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THE SOVIET EARTH SATELLITES

1957

Contents:

Epigraph

... "The steel birds find the air increasingly crowded, and this has become possible in our country only at this time when our whole industrious nation, every working man and woman in our Soviet land have all together set out to make real mankind's dream of conquering the heights beyond the clouds...

"Today I am very certain that my other dream, namely, interplanetary travel, which I substantiated theoretically, will also come true.

"For forty years I worked on jet-propelled engines and thought that a pleasure trip to Mars would begin only after several centuries. But times are changing. I believe that many of you will witness the first flight beyond the atmosphere...."

(From a speech by K.E. Tsiolkovsky recorded in 1933)

PUBLISHERS' NOTE

On July 1, 1957 began the International Geophysical Year. Joining their efforts, scientists of 64 countries are engaged in extensive investigations of the continents and islands, seas and oceans, the depths of the sea and the atmosphere.

To be studied are the aurora polaris and glow of the air, the cosmic rays, terrestrial magnetism, the earth's gravitation, and solar radiation; also the ice situation, the physics of the ionosphere and a number of problems of meteorology, oceanography, seismology, and so on.

Occupying a special place in the research is the study of cosmic space, one of the fascinating tasks of modern science. It is of tremendous interest for physics, astrophysics, astronomy, meteorology, aviation, chemistry, biology and many other spheres of science.

An important place in the IGY programme has been assigned to this exploration which is being conducted with the aid of rockets and artificial satellites of the Earth.

The Soviet Union plans to launch 125 rockets, to rise from different points in the USSR approximately along the same meridian, beginning with Franz Josef Land beyond the Arctic Circle, and from starting grounds in the middle latitudes belt. Rockets are also to be launched from the area of Mirny settlement in the Antarctic. The Soviet rockets will take up containers with instruments for different kinds of observations 100-200 kilometres high. The United States plans to send up 35 rockets, and Britain, France and

Japan, also intend to launch rockets for research purposes.

The IGY's most important problem is the launching of artificial satellites of the Earth. The very emblem of the IGY is a picture of our planet ringed by an orbit of a moving artificial earth satellite. Only two countries -- the Soviet Union and the United States -- have decided to undertake to carry out this task, one of the grandest man has ever set himself.

On October 4, 1957 a truly history-making event took place -- the Soviet Union successfully launched Sputnik-1, the first artificial earth satellite. And before another full month had passed it was followed by Sputnik-2., its younger but much bigger brother, which took up to the fringe of outer space the dog "Laika", the Earth's first messenger.

The launching of Sputnik-1 was a great triumph of man over nature. Man had surmounted "the physical barriers" which have kept him out of cosmic space; he had overcome the force of gravity and the resistance of the atmosphere. However, there still remained the biological barrier, as yet unexplored. Could a living organism endure the conditions of space beyond the Earth's atmosphere? "Laika's" heartbeats heard by the world's radio stations furnished the answer to this question. This is the first step toward man's travel in cosmic space.

In this booklet we offer for your attention material published in the Soviet press in connection with the launchings of the satellites, among them articles and other publications by the following authors:

Academician V. Ambartsumyan, President of the Academy of Sciences of the Armenian SSR; Academician A. Blagonravov, Academician -- Secretary of the Technical Sciences Section of the USSR Academy of Sciences; E. Blinov, Corresponding-Member of the USSR Academy of Sciences; S. Vernov, Corresponding-Member of the Academy; K. Gilzin, Candidate of Technical Sciences; Prof. V. Dobronravov, Doctor of Physical and Mathematical Sciences; S. Dolginov, Candidate of Physical and Mathematical Sciences; P. Isakov, Candidate of Biological Sciences; A. Karpenko, Learned Secretary of the National Commission for Interplanetary Communication of the USSR Academy of Sciences; V. Krasovsky, Doctor of Physical and Mathematical Sciences; Y. Krylov, Candidate of Technical Sciences; Prof. V. Komadin, Doctor of Technical Sciences; V. Parin, Member of the Academy of Medical Sciences of the USSR; N. Pushkov, Candidate of Physical and Mathematical Sciences; Prof. A. Predvoditelev, Corresponding Member of the USSR Academy of Sciences; Prof. Y. Pobedonostsev, Doctor of Technical Sciences; Prof. G. Pokrovsky, Doctor of Technical Sciences; Academician A. Topchiev, Chief Learned Secretary of the Presidium of the USSR Academy of Sciences; A. Shternfeld, Winner of the International Prize for the Promotion of Astronautics, and others.

