OPEN DATA'S IMPACT

UNITED STATES GPS SYSTEM

Creating a Global Public Utility

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By Andrew Young, Christina Rogawski and Stefaan Verhulst

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OMIDYAR NETWORK

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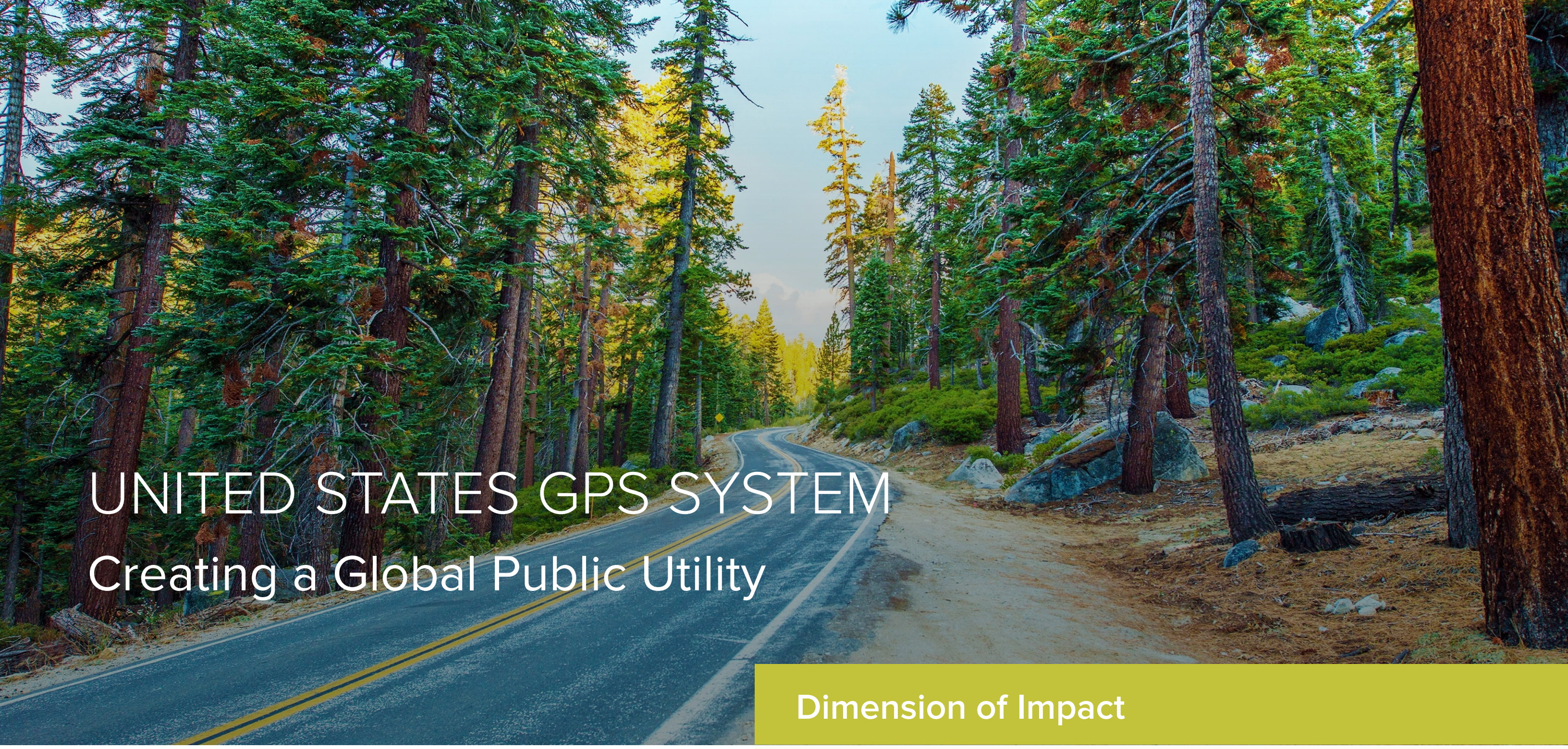

UNITED STATES GPS SYSTEM

Creating a Global Public Utility

Dimension of Impact

- ✓ Creating Opportunity
- ✓ Economic Growth

Summary

The Global Positioning System (GPS) data has had a major impact on both business and society – with estimated losses reaching $96 billion were the system to be somehow discontinued. GPS is a U.S. government-owned technology that provides military and civilian users with positioning, navigation and timing (PNT) services. The system was developed by the U.S. Department of Defense in 1978 and originally restricted to military use. Following the Korean Airlines disaster in 1983, the Reagan administration announced that GPS would be available for civilian use. In 2000, President Clinton announced a commitment to grant civilians access to un-degraded GPS signals on par with those used by the military, and in 2007, under President Bush, the Department of Defense made that commitment permanent. Over the past 20 years, GPS technology has led to a proliferation of commercial applications across industries and sectors, including agriculture, construction, transportation, aerospace and – especially with the proliferation of portable devices – everyday life. In addition to creating new efficiencies and reducing operating costs, the adoption of GPS technology has improved safety, emergency response times and environmental quality, and has delivered many other less-readily quantifiable benefits.

Key Takeaways

- One of the paradigmatic examples pointed to by open data advocates, the GPS system is not truly a data system. Rather, it is a service – like a dial-tone. That said, its role in demonstrating the incredible value and potential impacts of opening information to the public cannot be discounted.
- Open data initiatives can be self-reinforcing. When GPS was opened for civilian use, aviation was the only explicitly named industry that would gain access to the signal, and there was no mention of any kind regarding the system being free of charge. Once the system was opened, however, the impacts across industries and sectors was so massive that it would be nearly impossible to turn back to a more constrained system.
- Location information enabled by governments can be put to potentially troubling ends. While GPS has created incredible value for the global public, it has also enabled a diversity of privacy-intruding technologies – from smartphone games that share a user's location with unnamed third parties to employers tracking every move of their factory employees.

I. CONTEXT AND BACKGROUND

GPS in Our Lives Today

For most of human history, the ability to determine our exact location in the world at almost any time only existed in the realm of fantasy. The benefits and uses of such a capability – from easing travel headaches to ensuring kindergartners do not venture too far from the playground to uncovering elephant poaching rings[1] – are limited only by the imagination.

