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Natural influences on satellite navigation and positioning systems on planet Mars

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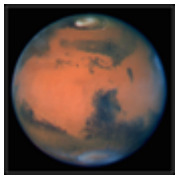

Navigation technologies and orbital systems used in environment of different worlds on another celestial bodies can be influenced by many aspects, many of which we even have not deeply examined. Very wide and important aspect is the local planetary conditions, especially the influence of the ionosphere, magnetosphere and several other conditions on the particular planet. In this paper we will focus on our most similar planetary neighbour – Mars, and on natural conditions influencing the possible use of satellite navigation and positioning systems there.

Mars as terrestrial type of planet from the inner part of the Solar System is characterized by the conditions similar to planet Earth although there are more significant differences. These differences are causing different inputs for design and construction of satellite positioning and navigation systems. Let’s focus on some of the most important of them.

1. Introduction

The planet Mars has long held a special fascination and even mythic status for humans. While not the closest planet to Earth, scientists have considered it to be the planet that most closely resembles Earth and thus is the other planet in our solar system most likely to contain life. Since before the space age began, people have wondered about the “red planet” and dreamed of exploring it. In the twentieth century, robotic spacecraft and then possible human space flights became a reality. [5]

Exploration of the other celestial bodies had begun and the mankind started to try to reach more and more targets in Solar System. Evolution of the next space systems needed for exploration of other planets brought another problems, which need to be resolved. One of the biggest challenges is exploration of planet Mars and looking for conditions once suitable for life development. Deep exploration of surface includes the use of rovers or even flying probes. Their precise positioning and navigation will depend on navigation systems deployed in dedicated area. As the most efficient solution in this case, can be used a satellite positioning and navigation system.

2. Planet Mars

Planet Mars is the fourth planet from Sun and is considered as a terrestrial type of planet. It is because its composition and the physical characteristics are mostly same as the characteristics of the other three terrestrial planets in inner part of Solar System. The influence of Sun and interplanetary radiation is more visible on this planet due to absence of stronger bipolar magnetic field. Missing protective bipolar magnetic field most probably caused the loss of the most of planet's upper atmosphere layers and nowadays it looks like a very cold and dry desert place. However there might be still places containing sub-surface water and suitable conditions for basic forms of life.

It might be useful here to mention the ongoing mission of NASA's MAVEN spacecraft. This spacecraft is currently en-route to Mars. MAVEN's aim is to explore and study the upper levels of Martian atmosphere and ionosphere, which will help us to understand and to simulate more precisely the influence of Martian ionosphere on distribution of positioning and navigation signal, transmitted from the satellites in orbit of this red planet to receivers on surface. We are expecting the ionospheric data from this mission during the Autumn of 2014.

3. Is Mars very different than Earth?

Mars can be compared with Earth in many ways. Both planets have north and south polar ice caps, volcanoes, rocks, canyon systems, flood plains, wind, weather, and dirt. Mars, at its heliocentric distance of approximately 1.5 AU (224 396 806 kilometers), exemplifies a terrestrial body that is affected by both a slightly greater distance from the Sun than Earth and a lower gravitational field at the surface. The radius of Mars is about 3395 km on average (compared to the 6371 km radius of Earth). [2] Although this planet is very similar, there are some major differencies which have impact on whole planetary environment and conditions and thus on functionality on some exploration systems.

4. Magnetosphere

One of the major differences which can have any influence on the navigation and positioning systems on Mars, is its different and very unique magnetosphere. The natural magnetic field of the planet Mars is not characterized by bi-polar structure as the magnetic field on planet Earth. To study and fully understand the magnetic field of Mars we can use the results of the MAG/ER (Magnetometer/Electron Reflectometer) experiment on the NASA's Mars Global Surveyor. [3] According the results we can see that the magnetic field is quite different and one of the most important things is that it does not consists of two major poles like the terrestrial magnetic field.

