the Availability Digest

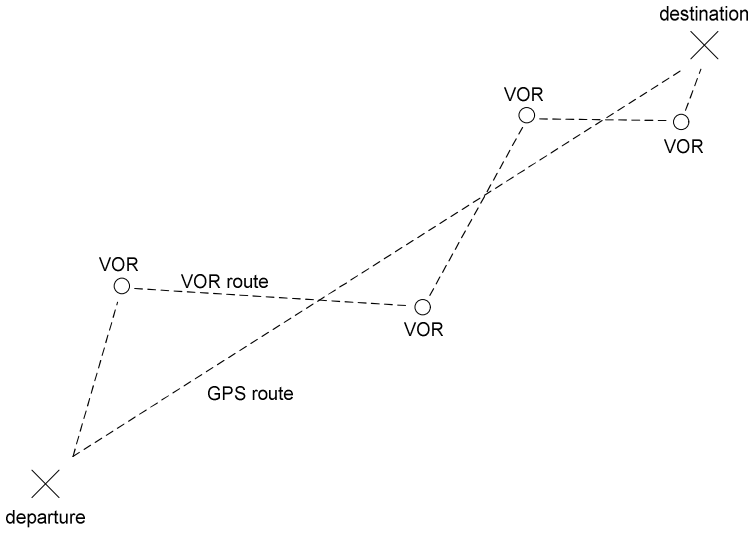
www.availabilitydigest.com
@availabilitydig

What If GPS Fails?

January 2017

As a private pilot, I am a big user of GPS. GPS allows me to fly a direct route from my point of departure to my destination. My GPS display even shows me restricted airspace so that I can navigate around it.

Without GPS, I would have to use VORs for navigation. A VOR (VHF Omnidirectional Radio Range) is a ground-based system of radio beacons that allows me to determine my position and distance with respect to any VOR. Knowing the location of the VOR, I now know where I am. If I have to navigate over any significant distance using VORs, my route can be rather circuitous as I fly from one VOR to another.



As most of you probably do, I also use GPS to find my way on the ground in my car. I use VZ Navigator for this purpose. I simply enter my destination, and VZ Navigator directs me to it turn by turn.

When I take a commercial flight, I am confident that the plane will land at my destination, thanks to GPS.

I shudder to think what would happen if our GPS system should fail. I'm not going to crash my plane or my car, but getting from here to there will be much more difficult in many instances.

What Exactly Is GPS?

GPS (the Global Positioning System) is maintained by the U.S. government. It is one of several GNSS (Global Navigational Satellite Systems) worldwide. Russia manages the GLASNASS GNSS system. Galileo is in the planning stages in the European Union. China is developing Compass, India is launching IRNSS, and Japan is expanding its QZSS (Quasi-Zenith Satellite System).

The U.S. GPS system is provided by 24 satellites placed in orbit by the U.S. Department of Defense. Twenty-four satellites are needed to ensure worldwide coverage. Actually, 32 GPS satellites have been launched – eight are spares. The GPS satellites circle the earth at an altitude of 12,600 miles (about 20,000 kilometers) with an orbital speed of about 8,700 miles per hour (about 14,000 kilometers per hour), transiting the earth twice per day.

The GPS system provides PNT services – positioning, navigation, and time. Actually, a single GPS satellite provides only time services. Each satellite is equipped with an extraordinarily accurate atomic clock – accurate to within a nanosecond. A satellite broadcasts its time and position to GPS receivers. Knowing the position of the satellite, a GPS receiver is able to calculate the length of time the signal takes to reach the receiver at the speed of light. Knowing this, the receiver knows how far away the satellite is.

By using the signals from three GPS satellites, a GPS receiver can determine its position via triangulation. By using the signal from a fourth satellite, a GPS receiver can also determine its altitude. In actual practice, the signals from up to nine satellites are used to guarantee positional accuracy.

The GPS system was initially conceived to aid military navigation. However, the U.S. government made GPS freely available to civilians and commercial operations in the year 2000. GPS has been widely adopted both by individuals (like me) and by commercial operations:

- Telecom networks rely on GPS clocks to keep cell towers synchronized so calls can be passed between them.
- Many electrical power grids use GPS clocks to fine-tune flow in overloaded networks.
- The finance sector uses GPS times to timestamp ATM, credit card, and high-speed market transactions.
- Computer networks use GPS time for synchronization.
- GPS time is used by digital television and radio.
- Doppler radar weather reporting depends upon GPS positioning.
- Seismic monitoring uses GPS positioning.

How Could GPS Fail?

A GPS failure would impact a wide variety of services that consumers take for granted. Some consequences would simply be an inconvenience, such as GPS navigation for automobiles. A GPS failure could affect financial markets, resulting in monetary losses. Even worse, a GPS failure could compromise public safety by preventing police, fire, and ambulance services from reaching their intended destinations. Certainly, the military would be compromised as war planes would be unable to find their destinations and GPS-guided munitions would be unable to find their targets.