The Global Positioning System (GPS) has become such a central piece of life for so many across the globe that, despite the system only becoming fully operational in the mid 1990s, "the Associated Press uses the GPS acronym without elaboration."[2] The story of how GPS came to occupy a nearly ubiquitous place in global life, creating impacts across regions and sectors, touches upon the Space Race and Cold War and involves a diversity of major technical, geopolitical and governing decisions.

1 "GPS Trackers in Fake Elephant Tusks Reveal Ivory Smuggling Route." NPR. August 12, 2015. http://www.npr.org/sections/goatsandsoda/2015/08/12/431908397/gps-trackers-in-fake-elephant-tusks-reveal-ivory-smuggling-route

2 Easton, Richard D. Easton and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

Early History of Satellite Navigation: Sputnik

The roots of this system can be traced back to October 1957, when the Soviet Union launched Sputnik, mankind's first satellite. A few days after Sputnik entered orbit and captured the world's attention, two physicists at Johns Hopkins University's Applied Physics Laboratory, George Weiffenbach and William Guier, realized that they were able to predict Sputnik's orbits by analyzing the Doppler shift of its radio signal as the satellite circled the earth.[3] By relying on the frequency of the Sputnik signals, which shifted between 500 to 1,500 hertz, they were able to calculate the satellite's orbital path with great reliability.

Weiffenbach and Guier were still in the midst of their work when the Sputnik radio went dead. However, a month later, in November 1957, the Russians launched a second satellite, Sputnik II. This one broadcast on two radio frequencies at once, a fact which not only made the signal more reliable but also helped the scientists get a more accurate fix on the satellite's location.

Even more importantly, the early work with Sputnik I and II led to a central insight that helped lay the groundwork for the modern GPS system. Scientists soon realized that if satellites could be tracked from the ground by measuring the frequency of their radio signals, then conversely, the locations of receivers on the ground could also be tracked by their distance from the satellites. This realization has been described as the "conceptual foundation of modern GPS"; indeed, much the same system is used today by the GPS in our smartphones or cars.

Early History of Satellite Navigation: Transit

During the 1960s, Guier and Weiffenbach built on the research they had conducted with Sputnik to develop the first satellite-based navigation system. This work was done in collaboration with the Defense Advanced Research Projects Agency (DARPA) which led to the deployment of the first operational satellite navigation system, Transit. Although Transit was invented by the United States as a military technology, it was accessible to any user – including both Argentina and Great Britain who used Transit as a navigational aid for their navies during the 1982 Falklands War.[4]

Transit was an extraordinarily effective technology, but it did have a couple of serious limitations. First, Transit satellites were not always within range, meaning that a ship at sea might have to wait several hours before one of the Transit satellites passed overhead. This was obviously a problem for any potential user or application that relied on continuous updates. In addition, because Transit was a two-dimensional system, a receiving unit could calculate only its latitude and longitude, but not altitude. So, for example, a user would know how far north, south, east or west he was, but not how high above the land or sea.[5]

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3 Easton, Richard D. Easton and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

4 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.

5 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.

II. PROJECT DESCRIPTION AND INCEPTION

The Arrival of GPS

In 1978, the first GPS satellite was launched into orbit – 20 years after Sputnik first inspired the system to be developed, and 14 years after Transit paved the way for space-based navigation. The GPS system began with a $150 million budget. This relatively meager funding, "and the fact that this program lacked the self-evident drama of the Apollo program," led to the completion of the fully operational GPS Network taking "about twice as long as putting a man on the moon."[6] Indeed, it was not until 1995 – three decades after the idea for GPS was initially developed – that constant, uninterrupted worldwide GPS coverage was achieved shortly after the 24th GPS satellite began to orbit the Earth.[7]

Who Deserves the Credit?

To this day, significant debate exists regarding who deserves the lion's share of the credit for GPS. Bradford Parkinson, the air force engineer who brought together the joint program that helped to initiate GPS, is one likely candidate. Parkinson and his collaborator, Aerospace Corporation president Ivan Getting, have received numerous honors "for conceiving and creating the GPS system." However, Navy engineer Roger Easton was in many ways the individual who put those concepts into practice. Easton created and helped to deploy TIMATION satellites. TIMATION was a precursor to GPS that built on Transit's early advances and included many of the central components of GPS, including space-based atomic clocks. All three of the men are now in the National Inventors Hall of Fame.[8]

The ideas behind GPS date back even before Parkinson, Getting and Easton began to move GPS forward in earnest. In 1964, Roy E. Anderson of the General Electric Corporate Research and Development Center was the first person to propose a navigation system based on 24 satellite coverage in a mid-altitude configuration. This passive design is a central feature of today's GPS system.[9] Moreover, the spread-spectrum signal structure that enables GPS signals to be received on Earth was invented in World War II by actress Hedy Lamarr and composer George Antheil.[10]

GPS Today

Today, the modern GPS system is built around a collection of satellites weighing around two

6 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.
7 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.
8 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.
9 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.
10 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

tons each that orbit the Earth at an altitude of around 12,500 miles. In the interest of ensuring constant signals from the satellites reaching Earth, the GPS satellites are separated across six orbital planes. The satellites orbit the earth approximately every 12 hours.[11] The GPS system available for military, commercial and civilian use is highly accurate, with the typical GPS signal in space providing a "worst case" pseudorange accuracy of 7.8 meters at a 95 percent confidence level. Note that this is not the same as user accuracy, as pseudorange is the distance from a GPS satellite to a receiver. The actual accuracy for users depends on uncontrollable variables such as atmospheric effects, sky blockage and receiver quality; however, data from the FAA shows that their high-quality GPS receivers provide better than 3.5 meter horizontal accuracy.[12] The average citizen or commercial users typically does not need higher levels of accuracy; however, greater accuracy is attainable through GPS augmentation systems, which in some cases enable real-time positioning to within a few centimeters.[13]

Currently, the GPS system is governed by a diversity of U.S. Government departments and agencies, which are coordinated by the National Executive Committee for Space-Based Positioning, Navigation and Timing, which was created by President George W. Bush in 2004. The secretaries of defense and transportation were tasked with jointly chairing the committee, along with officials from the State, Interior, Agriculture, Commerce and Homeland Security Departments, as well as representatives from the Joint Chiefs of Staff and NASA acting as members. Individuals from the White House and FCC also act as liaisons.[14] The permanent staff of the Committee make up the National Coordination Office Space-Based PNT (NCO).

