europe's Galileo, and China's BeiDou [9]. Although the US Congress passed a law in 2018 mandating the development of a land-based backup to GPS [10], the system has not been built, so users could not count on it if GPS failed.

According to the report, some sectors of the economy would suffer little if GPS was no longer available. Electrical utilities would continue to generate and deliver power, for example. Because they currently rely on GPS mainly for activities such as monitoring the power grid and analyzing service disruptions, the overall cost of an outage to this sector would be an estimated $275 million USD.

In contrast, the report's findings suggested that other sectors of the economy would be severely damaged. The maritime industry, for example, would incur huge losses. Although ships would still be able to navigate, interruption of GPS signals would cost the industry more than $10 billion USD, mainly due to port delays. Major ports depend on GPS to coordinate unloading of arriving vessels and to manage cargo containers. Without GPS data, port operations would slow dramatically, and ships might have to wait days to unload.

The telecommunications industry would also take a major hit. Precise timing from GPS is vital to many capabilities of telecommunications networks. For example, for someone making a call while riding a train, GPS allows the network to perform a handover, transferring the call from one base station to another as the train moves. If GPS failed, users would probably begin to notice deteriorating service within 24–48 h, including more dropped calls and slower data speeds. To maintain connections, callers would have to stay in the same spot. After two weeks, the report notes, telecommunications networks might begin to fail.

Loss of GPS would also eliminate the real-time, turn-by-turn directions provided by cell phones and other devices. Their disappearance would slow deliveries of goods, increase fuel consumption and production of pollutants, and delay first responders. A signal interruption would also take a toll on agriculture because GPS has become integral to the operation of many types of farm machinery, including self-driving tractors, planters, and crop dusters. Satellite navigation allows farmers to more precisely plant, water, fertilize, and harvest [11].

The report estimates the overall price tag of a GPS failure at $1 billion USD per day—or $1.5 billion USD if it were to occur during the April and May planting season. Given that the US gross domestic product is about $58 billion USD per day [12], that translates into a 1.7%–2.6% reduction in the country's economy. The effects on one industry would ripple through others, said report co-author and economist Kyle Clark-Sutton of RTI International, so "a billion dollars per day is the floor, not the ceiling." In the near future, the cost would be even higher, he said, because telecommunications networks are shifting to 5G and utilities are adopting smart grid technology, both of which are even more dependent on GPS. "We are on the cusp of a much greater reliance on GPS," he said.

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