I. HISTORIC EVENT IN THE DESTINY OF MANKIND

Our epoch is rich in great discoveries in the fields of science and technology, and some of them are so great that it is sometimes hard for us to assess them properly at once. Space flights and an artificial Earth satellite have been discussed in detail in the scientific literature of different countries for a long time, and one would think that the importance of this question had long been realised. However, now that the Soviet artificial satellites have been successfully launched and are whirling over various countries the history of the question should be re-examined once more and the success achieved assessed in a new way.

Many achievements of science and technology can be evaluated more correctly and objectively by first ascertaining to what extent they have given man greater power over the forces of nature.

If we approach the event of the successful launching of the Soviet artificial Earth satellites from this viewpoint, we may say the following:

Most biologists today are inclined to the view that organic life, the highest manifestation of which is man, had for more than 1,000 million years after emerging on Earth been bound to Mother Earth, her hydrosphere and atmosphere. And now we are witnessing the fact that machinery developed by man has left the Earth and its atmosphere and is striking root in cosmic space, where nothing emerging on the Earth had ever been before.

Obviously it will not be many years before flights to the Moon and other planets will be made not only by automatic space ships without crews but also by vessels carrying people on board.

In other words, we are now standing on the border line of two great epochs. The epoch in which the life of man was confined to the Earth is coming to a close, and the epoch of man's striking root in cosmic space is beginning. From a terrestrial being man is becoming a cosmic being.

There can be no doubt that this transformation will have little effect on the course of man's normal life on Earth in the next few years or even decades. However, there can be no doubt either that prospects are opening up for future centuries and millennia which we cannot begin to assess simply because there is no appropriate yardstick.

We may say that there are in science and engineering "tactical" and "strategical" achievements. "Tactical" achievements rapidly become part and parcel of life, bringing us much that is useful but not changing the nature of man's social existence. "Strategic" achievements do not affect the life of individuals directly. Their practical effect manifests itself slowly, but then they radically change all relations of human society and its environment.

We can assume that achievements such as the subjugation of fire, the making of metals, and so on, were "strategical" achievements of technology in hoary antiquity. But presumably all these human accomplishments are a trifle compared with the conquest of cosmic space. Only the discovery of nuclear energy -- an achievement of our days --

can in any way be compared with cosmic flights.

The beginning of space flights opened to mankind the prospects of conquering endless space. Nuclear energy and cosmic flights together open up to humanity boundless vistas for further development.

To master nuclear energy and cosmic flights fully, science, engineering and the economy have to be planned and managed in the interests of human society as a whole, and it is therefore far from accidental that it was precisely the Soviet Union which has found an excellent and reliable solution of the problem of building and launching artificial Earth satellites.

Russian science has splendid traditions in the building of rockets. Advanced scientists and inventors have occupied themselves with problems of rockets and jet propulsion since way back. Many valuable works on powder rockets were put out by K.N. Konstantinov, an eminent artillery engineer, who worked in the first half and the middle of the 19th century. In 1881 the famed Russian revolutionary N.I. Kibalchich suggested the idea of vertical flight by using a jet engine to overcome the force of gravity, and towards the end of the 19th century Professor N.V. Meshchersky of Petersburg Polytechnical Institute developed the theory of bodies of variable mass, which is even today the basis for all calculations in the sphere of rocket engineering. However, the most remarkable occurrence in Russian science in this direction is the works of K.E. Tsiolkovsky, works which received universal acclaim for brilliance in their purposefulness, concreteness and classic simplicity.

Tsiolkovsky was the first in the history of science to work out the principles underlying the theory of jet propulsion and the general theory of space flights as early as 1903, and a concrete scheme of multi-stage cosmic rockets in 1929.