In addition to collaborating with industry to ensure the system serves the needs of GPS users, the central role of the NCO is to coordinate the efforts of the many agencies involved in the GPS program – with particular focus on "modernization, funding, policy, interference detection, spectrum management, international cooperation, and applications," and on providing transparency among the agencies involved in governing the system.[15]

The Nature of GPS Data

One of the key features of GPS, responsible in many ways for its widespread adoption, is the fact that it has a "passive" character. Hiawatha Bray, technology columnist for *The Boston Globe* and author of *You Are Here*: *From the Compass to GPS, the History and Future of How We Find Ourselves*, likens it to "the same way any number of people can tune in to a radio station at the same time."[16] In other words, since a GPS user does not directly interact with the navigational satellites, but rather simply accesses the signals provided by those satellites, the

11 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.
12 "GPS Accuracy." GPS.gov. http://www.gps.gov/systems/gps/performance/accuracy/
13 "Augmentation Systems." GPS.gov. http://www.gps.gov/systems/augmentations/
14 http://www.gps.gov/governance/excom/
15 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.
16 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

number of simultaneous users is unlimited, a fact that makes the whole system much more robust and scalable.

Despite its robustness and scalability, however, there are some aspects of GPS that are surprisingly fragile. For example, GPS signals are relatively low-power “line-of-sight” communications. This means that while they can pass through clouds and other thin materials with little trouble, solid objects (e.g., buildings, walls and even tree foliage) can significantly disrupt reception.[17] In addition, the precision needed for GPS to successfully complete its many duties is extremely high. A time signal error of a billionth of a second can result in a GPS receiver missing its mark by about a foot.[18]

Finally, it is important to recognize that, while references to “GPS data” are common, as Jason Kim, senior adviser at the NCO states, GPS is actually “not really a data service at all. … GPS is a measurement tool. It’s just a beacon that, instead of being on the ground, it’s in space – like a lighthouse or a radio tower, and you just measure your distance from it.”[19] So while GPS is often seen as a paradigmatic example of how government openness can create major global impacts, the tendency to label the system as an “open data” initiative is not entirely accurate.

How GPS Became Open

While not truly an open data service, as Kim puts it: “[GPS has] been our gift to the world.”[20] This is all the more remarkable given that GPS originally emerged as an American military technology. Its general adoption for civilian purposes, by companies and governments around the world, is a significant development.

In fact, although the popular narrative of GPS often describes a system created exclusively for military use that was later made available for civilian use, GPS was always intended to be opened for civilians as well. Co-developers Bradford Parkinson and Stephen Powers have written that, “Contrary to some versions of GPS history, from the very beginning, GPS was configured to be a dual-use system.”[21] Nonetheless, it was a major civilian tragedy, the 1983 downing of Korean Air Lines (KAL) Flight 007, that provided the moment during which to push GPS from being primarily a military technology to widespread civilian adoption.

The KAL disaster was a significant milestone in Cold War history. It occurred on September 1, 1983, when the civilian airliner, on a flight from New York City to Seoul, strayed accidentally into Soviet airspace and was shot down by a Soviet fighter jet. All 269 people on board died. The fact that the plane deviated from its flight plan despite having “triple-redundant inertial

17 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

18 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

19 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.

20 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.

21 “Part 1: The Origins of GPS, and the Pioneers Who Launched the System.” GPS World. May 1, 2010. http://gpsworld.com/origins-gps-part-1/

navigation systems (INS) on board"[22] quickly made the potential value of GPS in averting such future tragedies clear. Fifteen days after the disaster, White House Press Secretary Larry Speakes announced that: "World opinion is united in its determination that this awful tragedy must not be repeated. As a contribution to the achievement of this objective, the president has determined that the United States is prepared to make available to civilian aircraft the facilities of its Global Positioning System when it becomes operational in 1988."[23]

Bray, author of *You Are Here*, argues that, "causes of the crash aside, Reagan's seemingly magnanimous offer of GPS technology was a clever propaganda coup, no more." He points to a notice from the Federal Register posted two years prior saying the completed network "will be made available to the worldwide civil/commercial community within the limits of national security considerations."[24] This posting was developed by the National Oceanic and Atmospheric Administration (NOAA) and included detailed technical standards for the civilian use of GPS and, at least in part, was meant to assure the surveying industry – eventually a key user of GPS, as discussed below – that GPS would be available for its use when ready.[25]

Since the administration's statement came at a time when only a few GPS satellites were in the air, and GPS did not yet exist as a fully operational service, it was, as Kim puts it, "kind of a futuristic statement." In fact, "it was really addressing civil aviation, but people read it to mean all civil applications," which obviously was the eventual outcome, but the statement "didn't say anything about free" at the time.[26]

It is only since that time that GPS has grown into the ubiquitous "global utility"[27] used in millions of applications and devices today. During that time, the nature of GPS data has also changed, growing more recognizably "open." Indeed, in 2004, the Bush administration released a policy adding another layer of openness to the GPS system. The U.S. Space-Based Positioning, Navigation, and Timing Policy enshrined a number of principles, including a commitment to "provide on a continuous, worldwide basis civil space-based, positioning, navigation and timing services free of direct user fees for civil, commercial and scientific uses, and for homeland security through the Global Positioning System and its augmentations, and provide open, free access to information necessary to develop and build equipment to use these services."[28]

According to Kim, the relevance of this announcement goes beyond just a commitment

22 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.
23 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.
24 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.
25 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.
26 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.
27 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.
28 "FACT SHEET: U.S. Space-Based Positioning, Navigation, and Timing Policy." http://www.aopa.org/-/media/Files/AOPA/Home/News/All-News/News-Archives/2004/Importance-of-GPS-to-GA-is-affirmed-by-Bush/041216space_facts.pdf

to sharing technical specifications; it also shows that innovators can depend on "the U.S. government to meet certain standards of performance in terms of accuracy, availability, reliability, continuity. … The stability of all those commitments over time … has really helped the private sector rely on and trust GPS."[29]

Continuously Operating Reference Station (CORS)

While there is significant debate regarding whether or not the GPS system truly fits the open data model, the closely related Continuously Operating Reference Station (CORS) system, on the other hand, exists comfortably within its contours. The CORS system is a massive network of GPS receivers and antennas that constantly collect data at specific sites. The satellite data collected is then transmitted to the National Geodetic Survey (NGS) and NOAA, where quality control is conducted before making that data available to the user.

