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Cosmos: Violent and Hostile Environment

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2.1 Introduction

Space attracts, worries, and questions human being for ages, as a frontier set between us and farther horizons to discover. Successive steps were made to unveil its mysteries, before the exploration really started fifty years ago. At the dawn of twentieth century, its main characteristics were not known and we had to wait until the early fifties to get the first data, with the help of balloons, sounding rockets, satellites, and finally human spaceflight to have a better view on this impalpable and elusive place.

2.2 Beliefs and Truths

Scientific description of space started in the middle of the second millennium, at a period when Copernic description of the solar system began to be accepted. Space was then seen as a medium where gods, stars, and comets reside. In Europe, it was described as successive spheres that symbolize way to paradise.

But, after Galileo Galilei (1564–1642), Tycho Brahe (1546–1601), and Copernicus (1473–1543) particularly, scientists started to determine whether space between bodies was empty or filled with a certain invisible fluid. René Descartes (1596–1650) thought that planetary motion was due to *ether* hurly-burly. Christian Huygens (1629–1695), then James Clerk Maxwell (1831–1879), suggested that light and other electromagnetic waves propagate within "light ether." At the beginning of the twentieth century, *ether* hypothesis vanished with the help of Einstein's theory.

By now, cosmologists have to deal with another puzzling story about dark matter and dark energy, a kind of a new step. But our subject is closer to Earth for now...

In the early fifties, some balloons and sounding rockets started to be launched at high latitude in order to study both the edge of the atmosphere and polar aurora phenomenon [1]. It brought the first data on the composition of upper atmosphere, ionosphere, and magnetosphere.

Then, the first human spaceflights sent men out of the protective shelter of Earth [1–4]. Again, these events were a way to answer a variety of questions. Particularly, it was believed that the space environment and weightlessness could deeply affect health and cause some irreversible damages to brain. Gagarin flight was not only a very unique event in a technical point of view, but also for the knowledge it brought on the brain behavior and adaptation in space.

We could now have the slight feeling that everything has been discovered on space. But many challenges are still facing us. We do not know how to safely send a crew to Mars. History of space exploration learnt that the cosmos is a violent and hostile environment!

2.3 Where Space Begins

Earth is wrapped up in a protective shell made of atmosphere and magnetosphere. The atmosphere protects us from neutral particles and high-energy light waves. The magnetosphere extends at a long distance from Earth and acts as a shield against charged particles from solar wind and cosmic rays.

The Kármán line lies at an altitude of 100 km and commonly represents the boundary between Earth's atmosphere and outer space. This definition was endorsed by the Fédération Aéronautique Internationale (FAI), which is a standard setting and record-keeping international entity for aeronautics and astronautics.

At higher altitude, satellites can travel in radiation belts or out of the magnetosphere. This subject is detailed in other sections.

2.4 Satellite Environment

Figure 2.1 shows vertical variation of temperature and pressure from sea level to 900 km. Above 100 km, the atmosphere becomes too thin to support aeronautical flight. There is also an abrupt increase in atmospheric temperature and interaction with solar wind.

Even if the density is lower than 10^{-5} kg/m^3 at satellite altitude, space is not a complete vacuum. It has four major consequences that affect lifetime of satellites. See [5] for further details.

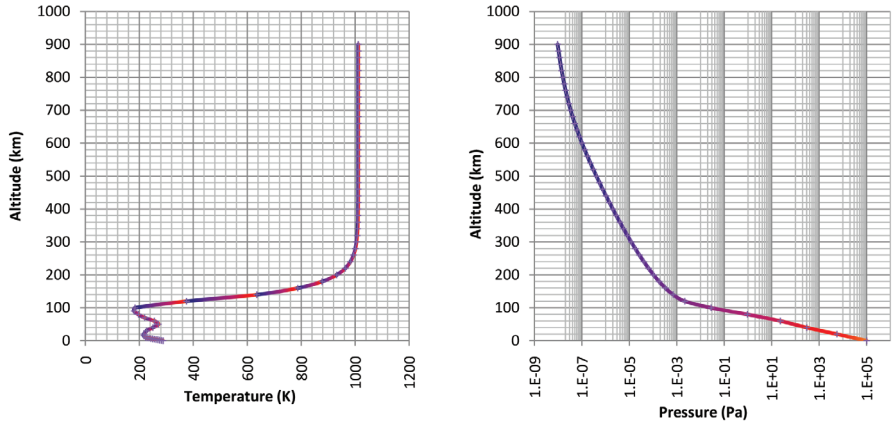

Figure 2.1 Vertical variation of temperature and pressure in Earth's atmosphere (model MSISE-90).

2.4.1 Temperature

In space, heat exchanges can only occur by conduction or radiation, as convection is not efficient anymore. Particles' temperature in the environment is around 1,000 K. But it has low effect on satellites by conduction due to low density/pressure of the atmosphere. Heating of materials is mainly controlled by radiation. It leads to the surprising thing that objects facing to Sun are heated to temperature close to 180 °C, while their shadowed face can have a temperature as low as –180 °C. It might create strong mechanical constraints on structures.

2.4.2 Atmospheric Drag

Considering high velocity of satellites (several km/s depending on altitude and shape of orbit), the residual neutral atmosphere creates a drag that continuously decreases the altitude of orbit. Ground controllers have to correct it regularly. For example, ISS altitude decreases by 50–100 m each day. The orbit has to be corrected 4–6 times a year.

2.4.3 Outgassing

The third effect is due to pressure reduction that creates outgassing of various materials. Moisture, sealants, lubricants, and adhesives are the most common sources, but even metals and glasses can release gases from cracks or

impurities. Outgassing products can condense onto optical elements, thermal radiators, or solar cells and obscure them. Space agencies maintain a list of low-outgassing materials to be used for spacecraft. Method of manufacture and preparation can reduce the level of outgassing significantly. Cleaning surfaces or baking individual components or the entire assembly before use can drive off volatiles.

ESA-NASA's Cassini–Huygens space probe has suffered reduced image quality due to a contaminant that condensed onto the CCD sensor of the narrow-angle camera. It was corrected by repeatedly heating the system to 4 °C.

2.4.4 Atomic Oxygen Oxidation

The fourth consequence is due to high-velocity impacts of oxygen atoms on satellite structures. Atomic oxygen density is significant until 1,000 km, and high-energy collisions increase the oxidation power of atoms. For example, oxidation of silver creates an insulating material. Solar array efficiency can be sharply decreased due to interaction between electrical circuit and oxygen.

2.5 Conclusions

The space environment affects the lifetime of satellites. For all the reasons listed in this section, we can conclude that man-made technology is not simple to bring safely into space.

For 50 years, engineers and space specialists in various domains have developed unique skills in order to make spaceships more resistant to temperature contrasts, low pressure, atomic oxygen collisions, and radiations.

The story is still on the way. Not only propulsion will be the key to send more specialized robotic missions and manned spaceships to Mars and beyond. We have to go further in terms of materials innovation and development to build stronger vessels that will be able to protect experiments and crews and send them back safely to Earth.

References

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