Towards the end of the twenties groups of engineers worked on a number of concrete problems in the physics and technology of jet propulsion. Tsiolkovsky was tirelessly carrying his research in the dynamics of rockets which he had begun at the beginning of the century, and by that time he had come to the conclusion that a one-piece rocket powered by chemical fuel would not be able to attain cosmic speed (8-11 kilometres a second), and in his search for the solution to the problem of attaining greater speed he conceived the idea of multi-stage rockets, an idea which proved so fruitful.

Research in jet propulsion was placed in the category of research of special state importance as far back as early five-year plans, and this made it possible early in the thirties, long before similar work was begun in other countries, to conduct stand tests of jet engines in the USSR, and in 1933 to launch a rocket designed and built by engineer M.K. Tikhonravov for meteorological observations.

After the war Soviet scientists began to design long-range guided rockets.

In 1947 regular investigations of the upper layers of the atmosphere were begun with the aid of instruments lifted in rockets, and study was begun of the processes taking place beyond the atmosphere. It was discovered that the Sun radiates X-rays, data was obtained on the chemical composition of the atmosphere over 100 kilometres high, a study was made of the concentration of free charges in the ionosphere, which plays a very important part in short-wave radio communication, observations were conducted of the condition of a living organism in the state of weightlessness, which occurs during the free flight of a rocket, and a number of other valuable investigations have been carried out which have widened the horizons of scientific knowledge and have paved the way for man's flight in space.

The artificial satellites were launched in the USSR under the IGY programme.

Artificial satellites are of importance purely for scientific research. The programme of scientific measurements on the artificial Earth satellites is very broad, encompassing many divisions of physics of the upper atmosphere and study of outer space near the Earth.

These problems include: a study of the state of the ionosphere and its chemical structure; measurement of its pressure and density; magnetic measurements; study of the nature of the Sun's corpuscular radiation, of the primary composition and changes in comsic rays, of the ultra-violet and X-ray regions of the Sun's spectrum, the electrostatic fields of the upper atmosphere and microparticles, and, lastly, a whole series of investigations into the vital activity of the living organism in cosmic flight.

To obtain all essential scientific data from the flight of the satellites their movement has to be systematically observed by means of astronomical (optical) instruments, radio and radar aids.

Observations of satellites can be conducted by scientists in all countries, and this will serve as a basis for the growth and enrichment of all of world science. The Soviet sputniks therefore not only symbolize achievements of the Soviet Union but also the friendship and co-operation of all peoples with the aim of giving man greater power over the forces of nature for the benefit of all mankind.

II. THE SPUTNIKS

The Problem of Launching Them

The difficulty of launching an Earth satellite is due first to the fact that it has to be imparted colossal speed: To indicate what these difficulties are it is enough to mention one figure: a rocket (single-stage) capable of attaining the so-called primary cosmic speed (roughly eight kilometres a second), at which it will become an artificial satellite of the Earth, has to take along 150 to 200 times as much fuel by weight as weigh its body, instruments and source of power required for the functioning of the instruments. So far we have succeeded in building rockets in which the weight of the fuel is 75-80 per cent of the total weight, in other words, only four times as much as the weight of the rocket itself.

But even so, even under these conditions, primary cosmic speed can be attained by applying Tsiolkovsky's idea of a multi-stage rocket, made up of two or three rockets, with their engines working in turn. When the fuel of the first (rear) rocket has been used up this stage falls away and the second starts working. And when the second has used up its fuel it falls away and the third will take the artificial satellite to its orbit.

It took many years of hard work by large teams of engineers and scientists to put into flesh Tsiolkovsky's daring ideas. The greatest difficulties were encountered in working out the carrier rocket which was to place the satellite in its orbit. The rocket had to be light and durable and it had to have powerful yet very light jet engines which could operate under the difficult thermal conditions and would ensure a propelling force of hundreds of tons for a sufficiently long period. Needed too was an exceedingly precise and reliable system of control over the rocket's flight. And, finally, compact and light power sources had to be designed for radio transmitters, and automatic and remote-controlled equipment which could be relied upon to function for a considerable time under conditions of interplanetary flight.