The network was originally designed by the father of CORS, Bill Strange, the chief geodesist and scientist at NGS and NOAA in 1993. The Network started with a single site in Gaithersburg, Maryland. Today, the 2,000 sites found in the CORS network cover nearly the entirety of the U.S.[30]

CORS users process GPS data that they have collected at a location of interest, together with associated GPS data from a CORS site, to calculate the coordinates of their data-collection points relative to the CORS site. With its associated tools such as OPUS (Online Positioning User Service), CORS provides free access to highly accurate (centimeter level) positions in the National Spatial Reference System (NSRS) using GPS, yielding a substantial improvement over "stand alone" GPS which can have meters of inaccuracy.[31]

The CORS Network not only provides information to users free of charge, it also exists as a cross-sector collaboration in itself. In addition to partnering with the Coast Guard, which has over 50 stations around the coast and inland waterways, "we partner with academic institutions, universities, state [Departments of Transportation] and the private sector. They follow a set of guidelines to build a uniform infrastructure, and then we manage it from there," says Dr. Neil Weston, chief scientist of the National Geodetic Survey, part of the National Ocean Service within NOAA.[32] Today, the CORS network has over 230 partners. This system allows NGS and NOAA to oversee a largely uniform network without being responsible for deploying and maintaining the equipment found at each site. That information was made available to the public almost from the start, when the "Internet was still in its infancy."[33]

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29 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.

30 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.

31 Leveson, Irving. "Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D." Final Report Prepared for the National Geodetic Survey. January 2009. http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf

32 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.

33 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.

Given its user-centricity, NGS's Geodetic Services Division has made a significant effort "to educate the public on how they could use this data; how it could be more efficient for them to collect it, what the benefits were, and what the numbers meant."[34] This focus on preparing the public to make use of the data has taken the form of webinars, in-person training sessions, conferences and more.

III. IMPACT

Like many other examples included in this series of case studies, the impact of GPS can be hard to capture. Unlike other examples, however, that difficulty does not stem from limited impact or a paucity of evidence and data. On the contrary, it is hard to capture the impact of GPS precisely for the opposite reason – because it has become so far-reaching and central to so many aspects of our lives. Nonetheless, in what follows, we attempt a broad overview of some of the most important ways in which GPS has transformed everyday life.

Economic Impact

According to Kim, it is a mistake to try to capture the impact of GPS primarily in economic terms. Pointing out that GPS was created for a range of purposes – including national security and public safety – he argues: "If there are economic benefits on top of that, well that's great, but that's not why we fielded the system. That's not why we continue to field the system."[35] Still, as with many technologies that have a wide variety of uses, examining the economic impact of GPS is a useful way to analyze the wider breadth of its impact. It allows us to better understand the sheer variety of fields that GPS has affected.

According to a 2011 NDP Consulting study, the U.S. government spent around $19.6 billion to build and maintain GPS satellites and ground stations.[36] The same report estimated that a complete degradation of the GPS signal would cost the United States $96 billion annually – with the vast majority of the impact being the result of lost productivity for commercial GPS users ($67.6 billion).[37]

Here, we examine a sampling of impacts across three industries:

34 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.

35 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.

36 Pham, Nam D. "The Economic Benefits of Commercial GPS Use in the U.S. and The Costs of Potential Disruption." NDP Consulting. June 2011. http://www.gpsalliance.org/docs/GPS_Report_June_21_2011.pdf

37 Pham, Nam D. "The Economic Benefits of Commercial GPS Use in the U.S. and The Costs of Potential Disruption." NDP Consulting. June 2011. http://www.gpsalliance.org/docs/GPS_Report_June_21_2011.pdf

Aviation

In 1984, defense contractor Rockwell International successfully flew a private jet from Cedar Rapids, Iowa to Paris – the first instance of a transcontinental flight relying exclusively on GPS for navigation. While the flight took four days due to the limited coverage of the GPS network at the time, the flight ultimately concluded within 20 feet of its targeted destination.[38] Pilots began using GPS equipment in 1993 as the primary means of en route navigation – though restrictions existed during landings. In March 1994, Continental Airlines testified before the House Subcommittee on Technology, Environment, and Aviation that GPS could help the industry save $5 billion annually as a result of reducing delays and the better-targeted routing of flights. Moreover, Continental itself was estimated to save $1.9 million each year as a result of fewer cancellations thanks to the ability to alter routes to avoid weather concerns.[39]

In addition to millions in cost savings, GPS allows aircrafts to fly pre-established routes "from waypoint to waypoint, where waypoints do not depend on ground infrastructure,"[40] enabling greater flexibility, efficiency and accuracy in route planning and execution, particularly when travelling across areas without suitable ground surveillance or navigation equipment, such as across oceans. GPS has also helped improve approaches to airports, making landing during poor visibility conditions safer, or even feasible under what were previously prohibitive circumstances.[41]

Engineering and Construction

GPS also increases productivity in engineering and construction, primarily by providing highly accurate mapping, machine guiding and measurements for a variety of processes such as surveying, excavating, transportation management, urban planning and jobsite safety monitoring. Often, a single GPS device can achieve in just a few hours what used to take several people many hours, using numerous instruments and labor-intensive processes. The resulting savings of this increased efficiency are estimated to be $7.6 billion in construction labor and $1.3 billion in capital machinery and equipment, according to the 2011 NDP Consulting study.[42]

Transportation

In the early days of GPS, the Department of Transportation estimated that traffic congestion cost over $73 billion in lost productivity annually.[43] GPS helps reduce this congestion by making traffic and mass transit management systems more accurate and efficient. Local and federal transportation agencies use GPS to help survey their road and highway networks and to locate,

38 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.