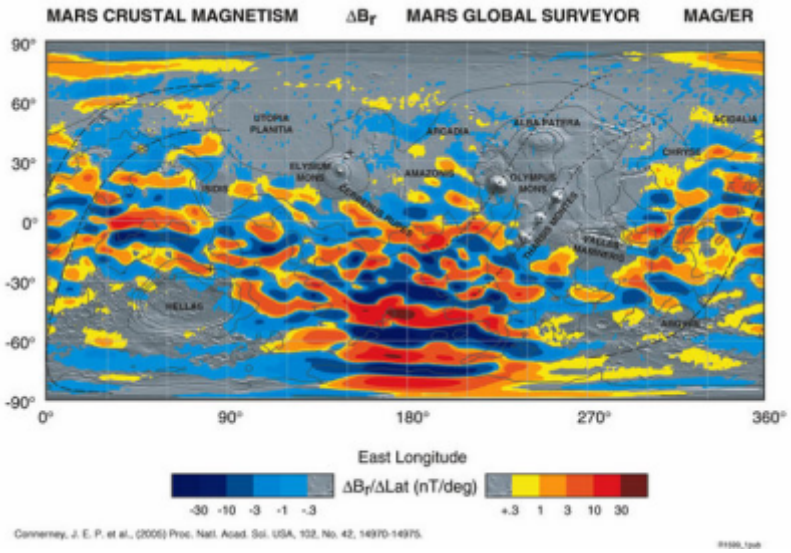

Figure 1 (Connerney 2005) – red color displays the strongest magnetic field on the planet

This can have an influence not only at navigation signal transmission, but it can have an influence on protection of navigation satellite fleet at orbit of Mars, because the solar wind can heavily interact with the operation of orbital systems. Especially during higher peaks of the Solar activity cycles. These interactions are well known also on planet Earth, for example in southern hemisphere's area above the Southern America region – the Earth's magnetic field here is weak and the first significant experience confirmed was when Hubble Space Telescope was crossing this area.

Due to very weak protection against the Solar wind particles, these heavily interacted with onboard electronic systems of orbiting Hubble Space Telescope. The protection of magnetic field at Mars is weak due to its inconsistency on whole planet. Some regions are protected but some regions are absolutely exposed to influence of radiation of Sun and to influence of interplanetary radiation sources.

The dynamo theory of planetary magnetism indicates that Mars may have had a dipole moment of about onetenth of Earth's when it was first formed. [7] The rotation rate of Mars is approximately that of Earth and is thus sufficient for the operation of this initial dynamo. The other necessary ingredient of a convection driver in the core was supplied by heat left over from the accretion of the planet, which may have been effective for up to a few billion years. If such a field did indeed exist, evidence of it may still be present on the surface in the form of magnetized rocks and crustal regions like those observed on the Moon. [2]

5. Ionosphere

Another important element of natural influence at satellite navigation and positioning systems at Mars, is the ionosphere. Ionosphere of the planet is the most important player in the whole operation of such system, because the interaction of ions and ionized gases in the high altitudes of the planet can cause significant range errors in positioning. The entire ionosphere at Mars is different on the planet's part facing to Sun (dayside ionosphere) than the other side of the planet. The dayside ionosphere is caused by the extreme ultraviolet light from the Sun which ionises the neutral atmosphere resulting in increased electron density. Measurements obtained over the

past eight years with the ESA's Mars Express Radio Science experiment have produced more than 500 vertical profiles of the ionosphere, some of which show features that had not been predicted by theories of how the ionosphere functions. [4]

A planet's ionosphere imposes a delay upon the radio transmissions from an orbiting artificial satellite to a ground receiving station, thus leading to ranging errors in systems designed for precise positioning. [6] The range errors caused by the ionosferic impact can reach distances in meters, which can be potentially dangerous for the systems using these results for positioning or navigation on the surface of Mars. The range errors could be corrected by using the local surface differential positioning system transmissing the actual range error for the dedicated location. This could be obtained as the difference on the exactly same principles as the terrestrial differential positioning systems on planet Earth.

6. Conclusion

Although there can be found more other factors which can have any influence on precise operation of the satellite navigation and positioning systems at Mars, the above mentioned are the most significant and thus should be deeply examined. Concept of the small satellite navigation system for planet Mars is a part of the current research at the Technical University of Kosice, Faculty of Aeronautics. This research is focused on determination of necessary conditions for construction and operation of global positioning and navigation system at Mars. The satellite navigation system at Mars will be one of the major systems helping in exploration of Red Planet, because it will avoid any other additional problems and costs on future missions.

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