ROCKETS

Present-day extra long-range rockets designed to fly at sub-cosmic speeds high above the Earth's surface, are set going by liquid-fueled jet engines. In the main part of such an engine -- the combustion chamber --

special fuel is burned continuously and the gases produced are ejected, developing the force of recoil, or what is called the engine's thrust. Since a rocket over most of its path has to fly in extremely rarefied layers of the atmosphere, where the amount of oxygen required for the burning of any substance is negligible, the oxygen has to be carried on the rocket along with the fuel.

In order that the rocket carrying the artificial satellite may attain the required speed, the engine has to develop a great propulsion force. The rocket should weigh as little as possible. Several engines have to be installed in such rockets, for to attain a propelling force of even several score tons from one engine is a problem which has not yet been solved.

Even on the best present-day rockets the structure weighs about 20 per cent of the combined weight of the rocket, and fuel. That is why the first thing that has to be done is to manage to attain the speed of cosmic flight with less fuel.

K. Tsiolkovsky showed that to accomplish this it will be necessary as far as possible to increase the speed at which the gases produced by the combustion of the fuel flow out of the engine, and then each kilogram of fuel will produce a more powerful "recoil," and then less fuel will be required to obtain the needed propulsion force for acceleration.

How is that to be done?

The answer to this question has long ago been furnished by thermodynamics and heat engineering: what should be done is to take the most calorific fuel and burn it in the combustion chamber under high pressure.

In an engine working efficiently on such fuel, pressures of 50 atmospheres or more should be developed at a temperature of some 3,000°. Although such an engine functions very briefly (a few minutes), no material available to engineering could stand the strain of work under these conditions. And such a problem has never come up before, as the most powerful thermal engines of other types developed only between 100th and 1,000th part of the power developed by liquid-fueled jet engines.

To build a reliably working engine it is necessary first to solve the problem of cooling and of making its walls strong enough. And that is not so simple. However, even with good cooling it is very difficult to obtain a wall temperature of less than 500-800°. Which means that the material of which the chamber is made has to be exceptionally heat-proof. The problem of cooling is a basic one but not the only one.

To make sure that the engine works reliably highly complex calculations have to be made of the processes taking place in it. We have to know what laws operate in the mixing and burning of the fuel, how to ensure that it is uniformly fed to the engine, how to produce safely the initial ignition of the fuel and, finally, what loads the engine parts are subjected to while it is in operation.

Special attention has to be given to ensure uniform feeding and combustion of the fuel, as otherwise strong vibrations will develop, leading to the destruction of the engine and the rocket. This problem is no less difficult than the problem of cooling.

Solution of all these problems would be impossible without the joint effort of scientists working in the field of gas dynamics, the theory of combustion, hydraulics and the theory of control. Only by starting out from the accomplishments in these spheres of science have Soviet engineers been able to design a powerful and reliably working engine for the carrier rocket.

Without the work done in ballistics, aerodynamics, gas dynamics and the theory of strength it would have been impossible to build the carrier rocket.

To ensure that the satellite gets exactly to the orbit, the whole path of the rocket had to be calculated in advance. Experts in ballistics and aerodynamics, especially the latter, had to labour much. The physical structure of the upper atmosphere differs sharply from the regular atmosphere: because of the considerable rarefaction the gas molecules travel at tremendous speed. At an altitude of 300 kilometres the rocket traveling at a speed of seven kilometres a second comes up against a pressure of five milligrams per square centimetre and as they bombard the flying body the molecules impart their energy to it.

To make sure that the rocket or satellite do not burn during the launching or flight highly complex computations had to be made to determine the force of resistance of the surrounding medium.

It is necessary to have an efficient and exact system of automatic control to look after the fuel feeding and the flight characteristics, to detach the used-up stages of the rockets, and to keep the rocket in the set trajectory. The following figures give an idea of what is demanded of the control system of a rocket: when it reaches its top speed of 28,000 kilometres an hour (which is 20 times as much as the velocity of sound), an error of 10-20 metres a second in the speed or 0.5° in the direction of the rocket's motion can prove fatal for the satellite.

A rocket is made up of tens of thousands of parts, each performing a certain task. And if any of them should not work perfectly the rocket may not fly and may not carry out the programme set for it.

Extreme care in making and assembling it was necessary to ensure success.