39 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

40 "Aviation." GPS.gov. http://www.gps.gov/applications/aviation/

41 "Aviation." GPS.gov. http://www.gps.gov/applications/aviation/

42 Pham, Nam D. "The Economic Benefits of Commercial GPS Use in the U.S. and The Costs of Potential Disruption." NDP Consulting. June 2011. http://www.gpsalliance.org/docs/GPS_Report_June_21_2011.pdf

43 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

map and analyze road features such as service stations, emergency services and supplies, entry and exit ramps, and road damage. GPS is also used to provide more accurate traffic updates to drivers and the media, such as construction or an accident ahead, and additional research is being conducted to examine how GPS can help enable minimal vehicle control when there is a clear need for action, such as the predeployment of air bags.[44]

Using GPS technology to better track and more accurately forecast the movement of freight has "made a logistical revolution" possible, for example through the application of what is known as "time-definite delivery." In time-definite delivery, companies can use GPS to guarantee delivery and pickup at a set time, over both short or long distances.[45] Aside from providing customers the convenience of near real-time status of their package, delivery companies like FedEx, UPS and even the U.S. Postal Service use GPS to improve services and reduce costs in three critical ways: 1) reducing fuel use via accurate monitoring of driver routes and idling times; 2) pinpointing vehicle dispatching; 3) providing roadside service and updates if something happens to a vehicle en route.[46] The use and future of GPS in transportation systems is further detailed below.

Precise Timing

In addition to its location services, another benefit and major impact of GPS stems from the way it has allowed for space-based worldwide clock synchronization. Today, GPS satellites act as the global standard for precision timing.[47] The resulting split-second accuracy provides major benefits to several industries. Telecommunications companies, for instance use GPS to synchronize call handoffs when a phone moves between areas serviced by different cellular stations.[48] Second, accurate timing helps financial companies reduce costs and improve algorithms, while improving market transparency and regulatory compliance.[49] As Kim notes: "Financial networks will have their requirements for timing accuracy going down to the microsecond within a couple of years. The only way you can get that is either run your own atomic clock, or use GPS."[50] Finally, time synchronization across the power grid enables the efficient transmission and distribution of power and enables power companies and utilities to quickly identify the site of power line breaks, which assists in avoiding larger-scale blackouts.[51]

44 "Roads & Highways." GPS.gov. http://www.gps.gov/applications/roads/
45 "Roads & Highways." GPS.gov. http://www.gps.gov/applications/roads/
46 Galloway, Ryan. 5 Ways GPS Tracking Gives Businesses a Competitive Edge. April 23, 2013. http://www.forbes.com/sites/fedex/2013/04/23/5-ways-gps-tracking-gives-businesses-a-competitive-edge/
47 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.
48 Jackson, William. "The serious side of GPS, where timing is everything." GCN. November 12, 2013. http://gcn.com/articles/2013/11/12/gps-timing-position.aspx
49 Bach, Andrew F. "GPS & precision timing's role in the financial services sector." Juniper Networks. 2014. http://www.gps.gov/governance/advisory/meetings/2014-12/bach.pdf
50 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.
51 "Timing." GPS.gov. http://www.gps.gov/applications/timing/

Smartphones / Mobile Navigation

Despite the relatively short period of time during which GPS has been available to the public, the system has enabled the creation of a massive consumer industry, and seen that industry's disruption by an even more omnipresent technology. In many ways, the story of consumer GPS from its initial release through its continued maturity has been the move from stand-alone GPS receivers to GPS-enabled smartphone applications.

Mobile navigation became an official heading in the NPD Group's market share annual report in 2004, with the industry garnering $72.8 million in revenues, chiefly among the top brands of Magellan, Garmin, Pioneer, Alpine and Kenwood.[52] By the end of 2009, more than a third of households in the U.S. were believed to have at least one personal navigation device.[53]

While the industry remained a market force over the next decade, especially market leader Garmin, smartphones began to eat into revenues in earnest in 2008 when Apple launched its first iPhone with GPS capabilities. By mid-2009, there were over 3,000 navigation applications in Apple's App Store.[54] As of 2015, a Pew Research Center survey found that nearly two-thirds of Americans own smartphones.[55] Back in 2012, when only 46 percent of Americans owned smartphones, Pew found that almost three-quarters of those smartphone owners used some type of GPS service on their phone.[56] If the prevalence of GPS usage among smartphone owners remained consistent, then in 2015, around 150 million Americans used GPS-enabled location services on their smartphones.[57]

While turn-by-turn navigation remains the quintessential use of GPS on smartphones, the system enables a wide diversity of uses, including check-in services like Foursquare and location-aware recommendation engines like Yelp.[58] Some widely used GPS-enabled applications include:

- **Google Maps:** provides users with directions via car, transport or walking, integrating real-time updates to transit service changes or traffic delays[59]

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52 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

53 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

54 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

55 "The Smartphone Difference." Pew Research Center. April 2015. http://www.pewinternet.org/files/2015/03/PI_Smartphones_0401151.pdf

56 Zickuhr, Kathryn. "Three-quarters of smartphone owners use location-based services." Pew Research Center. May 11, 2012. http://www.pewinternet.org/2012/05/11/three-quarters-of-smartphone-owners-use-location-based-services/

57 The 2015 Pew report found that over two-thirds of smartphone users at least occasionally use GPS for turn-by-turn navigation while driving, 25 percent to get public transit information and 11 percent to reserve a taxi or car service. The survey did not, however, ask respondents about their general use of GPS or location-enabled apps. "About the December Week 1 and Week 3 Omnibus Survey." Pew Research Center. http://www.pewinternet.org/files/2015/03/MethodsAndSurveyQuestions.pdf

58 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

59 http://www.gps-coordinates.net/

- **Nike+ Running:** uses smartphone GPS to track users' location and speed as they run,[60] similar to MapMyRun, which lets users record and share their workouts and goals[61]
- **Waze:** a social GPS navigation app that crowdsources traffic and road data, including accidents and speed traps, from users[62]
- **GasBuddy:** finds and directs users to nearby gas stations sorted by price and distance, including details on other services available[63]
- **Life 360:** creates private, invite-only maps showing where family members are – without sending dozens of text messages[64]
- **Uber:** hails taxies, private cars or ride shares and allows users to pay for their ride via phone[65]
- **Yelp:** locates and provides user-submitted reviews of businesses and restaurants near users[66]

Each of these mobile applications illustrates the growth of a whole new economic sector based on GPS, digital location-based services, the effects and impacts of which are still being discovered.

