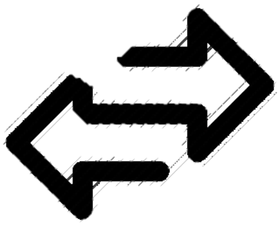
*Team **VallauriSAT** – I.I.S. "G. Vallauri"*

via San Michele, 68 – 12045 Fossano (CN) – Italy
phone: +39 0172 694969 – email: g.olivero.0278@vallauri.edu

Back to the Future



Why doesn't GPS seem to be influenced by effects of relativity? Actually, these effects affect it, but the study of such phenomena has managed to elide the undesired influence completely.

So the question arises as to how much time changes, depending on the distance from our planet. Are the effects of special or general relativity more influential? Can these phenomena be measured?

Our aim is the following one: to measure a certain number of piezoelectric oscillations on Earth's surface and in space to quantify the time variations during the development of the experiment.

When we have successfully completed this measurement, we will be able to find out the relationship between a second on Earth and one in space. In this way, we can notice the influence of both Einstein's theories on time. Moreover, we can establish how this phenomenon influences the life of a cosmonaut who experiences time differently from the people on our planet.

Idea

The idea was born on a cold day on a bus to Turin, when a group of young students wondered why the speed of light outside the bus was not affected by the acceleration of the same. In fact, light continues to travel at that famous speed that distinguishes it and makes it unreachable by any mass-equipped body.

The latter is the same property that allows the Earth to bend a light ray. Since the speed of light is constant and considering the same space crossed, it will need time to turn and slow down.

This effect is more evident on an orbiting object whose speed is clearly higher than that of a common means of transport, if observed by a sidereal reference system.

Consequently, the ratio between a second on the surface and a second in space will be less than one.

It is interesting to think of two people's beard, one on our planet and one in space. The beard of the second individual will grow faster than that of the first: if the two people met after a long time, the effect would be visible.

However, to measure this phenomenon better, there are methods to conduct experiments which are more suitable for the case described above. One of them is the oscillation of a piezoelectric material.

A piezoelectric is a particular crystal that, crossed by an electric current, oscillates at a given frequency that follows the laws of harmonic motion.

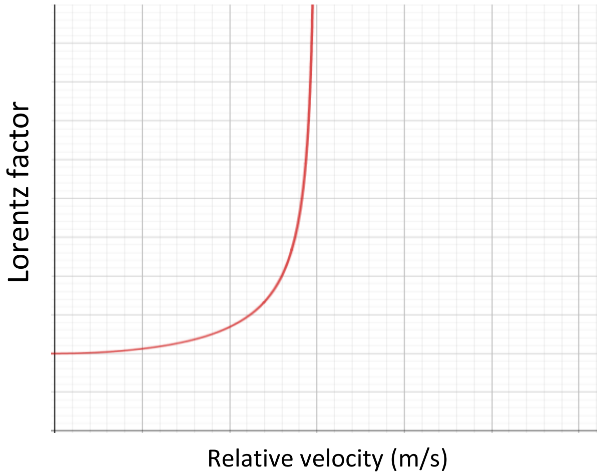
Once this frequency has been found, a sufficiently high number of oscillations can be measured and, obtaining the time spent on Earth and in space in the same conditions, one can understand how these effects affect our everyday life.

We must think, however, that a person with an atomic clock on Earth, always measures a second correctly according to his reference system. If a second person performs the same operation in space, he will get the same result again, this time correctly. Comparing both clocks we would not get the same result.

The Lorentz factor is a mathematical operator that appears in the transformations studied by the homonymous scientist.

Having to take into account the invariance of the speed of light to rewrite the now obsolete Galilean transformations, Lorentz is forced to introduce a factor ($\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$) to describe the variation of time with respect to the various systems.