In the few seconds that it takes the rocket to rise a monstrous power is developed as the fuel burns, reaching several million kw. The colossal speed of the outflow of gases from the engine, which is several times faster than the speed of a bullet, the tremendous temperatures require special fuels and special constructions to make it possible to use such fuels.

It is not without interest to note that the energy of the useful mass of Sputnik-2 , its kinetic force at a speed of 8,000 metres a second is equal to the energy of a goods train weighing 320,000 tons traveling at a speed of 36 kilometres an hour. No such train could travel on railway tracks, for it would have to be made up of thousands of waggons, making the train several score kilometres long.

Of course, it is impossible to attain a speed of some 8,000 metres a second on land. Such speed is possible only in outer space where there is no resistance "at all."

The construction of the rocket for launching the first artificial Earth satellites in the history of mankind shows that Soviet science has reached a high degree of development in every sphere and is capable of solving the most complex overall problems.

The Take-off

How is an artificial satellite of the Earth launched? It is done by means of a multi-stage ballistic rocket, and the flight of such a rocket can be pictured as follows.

... Towering over concrete grounds is the launching outfit, and through the open-work structure of steel trusses can be seen the streamlined rocket set up vertically. Immediately before the launching the steel framework of the outfit is taken away on a special track, the rocket standing by itself for a few minutes before the take-off as though taking leave of the Earth.

The people leave the take-off grounds, taking shelter behind thick reinforced-concrete walls. The launching is made automatically, the instruments installed in the rocket receiveing the order from the command point by radio.

A thunderlike roar deafens the people, even though they are in the shelter, and a dazzling torchlike flame bursts from the rocket nozzle, scorching the concrete. The rocket quivers as though hesitating for an instant and then slowly rising from the ground mounts faster and faster towards the sky. It takes off vertically to an altitude of about two kilometres, then, guided by a programmed control device, it begins to slope in a vertical plane. The first-stage rocket engine stops a minute or two after the start; by that time the rocket had attained a speed of something like 7,000-7,500 kilometres an hour and reached an angle of about 45° to the Earth's surface. After the first stage has fallen away the second-stage engine starts, bringing up the speed to 18,000-20,000 kilometres an hour. From then on the rocket travels by inertia tracing in space a gigantic ellipse designed so that its summit touches the set orbit, hundreds of kilometres high and so that the path is parallel to the Earth's surface. By that time the rocket was more than 1,000 kilometres away from where it started.

Then comes the decisive moment. The rocket is at the set altitude but the speed is not enough to make it a satellite. If the rocket does not get a further impetus, in a second it will start falling back on its course to the Earth, along the second half of the ellipse.

But this will not happen, for the last-stage engine begins to work. Another effort and the rocket picks up the needed circular speed of something like 8,000 metres a second. And then the rocket's engines grow silent forever. A satellite has been born. ...

Design

Sputnik 1 is spherical in shape. It is 58 centimetres in diameter and weighs 83.6 kilogrammes. Its hermetically sealed body is made of aluminium alloys and its surface is polished and specially treated. All its apparatus and power sources are located inside the body. Before being launched it was filled with a gaseous nitrogen.

On the outside surface aerials were put up; four rods 2.4 to 2.9 metres long. While the sputnik was taken out to its orbit the aerials were folded back to the body of the rocket, and after the two stages had fallen away the aerials turned on their hinges, assuming the position shown on the photo.

While moving in its orbit the satellite is subjected from time to time to sharply changing heat influences -- heating by the Sun's rays while on the lit side of the Earth and cooling when flying in the Earth's shadow, the influence of the atmosphere's heat and so on. Besides, a certain amount of heat is generated when the apparatus on the satellite is working. As far as heat is concerned the satellite is an independent heavenly body, exchanging radiant heat with the surrounding space. To ensure for a considerable period the normal temperature needed for the functioning of apparatus on the satellite is therefore a fundamentally new and rather difficult problem, The needed temperature on the Sputnik-I was ensured by incorporating in its surface the proper ratio of absorption to the Sun's radiation and by regulating the heat resistance between the envelope and the equipment through the forced circulation of the nitrogen in the satellite.