Public Safety and Emergencies

While the rise of cellular telephones is often credited with increasing public safety due to citizens' increased ability to reach authorities in the event of an emergency, the true game-changer for public safety came when a great number of cell phones became equipped with GPS. Rather than simply being able to report an emergency, often with little ability to pinpoint the exact location where it occurred, GPS capabilities enabled emergency response personnel to reach the exact location of the affected parties, whether the individual reporting the emergency was familiar with the location or not.[67]

Reducing the time to locate an individual in need saves lives, particularly in disaster events. For example, teams used GPS, combined with other mapping technologies, to find victims, provide aid and improve relief effort response for global disasters such as the 2004 Indian Ocean

60 Cassavoy, Liane. "21 Awesome GPS and Location-Aware Apps for Android." PCWorld. July 31, 2012. http://www.pcworld.com/article/260112/21_awesome_gps_and_location_aware_apps_for_android.html#slide22
61 "Top GPS-based apps for everything from traffic to travel." Qualcomm Snapdragon Blog. June 27, 2013. https://www.qualcomm.com/news/snapdragon/2013/06/27/top-gps-based-apps-everything-traffic-travel
62 Cassavoy, Liane. "21 Awesome GPS and Location-Aware Apps for Android." PCWorld. July 31, 2012. http://www.pcworld.com/article/260112/21_awesome_gps_and_location_aware_apps_for_android.html#slide22
63 Cassavoy, Liane. "21 Awesome GPS and Location-Aware Apps for Android." PCWorld. July 31, 2012. http://www.pcworld.com/article/260112/21_awesome_gps_and_location_aware_apps_for_android.html#slide22
64 "Top GPS-based apps for everything from traffic to travel." Qualcomm Snapdragon Blog. June 27, 2013. https://www.qualcomm.com/news/snapdragon/2013/06/27/top-gps-based-apps-everything-traffic-travel
65 https://www.uber.com/features
66 http://www.yelp.com/about
67 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.

tsunami, Hurricanes Katrina and Rita in 2005,[68] and the Ebola outbreak of 2014.[69] GPS is also used in tracking storms, hurricanes, floods, tornados and wildfires, mitigating both human and economic loss.[70]

In addition, a host of new applications and benefits use GPS technology to enable new ways of increasing public safety. One good example is the popular application ChildChecker – a safety vest marketed by Purple Scout that constantly reports a child's exact location to schools and day care centers charged with monitoring their safety.[71] Other examples include SPOT, a personal tracker for outdoor enthusiasts like hikers or skiers,[72] and MOTOsafety, a tool allowing parents to monitor teen driving safety.[73]

CORS Impacts

Looking exclusively at CORS, the system is being used across a diversity of industries, with uses including surveying, engineering, vehicle tracking, container tracking and more.[74] In 2008, CORS data was downloaded 10.6 million times.[75] A study prepared for the NGS in 2009 found that "the order of magnitude of CORS benefits is estimated as $758 million per year. ... If benefits grew at a 15 percent annual rate, less than the recent growth rate of 22 percent, the order of magnitude of the present value of CORS benefits over the next 15 years would be $18.5 billion."[76]

Industry is not the only sector making use of CORS. NOAA itself uses CORS "to monitor the ionosphere; to measure the troposphere, which helps with short-term weather modeling." Neil Weston notes, "We can estimate tectonic plate motion and coastal subsidence; enhance tsunami warning systems." Certain academic institutions also "download all of the CORS data that's collected every night. They use the CORS data to perform large simulations."[77]

68 "Public Safety & Disaster Relief." GPS.gov. http://www.gps.gov/applications/safety/
69 "2014 West Africa Ebola Response." OpenStreetMap. http://wiki.openstreetmap.org/wiki/2014_West_Africa_Ebola_Response
70 "Public Safety & Disaster Relief." GPS.gov. http://www.gps.gov/applications/safety/
71 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.
72 http://www.outdoorsafetygps.com
73 http://www.motosafety.com
74 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.
75 Leveson, Irving. "Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D." Final Report Prepared for the National Geodetic Survey. January 2009. http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf
76 Leveson, Irving. "Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D." Final Report Prepared for the National Geodetic Survey. January 2009. http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf
77 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.

Among other aims, CORS enables the analysis of data related to plate tectonics, precipitable water vapor, free electrons in the atmosphere and much more, to the ends of:[78]

- Defining legal marine and land boundaries
- Creating storm surge models
- Monitoring sea level rise
- Enabling restoration of coastal habitat
- Improving coastal resilience
- Predicting flooding vulnerability
- Mapping shorelines
- Predicting earthquakes
- Assessing hurricane damage
- Improving weather prediction
- Measuring space weather

IV. CHALLENGES

Although GPS has grown and spread rapidly, it has faced, and continues to face, a number of obstacles that either limit its spread or its potential to effect change. These include:

Governance Challenges

Effectively governing the GPS system poses significant challenges given the many agencies involved in the systems and the diversity of needs that it satisfies. As Jason Kim of NCO puts it: "Wrangling all the different cats under one roof is difficult because there really aren't that many governmental programs that touch so many different parts of the government – pretty much everyone uses GPS."[79]

Not only are many entities involved in the decision-making processes involving GPS, but different actors also take the lead on different issues. While the National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT) is co-chaired by the Department

78 Leveson, Irving. "Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D." Final Report Prepared for the National Geodetic Survey. January 2009. http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf
79 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.

of Defense and Department of Transportation, the DoD is the main driver of GPS in general and the DoT acts as the lead agency for civil uses. The FCC, on the other hand, handles all issues related to the private sector and any other non-federal users of the GPS spectrum. Making matters even more complicated, the Department of Commerce handles federal use of the system, while the National Telecommunications and Information Administration (NTIA) has authority over the GPS spectrum.[80]

All this overlapping authority can lead to turf battles and frequent confusion. Because a specific issue or problem may cover multiple dimensions, it is often unclear which agency or department has authority in a particular case. Kim adds, however, that one concern (and thus one agency) often trumps all others: "When it comes down to the nitty-gritty, hard decisions, who wins out? Well, it's usually National Security because they're paying the bills and we're just along for the ride."[81]

