Geek Trivia: A syncing feeling

May 2, 2006

Takeaway:
What phenomenon causes a consistent 38-microsecond "error" in GPS satellite clocks?

Mark your calendars, technogeeks, because you're overdue for the unofficial sixth annual Geocachers' New Year. For those who've never heard of it, geocaching is a form of techno-empowered scavenger hunting in which the players seek out targeted objects and locations based on Global Position System (GPS) coordinates. May 1 is something of a Geocachers' New Year because, on that date six years ago, technological and political fiat indirectly legislated the pastime into existence.

First, let's offer some background on GPS. The U.S. Department of Defense designed and deployed GPS for its own uses, and the 50th Space Wing at Colorado's Schriever Air Force Base centrally administers it.

The Department of Defense launched the first GPS satellite in February 1978, but a complete "constellation" of 24 GPS satellites wasn't in orbit until Jan. 17, 1994. The constellation ensured that at least four GPS satellites were always within line-of-sight of almost any place on Earth.

In simplest terms, any terrestrial GPS receiver can calculate its exact position by measuring the Doppler shift of the signals received from any four or more GPS satellites and matching a single intersecting location for those ranges. To ensure that the GPS signal intervals are reliable, each satellite boasts its own hyper-accurate atomic clock. At least four GPS birds are necessary to compensate for ionospheric interference, which could effectively slow or warp any single GPS signal by virtue of weather, sunspot activity, and any number of electromagnetic factors.

However, the U.S. military originally had no intention of allowing foreign organizations—or even American civilians—to employ the full power of the GPS network. (Considering that GPS is accurate enough to guide cruise missiles, this makes a certain amount of sense.)

In its early days of operation, the GPS civilian-accessible signals employed so-called *Selective Availability*, which intentionally encoded inaccuracies of up to 100 meters into GPS transmissions. This made GPS effective enough for long-distance navigation (usually by air) but not precise enough for ground-level street directions (or surgical-strike munitions targeting).

On May 1, 2000, the U.S. government disabled Selective Availability, removing that intentional variable from the system and making possible all those wonderful GPS-driven toys and pastimes we've since come to know and love.

Yet even though the government has disabled Selective Availability and compensated for ionospheric interference, another phenomenon consistently puts the onboard GPS atomic clocks 38 microseconds out of sync with their earthbound counterparts, leading some to suggest that the basis of the next-generation GPS system needs to be on very different communications principles.

WHAT PHENOMENON CAUSES A CONSISTENT 38-MICROSECOND "ERROR" IN GPS SATELLITE CLOCKS?

What physical phenomenon causes the atomic clocks aboard Global Positioning System satellites to consistently read 38 microseconds out of sync with their earthbound counterparts, leading some to suggest that the next-generation GPS should take this factor into account?

The culprit is none other than Einstein's theory of relativity (which, at this point, really appears to be more of a fact than a theory).

GPS satellites make two complete intermediate circular orbits of the Earth every day, maintaining a constant velocity (about 4 km/s) relative to the Earth. This velocity—although representing only 0.0013 percent of the speed of light—nonetheless presents

measurable effects of relativity within the context of GPS tracking.

In order for GPS systems to be accurate within one meter, the satellites' internal clocks must be accurate to within four nanoseconds (which is why constantly cross-synchronized atomic clocks are necessary). Thus, the 38-microsecond variance between the ground and orbital GPS chronometers requires an explicit compensation within the entire GPS network.

Some have suggested that the basis of the next-generation GPS deployment be on relativistic principles, rather than simply compensate for relativistic effects. The fact that several other organizations and nations are developing competitors for GPS—including the European Union's Galileo network and Russia's GLONASS—may spur U.S. developments in this direction.

For those of you concerned that GPS is a military-grade targeting system just waiting for someone to exploit it, worry not. Knowing a precise set of geometric coordinates and being able to develop a guidance system that can hit precise coordinates are two very different technical tasks.

Besides, the U.S. Air Force has proven techniques for so-called *navigational warfare*, which involves the selective jamming of GPS signals of specific combat theaters. And, if worse comes to worst, the government can toggle on Selective Availability again, virtually at will. That's not just a techno-tactical advantage—that's hard-core Geek Trivia.

Check out the Trivia Geek's blog!

Keep in touch with **Trivial Pursuits**, the Trivia Geek's online journal of rants, opinions, crazy ideas, half-baked notions, bizarre concepts, wild schemes, and trivial observations unfit even for Geek Trivia.

The Quibble of the Week

If you uncover a questionable fact or debatable aspect of this week's Geek Trivia, just post it in the discussion area of the article. Every week, yours truly will choose the best post from the assembled masses and discuss it in the next edition of Geek Trivia.

This week's quibble comes from the April 19 edition of Geek Trivia, "Stationary perspective." TechRepublic member **NickNeilsen** busted me for mislabeling the specific component on the Soyuz 11 return capsule that failed, leading to the death of the crew.

"The 'control valve' was actually a pressure equalization valve designed to allow fresh air into the Soyuz cabin at altitudes below four to five kilometers. Now, if you are really good, you can tell the rest of your readers what caused the valve to fail."

Before I even had a chance to respond, member **#1 Kenster** busted out the following citation from official Soviet documentation.

"'At approximately 723 seconds after retrofire, the 12 Soyuz pyro cartridges fired simultaneously instead of sequentially to separate the two modules. . . the force of the discharge caused the internal mechanism of the pressure equalization valve to release a seal that was usually discarded pyrotechnically much later to adjust the cabin pressure automatically. When the valve opened at a height of 168 kilometers, the gradual but steady loss of pressure was fatal to the crew within about 30 seconds.'"

Such quibbling dedication warms this Trivia Geek's heart. Keep up the good work, and keep those quibbles coming.

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The Trivia Geek, also known as Jay Garmon, is a former advertising copywriter and Web developer who's duped TechRepublic into underwriting his affinity for movies, sci-fi, comic books, technology, and all things geekish or subcultural.