Fa.S.T
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Merry Christmas

Quarterly Newsletter

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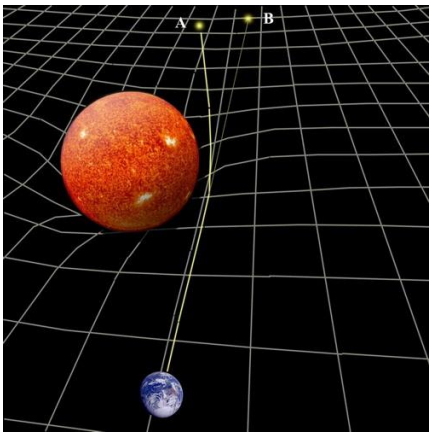
GPS and the Theory of Relativity

In March of 1916, Albert Einstein published a paper explaining his general theory of relativity. Einstein's theory rocked the world of physics and would go on to have a huge impact on the way scientists thought about gravity, time, and space, and how technology would use this theory to keep time and report positional location.

The Theory of Relativity "explains that what we perceive as the force of gravity in fact arises from the curvature of space and time. Einstein proposed that objects such as the sun and the Earth change this geometry."



General relativity predicts the gravitational bending of light by massive bodies
(Source: Time Travel Research Center)

What good is Relativity and how does that affect me? Remember back to your middle and high school days where the Theory of Relativity was discussed and somewhat studied, but you never paid that much attention to it, thinking the theory of relativity would never have an impact on your life? And for a moment you would be right. The theory of relativity would not impact your every-day life that much if you did not have a cell phone, enjoy mobile banking, or leverage anything more than a paper map to navigate. But most of us have become accustom to the convenience of asking Siri for directions, making mobile deposits, or booking your next flight to the Bahamas for vacation. Einstein's theory makes most of the mobile based luxuries we have possible.

The provided quote is from an article published by the Ohio State University on "Real-World Relativity: The GPS Navigation System. "Consider for a moment that when you are riding in a commercial airliner, the pilot and crew are navigating to your destination with the aid of the Global Positioning System (GPS). Further, many luxury cars now come with built-in navigation systems that include GPS receivers with digital maps, and you can purchase hand-held GPS navigation units that will give you your position on the Earth (latitude, longitude, and altitude) to an accuracy of 5 to 10 meters that weigh only a few ounces and cost around $100."

Navigating the Earth is often taken for granted at a time when we are surrounded with the convenience of not actually having to pay attention to our surroundings in order to navigate or to communicate location. Map reading is an art now performed by Siri or Alexa at your request. Thanks to Einstein we are able to be passive in the way we approach land navigation and location identification.

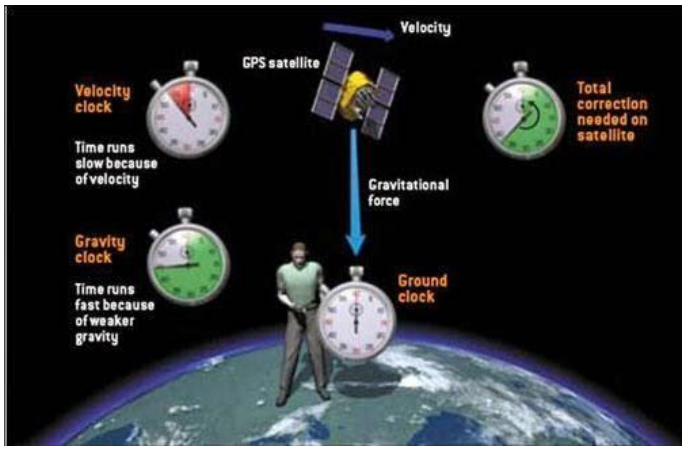
Professor Adam Frank of the University of Rochester stated "All of us are using GPS technologies, right?

It's in our phone. And the only reason it's accurate is because we have to take into account that time difference. You know, GPS works by having these satellites orbiting, and they're sending signals back and forth. And if we didn't take into account the fact that the time is flowing at a different rate for the satellites as it is for us on the ground, it would start to lose time in some sense. It would lose accuracy - about 45 microseconds per day. And you think, oh, that's not very much. But, you know, after a week, for example, if you were to step out on your porch in Columbus, Ohio, the GPS would tell you that you were 5,000 meters above Detroit. So GPS is so accurate, the small differences matter a lot."

