Radiation Hazards in Outer Space

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DURING HIS FLIGHT in the *Voskhod II* spaceship, Soviet cosmonaut Alexei Leonov, who was the first man in the world to step out into space, got 65 millirads of cosmic radiation. This is not enough to endanger the cosmonaut's health, but the radiation barrier, nevertheless, will be the main obstacle in the longer space flights that lie ahead. We know this from the data obtained by means of sputniks, rockets and sondes.

It has been established that galactic cosmic rays or "primary cosmic radiation," is comprised of protons (about 85 per cent), alpha particles (about 13 per cent) and heavy nuclei (about 2 per cent). The energy of all these particles is rather high, and it is practically impossible to fully protect a cosmonaut from them. However, the biological effects of primary cosmic radiation are 70-80 per cent due to the action of the heavy nuclei, though its quantity in the composition of the radiation is negligible.

The stream of primary cosmic radiation is practically stable, and the average dose, that is likely to be absorbed by human tissues without any protection at all will amount to about 40 millirads a day. But during orbital flight, a cosmonaut usually remains inside his capsule and is protected by the walls of the spaceship; the ship's orbit passes near the earth, which screens off a definite portion of the cosmic rays. It was calculated that at an altitude of 200-600 kilometers, at a 65° orbital angle to the equator, and with the walls of the ship providing a protection of approximately two grams per square centimeter, the average daily dosage amounts to 8-11 millirads inside the vehicle. (This is approximately .002 the human tolerance dose, which is 15,000 millirads, while the radiation morbidity dose is 50,000 millirads.)

Somewhat greater radiation hazards in outer space are the radiation belts of the earth, discovered by means of the Soviet and American satellites and rockets in 1958. The inner belt starts at an altitude of 500-1,500 kilometers and extends for a distance of from 5,000 to 10,000 kilometers. It consists of high-energy protons and electrons of relatively low energy. The radiation dosage is about a lethal 75-100 rads per day.

The external belt girdles the inner one. Its protrusions in the near-polar zones descend to an altitude of 300 kilometers, but in the equatorial zone the belt is about 13,000-50,000 kilometers away from the earth. It consists of electrons which can be screened off by rather slight protective shielding. It has been calculated that the total dose will amount to about 20 rads a day if the protection equals some two grams per square centimeter. Unfortunately, the hazards from this radiation have not yet been sufficiently studied and consequently calculations of protection against the electrons of the outer belt are conjectural.

The third and most dangerous source of cosmic radiation are the solar chromospheric eruptions. During the peak solar activity, which recurs every 10-11 years, we observe from 5 to 13 eruptions of up to a few hours in duration. During the low periods of solar activity their number decreases several times over. The eruptions give rise to streams of protons and alpha particles of high energy. During the eruptions the radiation dosage inside the spaceship may rise to hundreds of rads, if the protection is about two grams per square centimeter, and far exceed the danger level.

At present it is practically impossible to protect a cosmonaut from radiation during solar eruptions. That is why the satellite spaceships have so far been placed in comparatively low orbits. The astrophysicists keep constant watch of the sun during the flights, while geophysicists study the radiation in the upper layers of the atmosphere by means of sondes. In the event of an unexpected eruption or enhanced radiation hazard, a cosmonaut is immediately returned to the earth, within the protection of the atmosphere.

It is still difficult to forecast solar eruptions with sufficient accuracy, but such forecasts are being made in the Soviet Union, and no Soviet cosmonaut has yet had to be returned from the orbit urgently. For instance, on June 10-13, 1963, just before the flights of the satellite space ships *Vostok V* and *Vostok VI*, the configuration of magnetic fields on the sun, the increased radio noise on the centimeter waves, plus a small magnetic storm indicated the possibility of a solar eruption. It actually did occur on June 12, but it was rather weak and did not produce a dangerous quantity of solar protons in the near-earth space. The flights of the space ships *Vostok V* and *Vostok VI* began on June 14 and 16, and ended successfully on June 19. The cosmonauts Valeri Bykovsky and Valentina Tereshkova received no excessive radiation dose.