Two radio transmitters were installed in the satellite constantly emitting signals on frequencies of 20,005 and 40,002 megacycles (15 and 7.5 metre wave-lengths respectively).

Sputnik-2, unlike Sputnik-1, is the last stage of the rocket on which all of the scientific and measuring instruments are installed. This arrangement has materially simplified the problem of determining the satellite's coordinates with the aid of optical instruments; our experience with Sputnik-1 showed that observations of the carrier rocket were simpler than of the satellite itself. The carrier rocket was brighter than the Sputnik-1 by several stellar magnitudes. The combined weight of the apparatus, of the animal taken up and source of electricity on Soutnik-2 amounted to 508 kilogrammes and 300 grammes.

Installed on a special frame in the forward part of the last stage of the rocket are an instrument for measuring solar radiations in the ultra-violet and X-ray regions of the spectrum, a spherical container with the radio transmitters and other apparatus, and the hermetically-sealed chamber in which the dog was kept. The instruments for studying the cosmic rays were mounted outside the body of the rocket. A special cone protects the instruments in the frame and containers from aerodynamic and thermal influences during the rocket's flight in the dense layers of the atmosphere. After the last-stage rocket had been taken out to the orbit the cone was discarded.

The radio transmitters and their sources of electricity, the system of heat regulation and the sensitive elements registering the changes in the temperature and other parametres were put up in the spherical container which resembles Sputnik 1 in design.

The signals from the transmitter on 20,005 megacycles (15 metre wave-length) sounded like telegraphic clicks. They lasted on the average about 0.3 seconds, just as did the pauses between them, changing within certain limits when there were changes in the parameters in the spherical container (temperature and pressure).

The transmitter on 40,002 megacycles (7.5 metre wave-length) continuously gave out signals. These frequencies permitted the investigations of the propagation of radio waves coming from the satellite and measurement of the parameters of its orbit, and audibility of the signals was ensured regardless of the state of the ionosphere.

It should be mentioned that because of their relatively large weight it was found possible to set up powerful radio transmitters on both sputniks. This and the selection of the wavelength have ensured getting signals from the sputniks over great distances, enabling a great many radio amateurs in all parts of the world to cooperate in the observations. The latter's observations structural elements. The radiotelemetric apparatus ensured transmission to the Earth, of the readings of all measuring instruments on the sputnik. It was timed to transmit the readings at regular intervals.

The programme of investigations connected with the measurements on Sputnik 2 was calculated to work for seven days after which the radio transmitters and the radiotelemetric apparatus on board ceased functioning. Further observations of the movement of Sputnik 2 for studying the characteristics of the upper atmosphere and predicting the sputnik's movement are being carried on by optical instruments and radar.

III. THE SPUTNIKS' ORBITS

Missiles have been shot over a long distances before, but no matter how fast they traveled they always remained within the confines of our planet. Now that the sputniks have been given a speed roughly 10 times as great as the initial speed of shells leaving long-range guns, their flight distance increased by leap almost to infinity: man-made structures began to revolve around our planet just like celestial bodies, and if there were no resistance, which though it does not amount to much in the rarified air is nevertheless appreciable their movement would never stop.

The artificial satellites do not move westward, as do all heavenly bodies. Observers, depending on where they are, see them flying northeastward or southwestward, and observers near the 65th parallel in the northern or southern hemisphere see them on rare occasions flying in an eastern direction. It may seem therefore that the curve along which the sputniks move is very intricate. They move in orbits that are ellipses, in first approximation, with one of the foci lying in the Earth's centre.

Sputnik 1

Since the Earth rotates on its axis, the sputnik should appear over a different area, at each succeeding turn, shifting approximately 24° in longitude each time. Actually, the longitudinal shift will be a little greater (roughly a quarter degree greater each revolution). As a result of the motion of the Earth relative to the orbit plane each succeeding turn will pass approximately 1,500 km. west of the preceding one at Moscow's latitude, while at the equator the shift is roughly 2,500 kilometres.

The plane of the sputnik's orbit is inclined at an angle of 65° to the plane of the Earth's equator, as a result of which the sputnik's path crosses the land areas lying approximately between the Arctic and Antarctic Circles. Because of the Earth's rotation about its axis the angle of slope of the path to the equator differs from the angle of slope of the plane of the orbit. On entering the northern hemisphere the path crosses the equator at an angle of 71.5 degrees in a northeasterly direction.

