

The Development of GPS Technology: How It Changed the Way We Navigate

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February 13, 2026

Abstract

The Global Positioning System (GPS) is one of the most important technologies created in modern times(Kaplan & Hegarty,2006). It has completely changed how people find their way around the world.GPS was first built by the United States military in the 1970s to help soldiers know where they were. Today, everyone uses it in their phones, cars, and watches. The system works by using satellites in space that send signals to devices on Earth (Hofmann-Wellenhof et al.,2008). These devices then figure out exactly where you are. Three important people helped create GPS: Roger L. Easton worked on timing systems, Ivan Getting created the math behind it, and Bradford Parkinson led the project. They had to solve many problems, like making the satellites work in space and getting enough money to build the system.GPS now helps farmers grow crops better, helps ambulances find people quickly, and lets everyone use map apps on their phones. It saves lives and makes everyday tasks easier for billions of people around the world.

Introduction

Today, finding any place on Earth is easy. You just type the address into your phone and follow the directions. But this was not always true. For hundreds of years, people got lost all the time. Before GPS, people used stars, maps, and landmarks to find their way. Sailors looked at the sun and stars. These old methods did not work well, especially in bad weather or at night. Many people died because they got lost.GPS changed everything. It uses satellites flying around Earth to tell you exactly where you are. These satellites are about 20,200 kilometers above us. They send out special signals that your phone or car can read. By checking signals from several satellites, your device can figure out your exact location.GPS is now used for much more than just finding directions. Farmers use it to plant crops in perfect rows. Banks use it to record the exact time of money transfers. Ambulances use it to reach sick people faster. Scientists use it to study earthquakes and track animals.GPS is worth more than \$1.4 trillion to the U.S. economy alone(National Space-Based Positioning,Navigation,and Timing Advisory Board,2021). It started as a military project during the Cold War but became something everyone uses every day.

This research aims to answer the following questions:

- 1. What Made GPS Possible?**
- 2. What Problems Did the Scientists Face?**

Literature Review

Navigation Before GPS

Before GPS, finding your way was hard and dangerous(Kaplan & Hegarty, 2006). Sailors used special tools called sextants to measure the position of stars. They also used clocks to figure out how far east or west they were. These methods only worked if you could see the sky, so cloudy weather was a big problem. Airplane pilots used radio stations on the ground to navigate. But these systems only worked in certain areas. Over oceans or deserts, pilots had to guess their position. During World War II and the Cold War, the military needed better navigation. Submarines had to launch missiles from underwater. Planes had to fly over enemy territory without using radios. The old navigation systems were not good enough(Parkinson & Spilker,19996).

The Scientists Who Built GPS

Three main scientists created GPS:

Roger L. Easton worked for the U.S. Navy. He built a system called TIMATION that used very accurate clocks in space. These clocks, called atomic clocks, keep perfect time. They are so accurate that they only lose one second every million years. Easton proved these clocks could work in space (Parkinson & Spilker,1996). Iván Getting worked at The Aerospace Corporation. He figured out the math for GPS. He discovered that you need signals from four satellites (Hofmann-Wellenhof et al.,2008) to know your exact position and the correct time. His math showed that GPS could work for millions of people at once. Bradford Parkinson is called the "father of GPS." In 1972, he became the director of the GPS project for the U.S. Air Force. Different parts of the military were working on different navigation systems. Parkinson brought everyone together to build one system. He made the important choices about how GPS would work.

Development Challenges and Selective Availability

Building GPS was very difficult and expensive. Launching satellites costs billions of dollars. The early satellites did not last long in space and had to be replaced often. The atomic clocks had to survive in space, where there is extreme cold, heat, and dangerous radiation. The signals from satellites also get bent and slowed down when they pass through the air around Earth. Scientists had to create ways to fix these problems. The military was worried that enemies would use GPS to attack the United States. So from 1993 to 2000, the government made GPS less accurate for regular people. This was called Selective Availability. It made civilian GPS only accurate to about 100 meters (the length of a football field).In May 2000, President Bill Clinton turned off Selective Availability. Suddenly, GPS became accurate to within 10 meters for everyone. This decision made GPS much more useful and led to many new businesses and apps.