Rather difficult also were the radiation conditions before the launching of the space ships *Vostok III* and *Vostok II* (cosmonauts Andrian Nikolayev and Pavel Popovich). The United States had touched off a high-altitude nuclear explosion over the Pacific Ocean on July 9, 1962, shortly before their flight. This produced an artificial belt which increased the radiation consider-

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ably at the altitude of the projected flight. To check the radiation conditions a *Cosmos-7* satellite was launched on July 28. It was put into orbit with an equatorial angle of 65° and an altitude slightly exceeding that of the projected orbits of the spaceships. *Cosmos-7* carried radiation pickups, and the data they transmitted confirmed the apprehensions of the scientists: the dosage measured by the *Cosmos-7* radiation satellite was many times higher than that gauged by the instruments of the second satellite spaceship. But the speed of the artificial belt's decay was of the order of a few days, the projected altitude for the ship's orbits was lower (about 250 kilometers instead of 369) and so the formation flight of Nikolayev and Popovich was pronounced safe as regards the radiation hazard, provided there was no major solar eruption during the flight. This calculation proved correct.

The effects of different radiations are not the same, while the effect of the same kind of radiation may differ, depending on the dosage. Protons are most effective in small doses, while X-rays are most effective in large ones. The effect of radiation also depends on the area of the body exposed to it. Radiation of the order of 500 roentgens (one roentgen is an amount of radiation that produces two billion pairs of ions in one cubic centimeter of air at normal pressure and temperature) is lethal if it covers the entire surface of a human body. At the same time, malignant tumors are cured by applying repeated radiations of the order of tens of thousands of roentgens to a small area of the body.

Radiation conditions are checked constantly during space flights, both by means of ground installations and shipboard dosimeters, which record the radiation dosage both inside and outside the cabin. The flight instrumentation of Soviet spaceships includes signals which warn the cosmonaut about increasing radiation. The cosmonaut is provided with medicines for preventing radiation injury, which are to be taken if the radiation rises suddenly to dangerous proportions. The cosmonauts did not have to resort to these protective medicines during the flights of the spaceships *Vostok* and *Voskhod*. The average tissue radiation dose they received was rather small, as is borne out by the following table:

Cosmonaut	Flight duration (hrs.)	Average dose of radiation received during flight (milliards)
Yuri Gagarin	1.8	2.3
Gherman Titov	25.3	10
Andrian Nikolayev	95	62
Pavel Popovich	71	46
Valeri Bykovsky	119	80
Valentina Tereshkova	71	44
Vladimir Komarov	24.3	25
Konstantin Feoktistov	24.3	29
Boris Yegorov	24.3	32
Pavel Belyayev	26	75
Alexei Leonov	26 (including 10 min. in open space)	65

It is worth noting that Alexei Leonov got a somewhat smaller dose than Pavel Belyayev, who remained inside the cabin. This is explained by the fact that the walls of the ship did not absorb the radiation evenly, and Belayayev was in an area where he got a slightly larger dose. On the other hand, the flight proceeded below the radiation belts, there were no solar eruptions, and the cosmonouts were exposed only to primary cosmic radiation, which is poorly absorbed by the ship's walls and has practically the same effect on the cosmonauts inside and outside the ship.

Soviet scientists have obtained interesting data in recent years while experimenting on radiation effects by means of the synchrocyclotron of the Joint Nuclear Research Institute in Dubna. This accelerator, one of the largest of its kind in the world, yields a proton flux comparable to the radiation streams in the inner belt, and even to the streams produced by some solar eruptions. Such experiments were carried out on a large scale for the first time in the Soviet Union. They permitted us to clarify the effects of high-energy proton radiation and map out ways of solving the problem of the radiation hazard. In the course of these experiments the effectiveness of dosimeters was checked as were the preventive medical measures. The investigations in Dubna are being continued.

Soviet scientists, who have tackled successfully the problem of radiation protection during past flights, hope to find ways to safeguard the cosmonauts in longer and more distant space flights.

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