Then the path gradually turns more and more to the east and touching the parallel meeting 65° N.L. it deviates to the south, crossing the equator at an angle of 59° to the southeast. In the southern hemisphere the path touches the parallel meeting 65° S.L., after which it is deflected to the north and again enters the northern hemisphere. (See picture).

Owing to the large angle of slope to the plane of the Earth's equator the sputnik flies over almost all continents and expanses of water, except some small regions beyond the Arctic and Antarctic Circles. This has opened up considerable possibilities for solving various scientific problems. It can be stated that launching the sputnik on this orbit is a more difficult task than launching it on an orbit near to the plane of the equator. If launched along the equator the speed of the Earth's rotation about its axis could be utilised to a larger extent to accelerate the speed of the rocket.

How to Find the Orbit

Sputnik 1 made approximately 15 revolutions around the Earth in 24 hours in the initial stage of flight.

Readers can easily see what areas the sputnik will fly over and when by doing the following.

Put a ring around a globe at an angle of 65° to the equator and fasten it to the leg of the globe. At a certain moment, let us say, when Sputnik flies over Moscow turn the globe so that Moscow comes in the plane of the ring, which represents the orbit of the sputnik. Now by simple calculation you can figure out where the sputnik is at any particular time. For instance, let us locate Sputnik after it has passed over Moscow. In one minute Sputnik flies over 360° divided by 96.2 (the period of its revolution around the Earth in the given time; we arbitrarily took the initial period) or 3.74 degrees and in 12 minutes, roughly 45°. Mark the ring accordingly. During the same time the Earth has turned around its axis three degrees to the east, and the mark on the ring will show the spot sought.

In the same way we can solve the problem in reverse, namely: the time when Sputnik passes over a particular locality. We can also figure out whether Sputnik will fly over a particular territory at all.

If we make with the help of this device the consecutive projections of Sputnik on the globe along its orbit we shall find that the 16th turn of such projection coincides almost exactly with the first, the 17th with the second, and so on.

We may say that Sputnik 1 appears at regular intervals (with slight variations), since every 24 hours it appears over approximately the same area over which it had already flown.

Using our device (the ring and globe) we can easily understand a number of other features of the movement of the artificial satellite.

It may be thus: an observer notes, for instance, that Sputnik travels in a southeasterly direction. Then some time later it again appears over the same area but this time flying northeast, Does this mean that Sputnik is flying in
1 a different direction? Of course, not. Sputnik keeps revolving all the time in a so-called straight direction, and the apparent change in direction of its movement is due to

the fact that in the interval between two regular observations the observation spot on the Earth's surface has made along with our planet half a revolution (or one and a half, two and a half revolutions, and so on) about its axis.

As Sputnik makes a complete revolution the observation point on the Earth's surface shifts, as a result of the Earth's daily motion, 1,130 to 2,670 kilometres, depending on whether the observation point is on the 65th parallel or on the equator. However, if Sputnik were up at an altitude of even 200 kilometres the diameter of the area from which it could be seen would be more than 3,000 kilometres. This means that approximately an hour and a half after the artificial satellite passes over the given locality it would again come into the field of vision of the particular observer. But that does not mean that it really would be noticed, for this would require special conditions, namely, that our "little star" should be flooded with sunshine, and the surface of the Earth where the observations are conducted should be dark. Twilight is therefore the best time for observations.

From what has been said before, it is clear that the artificial satellite will never rise in the east or set in the west as we are accustomed to see the Sun do. Why is that so? Theoretically it is possible to launch a satellite to revolve so to speak in the general stream of heavenly bodies. Practically however, this is not done for the following reasons. Rotating as it is on its axis the Earth can help in the launching of an artificial satellite if the latter is launched in the same direction, or hinder imparting to it the needed speed if it is launched in the opposite direction. (The Earth, as we know, moves from west to east).