Funding and U.S. Policymaking

The initial investments in the GPS system have of course long since been recouped. But funding for any new challenges or investments remains challenging. This challenge is closely related to another challenge: GPS' reliance on U.S. Government decision-making, particularly in these fiscally challenged times. As Kim notes, whenever the possibility of expansion or spreading GPS is considered, "that's considered a new start and basically, any new start under this current fiscal environment is impossible. ... It's kind of a sad situation, but it's true."[82]

A deeper, underlying concern here relates to the U.S.' central role in maintaining and running the GPS system. This role continues to elicit some international concern, whether over the U.S.' willingness to keep funding needed investments (for example, to ensure that updates to the system allow for backward compatibility)[83] or in ensuring that the system will remain open to international actors and will not return to the two-track system (one for civilian use, one for military) that used to exist. Such concerns were heightened in the wake of the September 11 terrorist attacks, when some observers feared the U.S. might deliberately degrade a system that could in theory be used by terrorists to target the U.S. itself. Today, such concerns are largely unfounded; however, as the current generation of GPS satellites that began to be deployed in 2014 do not have the hardware capability to reintroduce selective availability.[84]

Privacy Concerns

The increased adoption of GPS, driven in large part by a proliferation of GPS-enabled devices,

80 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.
81 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.
82 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.
83 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.
84 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.

has also led to growing concerns over privacy. While GPS allows individuals to know exactly where they are, it also often allows the makers of devices and applications to access the same information. In a 2010 report, the *Wall Street Journal* found that nearly half (47 out of 101) of the most popular smartphone applications share users' location with third parties. It is important to note that many of these applications do not require access to users' location in order to perform their core functions.[85] They may nonetheless share this data with companies (such as advertisers) or even government agencies. Similar concerns over privacy have swirled around car manufacturers and popular ride-sharing services, many of which collect potentially sensitive location-based information about individuals.[86]

In 2011, a bill was introduced in Congress titled The Geolocation Privacy and Surveillance Act (GPS Act). The bill, sponsored by Rep. Jason Chaffetz and Sen. Ron Wyden, sought to limit government surveillance using geolocation signals from mobile phones and GPS devices. The bill was reintroduced in 2015, but, as of early 2016, has not been passed.[87] Regardless of such efforts, however, concerns over privacy persist. If left unaddressed or unchecked, they have the potential to reduce trust and thus limit the spread (and potential benefits) of GPS technology.

GPS "Jamming" / Hacking / Security

As GPS grows in popularity and becomes increasingly intertwined with networked devices, the security challenges are also likely to grow. The potential impact of a successful hack into the GPS system could be devastating. As Kim notes: "These satellites are up there. They're pretty much sitting ducks. If anyone wants to try to mess with them, either through jamming or actually attacking the satellites – there's just so many ways that you could massively disrupt our security, our economy, our safety."[88]

The potential impact of an attack that would degrade or otherwise affect GPS signals was felt in 2010, when the Newark Airport found that its new ground-based augmentation system (GBAS) – a system designed to improve the precision of GPS to aid in flight landings – was degrading intermittently. Upon investigation, the FAA found that GPS signals were being lost when truck drivers on the nearby New Jersey Turnpike drove past the site's antenna while using GPS jammers in order to obscure their movements from managers and dispatchers.[89] While no major disasters resulted from this incident, it heightened concerns about the potential consequences of a security breach.

It is because of such longstanding concerns that Kim's office is working to develop a ground-based system for providing redundant GPS signals in the event of any major issues with the satellites' signals. The U.S. government is "so concerned about fielding a backup," he notes, because "we

85 Thurm, Scott and Yukari Iwatani Kane. "Your Apps Are Watching You." The Wall Street Journal. December 17, 2010. http://www.wsj.com/articles/SB10001424052748704694004576020083703574602

86 Timberg, Craig. "Is Uber's rider database a sitting duck for hackers?" The Washington Post. December 1, 2014. https://www.washingtonpost.com/news/the-switch/wp/2014/12/01/is-ubers-rider-database-a-sitting-duck-for-hackers/

87 "Geolocation Privacy Legislation." GPS.gov. http://www.gps.gov/policy/legislation/gps-act/

88 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.

89 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

recognize that GPS is a highly vulnerable system. The technology was developed in a different era when we didn't have to worry about hackers or malicious threats through jamming."[90]

CORS Challenges

The central challenges for the CORS system are more in line with other open data initiatives included in this series of case studies. The first involves standardization. NOAA found that many of the people running its sites "wouldn't quite configure their receivers correctly, so it wouldn't output all of the information necessary." NOAA's ongoing outreach efforts and the continued maturity of the system should help to mitigate the standardization challenge.

Second, at the beginning, the sheer volume of data reaching the CORS handlers could be almost overwhelming. Weston recalls, "We were constantly buying hard drives and big systems to do the data management. … Data comes in 24/7, round-the-clock, and we only had four or five individuals to do this." Weston himself played a central role in mitigating the challenge through automating much of the process: "My scripts were refined over the years to scale up from a handful to a hundred sites across the country to over 2,000."[91]

V. LOOKING FORWARD

Notwithstanding the debate over whether GPS data can truly be considered "open data" or not, there is no doubt that GPS stands as a paradigmatic example of the transformative potential represented by accessible and freely available information. Going forward, it is certain that its influence is likely to grow, and be felt in a wider range of sectors and activities. We identify the following as some of the key areas in which GPS' impact is likely to be felt:

Precision Farming

Agriculture is one of the key industries benefiting from GPS. As far back as 1996, around 5 percent of farmers used GPS to better target their efforts – down to fractions of an inch – in order to avoid overlapping the spread of "seeds, irrigation, fertilizers and herbicides." A 2011 NPD Consulting study estimates that the aggregate annual benefits of GPS to crop farming totals $19.9 billion per year.[92] The next wave is so-called precision farming, which is expected to reach a 100 percent adoption rate by the early 2020s.[93] Beyond GPS-guided tractors and

