Einstein and GPS

Learning Objective	In this lesson we will discuss how GPS would not be possible without the theories of Albert Einstein.
Grade Level	6 – 8

GPS Satellite – image: Wikipedia

– Introduction –

Whenever we get the chance to teach young students about flight we find that what really excites them are the real world applications of theories and mathematics. The amazing thing about aerospace education is that there is an opportunity for students to work with their own hands to build vehicles that demonstrate the laws of aerodynamics.

However, an education on aerospace wouldn’t be complete without a discussion of space travel and applications of space technologies. One of the most useful space technologies ever are

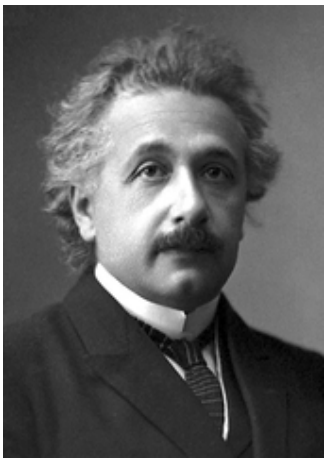
GPS satellites.

GPS has changed the world like few other technologies have. Did you know that GPS would not be possible without the theories of one of the greatest minds of all time?

We are referring of course, to Albert Einstein and his Special Theory of Relativity and General Theory of Relativity.

How does GPS work?

The Global Positioning System or GPS, is a space-based navigation system using satellites to provide accurate location data to anyone on Earth using a GPS receiver.



Einstein in 1921 – image: Wikipedia

Each GPS satellite contains an atomic clock for precise and accurate time keeping. Distance from respective satellites is determined by using the speed of light and the time transmitted by the satellite. By using the signals from multiple sources, the receiver is able to determine its position.

Albert Einstein

In 1905, a 26 year old Albert Einstein published an article on his Special Theory of Relativity. The two parts to his theory are, the speed of light is constant and space and time are not absolutes. Space and time are actually relative to the observer.

For example, a person walking down the aisle of a train towards the back of the train is moving at a speed relative to the moving train. An observer outside would see that person moving at the speed of the train minus the speed that the person is walking.
If a flash of light happened on the train the light would hit the back of the train after a very short period of time. To the outside observer, the light would hit the back of the train at a time that is faster than would be witnessed by a person on the train as the train is moving relative to the outside observer. Since it is the same source of light that is observed it can be concluded that time must be faster for the outside observer as compared to the observer on the train.
In 1915, Einstein published his General Theory of Relativity. In this theory he determined that gravity from massive objects cause a distortion in space and time. Time slows down as gravity increases and thus speeds up as gravity decreases.

How does this apply to GPS satellites?

Observing a fast moving satellite above us, the Special Theory of Relativity predicts that the clock on the satellite should tick more slowly relative to us. This in fact has proven to be true. The clocks on GPS satellites actually are slower by 7 microseconds a day due to this theory.
Affecting the clock on-board the GPS more than the speed is the lower gravitational force due to its distance from the Earth. Using the General Theory of Relativity, the clock on the GPS satellite should move more slowly than a clock on the surface of

the Earth.

This in fact has been proven true as the clocks are 45 microseconds slower on the GPS satellite than they are on Earth due to the General Theory of Relativity.

To compensate for this, the clocks on GPS satellites are adjusted for the 38 microseconds (45 microseconds minus 7 microseconds) difference. If Einstein’s theories were not taken into account GPS as we know it would not exist. In fact it would only take 2 minutes for the times to be false and positions would be off cumulatively by 11 kms per day.