GPS signals are very weak (one engineer has characterized GPS signal strength as trying to spot a 25-watt lightbulb that is 10,000 miles away). The GPS frequency range is well known. Therefore, it is easy to jam GPS signals. In fact, inexpensive GPS jammers are available on the web. They are often used by couriers, cab drivers, delivery personnel, and others to prevent management from determining their activities (time for a cup of coffee, turn on the jammer). It would not be difficult to construct a GPS jammer that could disable GPS throughout an entire city.

There are several threats to GPS:

- Local interference, as described above.
- Atmospheric interference (a solar flare can mask GPS signals).
- A malicious attack (for instance, antisatellite weapons).

- System issues.
- Human error.

In January, 2016, the U.S. Air Force was taking one GPS satellite out of the country's constellation. During this process, a wrong time, off by thirteen microseconds. was uploaded to some of the other satellites. This error disrupted GPS timing equipment around the world for more than twelve hours.

In terms of malicious attacks, it is known that the Russians have distributed jammers for interfering with GPS satellite signals.

GPS timing signals can be spoofed. Spoofing involves sending a fake GPS signal with a different time to receivers in an area, thus throwing off all positional calculations. Spoofing signals have been sent to Customs and Border Protection drones along our southern border to mask illegal immigration.

In addition to spoofing, GPS positional calculations can be compromised by the incorrect processing of valid signals by faulty receivers or by the failure of a receiver to locate enough visible satellites.

The GPS system is potentially vulnerable to attack by anti-satellite missiles taking out multiple GPS satellites. A number of nations have demonstrated their capability to deploy anti-satellite missiles.

A GPS failure can have significant business implications. Many companies are unaware of the extent to which different functions in the company depend upon GPS. These dependencies should be documented and contingency plans created for an extended GPS outage.

Is There an Alternative to GPS?

Yes, there is an alternative that can be used as a backup for GPS. It is eLORAN. LORAN (Long-Range Navigation) is a ground-based system initially run by the U.S. Coast Guard. LORAN has been taken over by the U.S. Department of Homeland Security, which is upgrading it to eLORAN.

LORAN is an old system that has been used by mariners for navigational purposes since World War II. Users determine their positions by acquiring signals from several LORAN stations and triangulating. LORAN has been teetering on the edge of retirement since the 1980s. However, its usefulness as a backup for GPS has given it new life.

The conversion of the old LORAN system to eLORAN involves upgrading the LORAN stations with modern electronics and solid-state transmitters.

Whereas GPS signals are very weak and therefore easy to jam, eLORAN uses high-powered transmitters that would require a great deal of power to block. GPS signals are useful only in the line of sight. They are blocked by metal, mountains, and reinforced concrete. eLORAN signals bend around the Earth's curvature and can penetrate urban canyons, natural canyons, and dense foliage.

Large solar flares can disrupt GPS signals. However, cosmic radio waves cannot penetrate the ionosphere, so LORAN signals are immune to this sort of interference.

Ground-based missiles could knock out GPS satellites. However, the eLORAN ground stations are more easily guarded from such attacks.

Summary

GPS has become a service that we all use. The failure of the GPS system would wreak havoc across a wide spectrum of individuals and companies. Unfortunately, there are many threats to the GPS system; and we must all be aware that we may be denied GPS services in the future.

LORAN has been available as a backup system since the inauguration of GPS. Unfortunately, bureaucracy initially blocked this approach. But with the Department of Homeland Security now updating the old LORAN system to eLORAN, eLORAN will become the de facto backup for GPS.

There are other possible solutions for critical applications. One is the implementation of improved atomic clocks. These clocks would maintain the correct time over an extended period of time in the absence of GPS signals. They would be a high-cost item, but would serve well in critical applications.

Another possible solution is interoperability with other global navigation systems, such as Russia's GLONASS.

Whatever the backup solution, GPS has become so important to many critical applications that it is imperative to have a means to continue to function in the absence of GPS.

Acknowledgements

Information for this article was taken from the following sources:

Inside the Government's Backup Plan for GPS Failure, *Popular Mechanics*; October 30. 2009.
Our terrifying reliance on GPS, and the need to develop a ground-based alternative, *Extreme Tech*; November 7, 2014.
What Happens if GPS Fails?, *The Atlantic*; June 13, 2016.
With GPS, Failure is Not an Option, *Atlantic Council*; October 17, 2016.
Wildcard: GPS Failure, *Future in Focus*; undated.
What would we do if GPS failed?, *NewStatesman*; undated.
Can You Trust Your GPS?, *Maritime Accident*; undated.