The Global Positing System (GPS) is a global navigation satellite system (GNSS) that provides geolocation and time information to a GPS receiver in all weather conditions, anywhere on or near the Earth. GPS is a network (constellation) consisting of 24 satellites in high orbits. Each satellite in the GPS constellation orbits at an altitude of about 20,000 km from the ground, and has an orbital speed of about 14,000 km/hour (the orbital period is roughly 12 hours) and are distributed so that at least 4 satellites are always visible from any point on the Earth at any given instant (with up to 12 visible at one time). Each satellite carries an atomic clock that "ticks" with an accuracy of 1 nanosecond (1 billionth of a second).

A GPS receiver in an airplane determines its current position and course by comparing the time signals it receives from a number of the GPS satellites (usually 6 to 12) and trilaterating on the known positions of each satellite.

To achieve this level of precision, the clock ticks from the GPS satellites constellation must be known to an accuracy of 20-30 nanoseconds, but because the satellites are in constant motion relative to the observers on Earth, effects predicted by Einstein's Special and General Theories of Relativity must be taken into account. Because the observer on the ground sees the satellites in motion relative to them, Special Relativity predicts that we should see their clocks ticking more slowly, falling at a rate of about 7 microseconds per day due to the time dilation effect of their relative motion.



Further, the GPS satellites are in high orbits above the Earth, where the curvature of space-time due to the Earth's mass is less than it is at the surface of the Earth. Einstein's General Relativity predicts that clocks closer to a massive object (Earth) will seem to tick more slowly that those located further away. As such, when viewed from the surface of the Earth, clocks on the satellite appear to be ticking faster than identical clocks on the ground, thus using General Relativity calculations to predict that clocks on each GPS satellite should tick ahead of ground-based clocks by 45 microseconds per day.

High-precision is required in order to operate a GPS system that requires nanosecond accuracy. Relativity is not an abstract mathematical theory developed by Einstein, but an essential theory necessary for the implementation of GPS into everyday life.

what3words

When is the last time you thought about your street address? I mean really thought about. Have you ever wondered why your mailing address is what it is or where the concept for addressing came from?

Your mailing address is as much a part of you as is your name, birthday, or social security number. Your mailing addresses identifies your place on the Earth, a place that is quite unique to you. It is where you

live, where you sleep, where you raise a family and maybe even where you retire.

Aside from being your little dot on the map, your address communicates where you live, where you receive your mail or where to send help in case of an emergency. We assume that the address will always be there. 1237 N. Main St. will always be 1237 N. Main St., right? This may not always be the case, since most mailing addressed are based of road centerlines, 1237 N. Main St. could easily become 1239 N. Main St. if adjacent properties are developed.

Alternative forms of location identification have existed well before street addressing was developed. Coordinate based addressing is used throughout the military and in disaster response, but might not be a sufficient solution for the novice in communicating location. Can you remember a 15 digit location (18STH5685488641 – US National Grid (USNG)) address for 29 Ashby St. Warrenton, VA) or do you know the distance between a point of latitude and longitude?

There is no easy way to say this, but let's face the facts, the World is poorly addressed with 75% of the world with poor or no addressing.

Let me introduce you to an alternative to the street addressing most of you are used to; "what3words" is a unique combination of just 3 words that identifies a 3mx3m square, anywhere on the planet. It's far more accurate than a postal address and it's much easier to remember, use and share than a set of coordinates. Better addressing improves customer experience, delivers business efficiencies, drives growth and helps the social & economic development of countries.

Using words means non-technical people can find any location accurately and communicate it more quickly, more easily and with less ambiguity than any other system like street addresses, postcodes, latitude & longitude or mobile short-links. People's ability to immediately remember 3 words is near perfect whilst your ability to remember the 15 numbers digits that make up the USNG address, decimal points, or N/S/E/W prefixes that are required to define the same location using LAT/LONG is zero.

Each what3words language is powered by a word list of 25,000 – 40,000 dictionary words. The word lists go through multiple automated and human processes before being sorted by an algorithm that takes into account word length, distinctiveness, frequency, and ease of spelling and pronunciation. Offensive words and homophones (sale & sail) have been removed. Simpler, more common words are allocated to more populated areas and the longest words are used in 3 word addresses in unpopulated areas.

The Fauquier County GIS Department is introducing this alternative form of addressing to public through the Fauquier County GIS website: http://www.fauquiercounty.gov/government/departments-a-g/gis-mapping/what3words with the idea of providing an alternative approach to location identification and is currently exploring uses for the technology within the county. This form of addressing will never replace the street address, nor is it intended to replace the street address. Coordinate based addressing is merely another tool in the tool box and a technology worth knowing about.