90 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.
91 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.
92 Pham, Nam D. "The Economic Benefits of Commercial GPS Use in the U.S. and The Costs of Potential Disruption." NDP Consulting. June 2011. http://www.gpsalliance.org/docs/GPS_Report_June_21_2011.pdf
93 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

precision farming strategies, location-aware data collected from farmers is increasingly being aggregated to yield new insights into optimal strategies for agricultural development. Scott Shearer, chair of the Department of Food, Agricultural, and Biological Engineering at Ohio State University notes that this aggregated information can provide prescriptions to enable individual-level farms to, for instance, plant two different hybrid plants in different zones, allowing for improved returns – "the analytics are going to drive the development of those prescriptions."[94]

That said, major questions still remain about who owns the data generated by farms. Companies like Monsanto and John Deere are leading the precision farming big data revolution, and while providing data to companies that aggregate information from many farms can lead to better individual-level models and more strategic farming, some remain reluctant to surrender their data to large players in the field.[95]

Indoor Navigation

One of the key weaknesses of GPS is the lack of indoor navigation capabilities. Taking lessons from GPS and the multi-billion-dollar industry it enables, private sector players are making moves to give consumers the ability to place themselves in large indoor areas. Companies big and small are increasingly providing detailed information on spaces like airports, museums and shopping malls to improve navigation capabilities.[96] Indeed, analysts predict that by 2018 the indoor location market will swell to $2.6 billion worldwide from $449 million in 2013.[97]

A controversial application of indoor GPS can be seen in Amazon warehouses, where the retail giant has its employees wear GPS tags that, combined with a handheld scanner, direct them to the most efficient route to move products. However, critics argue that not only is monitoring an employee's every movement an invasion of privacy, but that such hyper-focus on efficiency is leading to oppressive employee surveillance, resulting in increasingly higher demands from employers and decreasing employee morale.[98]

Intelligent Transportation Systems and Driverless Cars

GPS is in many ways at the heart of efforts by companies like Google, Apple, Tesla and others to introduce driverless cars. In a driverless car, GPS defines the "mission" of the autonomous vehicle by setting the starting and ending point of the drive. It considers all the road options and chooses the best path.[99] Of course, GPS cannot handle every variable on the road, and to

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94 Bobkoff, Dan. "Seed by seed, acre by acre, big data is taking over the farm." Business Insider. September 15, 2015. http://www.businessinsider.com/big-data-and-farming-2015-8

95 Bobkoff, Dan. "Seed by seed, acre by acre, big data is taking over the farm." Business Insider. September 15, 2015. http://www.businessinsider.com/big-data-and-farming-2015-8

96 Bray, Hiawatha. You Are Here: From the Compass to the GPS, the History and Future of How We Find Ourselves. (New York: Basic Books), 2014.

97 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

98 Solon, Olivia. "Wearable Technology Creeps into the Workplace." Bloomberg Business. August 7, 2015. http://www.bloomberg.com/news/articles/2015-08-07/wearable-technology-creeps-into-the-workplace

99 Pullen, John Patrick. "You Asked: How Do Driverless Cars Work?" Time. February 24, 2015. http://time.com/3719270/you-asked-how-do-driverless-cars-work/

account for the many factors and obstacles, technology and other companies are innovating with a form of "differential GPS" that would leverage radar and cameras to help vehicles deal with the shifting dynamics of a road.[100]

While the widespread use of driverless cars in many ways still smacks of science fiction, in June 2015, Google announced that its experimental versions eclipsed the 1 million-mile mark – the equivalent of 75 years of typical adult driving. In a Google+ post, the Google Self-Driving Car Project team announced that, "along the way, we've navigated more than 200,000 stop signs, 600,000 traffic lights, and seen 180 million vehicles."[101] By 2040, the Institute of Electrical and Electronics Engineers expects that autonomous vehicles will represent three-quarters of cars on the road.[102]

Terrestrial Backups

As mentioned above, the development of a terrestrial backup system to mitigate the impacts of a potential GPS outage – whether intentional or otherwise – is a key priority for the U.S. government. Jason Kim believes that, "we need it like yesterday because the vulnerability is the same it's always been, but I think the recognition of it is becoming more recognized, is becoming more acute. The threat of exploiting that vulnerability is going way up." The government is looking to explore potential scenarios – from disruptive solar activity to malicious attacks – and take steps to field a land-based alternative in the event of an interruption to GPS service.[103]

Evolving the CORS System

The CORS network has two main next steps: expanding coverage to the entire U.S., and increasing the capacity of data passing between stations. On the first point, Weston notes that, "there are some areas in the country – North and South Dakota, Wyoming – where there aren't that many CORS stations. There are enough up there to do a certain type of positioning, but the people want the data faster."[104] This leads into the second point, for NOAA, Weston notes, "our focus is to get the data from all the stations in real time. Once it's available to NOAA, we can quickly turn it over and make it available to the public. Now, the sooner they have access to it, the sooner they can make use of it. Near real-time data access is critical."[105] Gaining real-time data poses a few challenges, arising from both the government end and the outside partner segment. Weston explains, "we have to get all the site operators to modify their infrastructure to send the data to us as fast as they can. We, in turn, have to quality control that data in a fast time frame and

100 Pullen, John Patrick. "You Asked: How Do Driverless Cars Work?" Time. February 24, 2015. http://time.com/3719270/you-asked-how-do-driverless-cars-work/

101 https://plus.google.com/+SelfDrivingCar/posts/iMHEMH9crJb

102 Easton, Richard D. and Eric F. Frazier. GPS Declassified: From Smart Bombs to Smartphones. (Lincoln: Potomac Books, University of Nebraska Press), 2013.

103 GovLab interview with Jason Kim, Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing, September 22, 2015.

104 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.

105 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.

make it available."[106] Although increasing the turnaround of CORS data is a focus, Weston is quick to point out that "CORS data is not intended to do real-time positioning."[107]

As the world's first and only global public utility, GPS is testament to the incredibly deep and broad impact that can arise from a government opening information. Today, GPS has become such an essential part of everyday life, so woven into the fabric of ordinary activities, that its relatively recent creation is often overlooked. While the debate over whether GPS should truly be labeled as "open data" persists, the success of GPS makes clear the type of innovation, economic development and broad social impacts that can follow from the free flow of information to the public.

106 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.

107 GovLab interview with Dr. Neil D. Weston, Chief Scientist, National Geodetic Survey, National Ocean Service, NOAA, September 24, 2015.