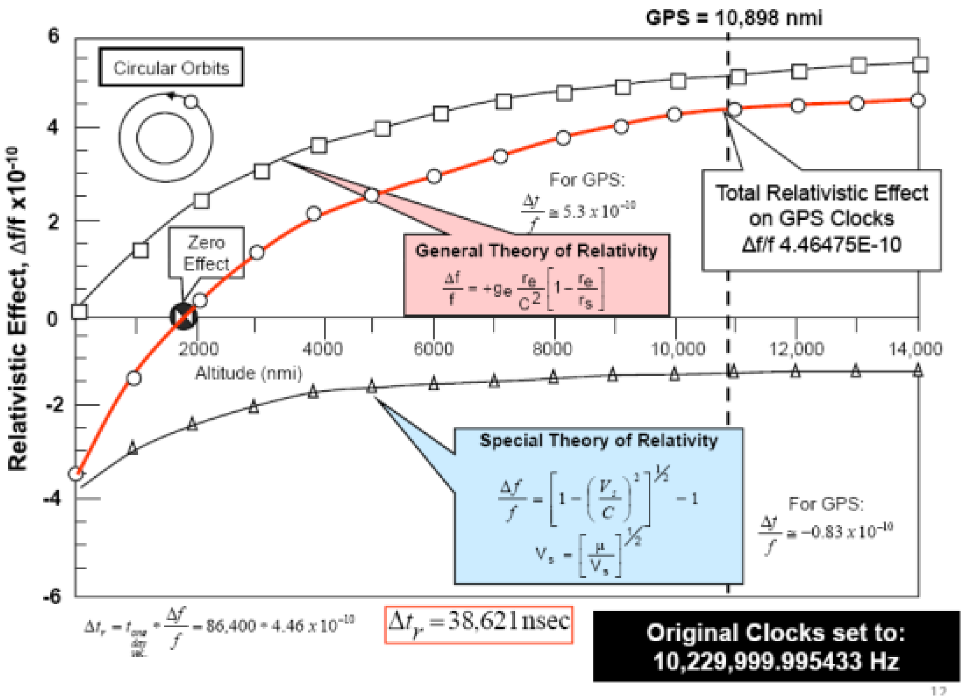
The variation of the influence of the Lorentz factor according to the relative speed between two inertial reference systems is represented in *Graph 1*.



Graph 1 Influence of the Lorentz factor

As already expressed, the effects of special and general relativity are added together: the result of this effect is represented in Graph 2. Even without making more in-depth calculations, it can be seen that the effect of the International Space Station is perceptible over a long period of time. We will therefore assume a period of approximately one month as the duration of the experiment.

The graphic takes into consideration the effects on the orbit of the geostationary satellites in particular and uses, as a unit of measurement, the nautical mile (1 nmi = 1.852 km). As you will notice, the effect on the orbit of interest can still be seen considering the average altitude of the ISS at 405 km = 219 nmi.



Graph 2 Special and general relativity effects

Experimental equipment

Experimental equipment will include:

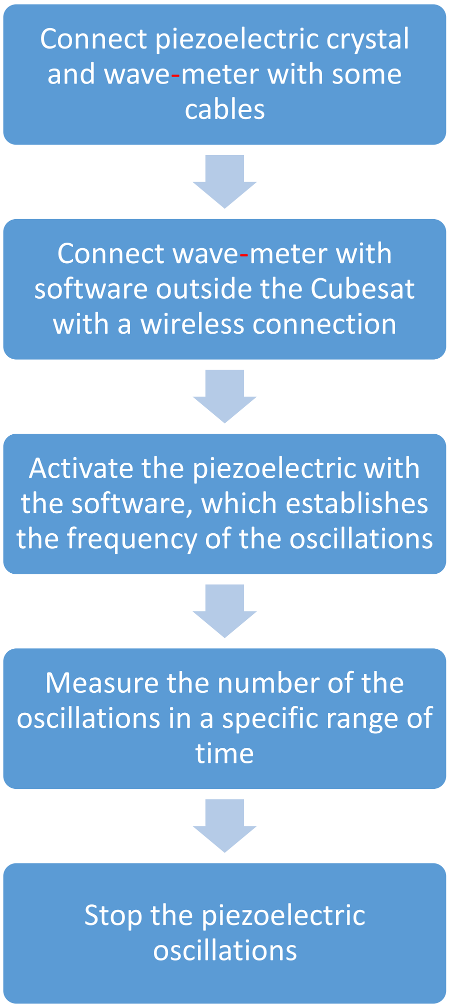
- Piezoelectric crystal
- Wave-meter
- Instrument and software that measure the number of oscillations.

All the necessary equipment will be positioned inside a single Cubesat and will need to have a power source with a very low average power.

The same experiment will be done on the Earth and at the elevation of the ISS and will last for the same range of time.

The principal phases of the experiment are summarised in the flow chart on the right.

At the end of the experiment, it will be enough to compare the number of oscillations achieved in the two cases. In this way, we are going to prove the validity of the special relativity and general relativity theory, by means of a comparison between experimental results and the theoretical calculation.



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