Global Impact and Civilian Applications

GPS is now used in almost every part of life:

Transportation: GPS gives directions in cars. Pilots use it to land planes safely. Ships use it to navigate through fog. Delivery trucks use it to find the fastest routes. **Emergency Services:** When you call 911, GPS helps find you quickly. This saves lives when every second matters. **Farming:** Tractors with GPS can plant seeds in perfectly straight lines. This saves seeds and fertilizer, which helps the environment and saves farmers money. **Banking:** Banks use the super-accurate clocks in GPS satellites to record when money transfers happen. This helps prevent fraud. **Science:** Scientists use GPS to measure how tectonic plates move. They track how glaciers are melting. They follow animals to study their behavior. **Smartphones:** Most importantly, GPS is now in almost every smartphone. Billions of people use apps like Google Maps, Uber, and many others every day. Getting lost is now rare.

Results and Discussion

Question 1: What Made GPS Possible?

GPS needed several important inventions to work:

Atomic Clocks: These super-accurate clocks are the heart of GPS (Hofmann-Wellenhof et al., 2008). They work by counting vibrations of atoms. GPS needs perfect timing because light travels 30 centimeters in one billionth of a second. Even tiny timing errors would make GPS useless. **Satellites:** Scientists had to build satellites that could stay in space for years. The satellites need solar panels for electricity, batteries for backup power, and systems to send signals to Earth constantly. **Signal Processing:** GPS receivers had to be invented that could hear very weak signals from space. Early GPS receivers were big and expensive. Now, a tiny chip in your phone can do the same job. **Math Models:** Scientists created complex math to fix the problems caused by Earth's atmosphere. The atmosphere bends and slows the GPS signals. The math formulas correct these errors so GPS can be accurate.

Question 2: What Problems Did the Scientists Face?

The GPS team faced three main types of problems:

Technical Problems: Making atomic clocks work in space was very hard. They had to survive extreme temperatures, radiation from the sun, and the vacuum of space. The early satellites broke down quickly and had to be replaced. **Money Problems:** GPS cost billions of dollars. The project took decades to complete. Every year, Congress had to decide whether to keep funding it. Many times, GPS almost got canceled because it was so expensive. **Political Problems:** Different branches of the military (Navy, Air Force, Army) each wanted their own navigation system. Bradford Parkinson had to convince everyone to work together on one system. This required meetings, compromise, and leadership. The decision to remove Selective Availability was also hard. Military leaders worried that making GPS accurate for everyone would help enemies. But President Clinton decided the benefits were worth the risk. This turned out to be the right choice.

Conclusion

GPS is one of the most important technologies ever invented. What started as a military project became something that helps everyone on Earth. It took brilliant scientists, decades of work, and billions of dollars to create. The success of GPS came from combining many discoveries: atomic clocks, satellites, signal processing, and math. Roger Easton, Ivan Getting, and Bradford Parkinson led the way, but thousands of other scientists and engineers also helped. The challenges were huge. The technology was complicated. The cost was enormous. Different parts of the government disagreed about how to build it. But the team kept working and eventually succeeded. Today, GPS touches almost every part of our lives. It helps us drive, fly, farm, bank, and find our way. It saves lives through better emergency response. It makes the world easier to explore. The value of GPS is measured in trillions of dollars. However, GPS also creates some problems. People worry about privacy because GPS tracks where we go. The system can be jammed or fooled by criminals. If GPS stopped working, many important services would break down.

Recommendations for Future Research and Policy

Future research should focus on making GPS more secure and reliable. We need backup systems in case GPS fails. Other technologies like 5G networks and camera-based navigation could help. Countries should work together to make sure everyone can use satellite navigation. This would make the system more reliable and reduce conflicts. Schools should teach students how GPS works and why it matters. Young people use GPS every day but often don't understand the technology behind the story of GPS teaches an important lesson: great technologies often come from long-term investment in science. GPS took decades to build and cost billions of dollars. But it has paid back that investment many times over by helping billions of people and creating new industries.

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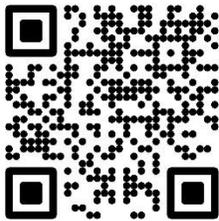
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