However, to turn to account the speed of the Earth's rotation is not always expedient. In fact if the satellite is launched in the direction of the Earth's motion it will fly only over a belt confined on the north and south by the parallel of the starting point relative to either sphere. For Sputnik-1 a compromise decision was adopted under which the Earth's daily rotation is utilised to an insignificant degree. This is apparently because of the tasks connected with the International Geophysical Year, namely, that Sputnik should fly over as much terrestrial space as possible.

The Evolution of Sputnik-1's Orbit

In our reasoning before/we assumed that Sputnik moved along its orbit at a uniform speed. However, even where there is no air resistance this movement would be possible only if the orbit were a perfect circle with its centre coinciding with the Earth's centre. Actually, however, Sputnik describes an ellipse, and for this reason, when it passes through its perigee (the point on the orbit nearest to the Earth's centre) its speed is appreciably greater than when it passes through its apogee (the point on the orbit farthest from the Earth's centre). As to the ellipse along which Sputnik moves it may be pointed out that it is very slightly flattened: the difference in length between its major and minor axes is less than a quarter of one per cent. As can be seen, this is practically a circle, but the centre of this "circle" is a little off from the Earth's centre.

The period it takes Sputnik to circle the Earth gradually changes because of the braking force it encounters, and as the orbit contracts the period too will grow shorter. The rapidity with which the period changes will serve to show how fast the shape of the orbit changes. Since on great heights where Sputnik moves the density of the atmosphere is very small the evolution of the orbit will at first be very slow. The height of the apogee will decline faster than that of the perigee and the orbit will more and more approximate a circle, and when Sputnik enters the denser layers of the atmosphere the braking force will be quite substantial. Sputnik will then grow burning hot and burn up like meteors from interplanetary space when they enter the Earth's atmosphere.

Other conditions being equal, the greater the mass of a satellite the longer it will survive, since the greater the mass the less speed it will lose on crossing through upper layers of the atmosphere.

Why Must the Rocket and Sputnik Burn up?

After the take-off the rocket used for launching a satellite rises straight up, which enables it to cross the lower and dense layers of the atmosphere the shortest way. The rocket's speed rises gradually. Passing through the dense layers of the air there is not enough time for it to become greatly overheated; it will therefore not burn and manage to get out to a greater altitude where the air is very much rarefied.

On returning to Earth the movement of the satellite and carrier rocket will present a different picture. Gradually descending the rocket and satellite will enter the dense layers of the atmosphere at a tremendous speed and at a relatively small angle to the horizon. Moving towards the Earth in a spiral they will have to travel longer in these layers, and as the friction of the air will be very great both bodies will rapidly grow very hot and "burn up."

Apparently the carrier rocket will burn up first as it will land in the lower strata of the atmosphere somewhat earlier.

Are There Impermissible Orbits for Satellites?

First of all, the orbit of a satellite must absolutely lie in one of the planes passing through the centre of the Earth. A satellite can be designed to revolve in the plane of any meridian or in the plane of the equator, but its orbit will never stay in the plane of a parallel. A satellite launched on such an orbit will certainly shift to the plane of the equator or fall back on Earth.

A satellite's path has to lie at a great height, beyond the dense atmosphere, otherwise the resistance of the air will act as a brake and the circular flight will turn into a spiral, ending in the satellite falling to earth. Fortunately, it is not necessary to lift it too high. In the neighbourhood of 200 kilometres above the Earth the resistance of the air is virtually impalpable.

In selecting orbits for future satellites specific features of some of them must be taken into account. For instance, a characteristic feature of an orbit at an altitude of 557 kilometres is that the satellite's period of revolution along it will equal exactly an hour and a half, and it is therefore sometimes called an "hour-and-half" orbit. Traveling in it the satellite will circle the Earth 18 times in 24 hours. Moving in a "two-hour" orbit, which lies at an altitude of 1,669 kilometres, it will circle 12 times. Obviously there is also a "24-hour" orbit, for which the period of revolution will be exactly 24 hours. This orbit should be at an altitude of approximately 36.000 kilometres. Especially interesting is a 24-hour orbit in the plane of the equator. Indeed, in such a case the satellite, which actually travels at breakneck speed, will hover motionless over some point of the equator as though on top of an invisible tower tens of thousands of kilometres high. There are also a number of other no less interesting orbits.

Sputnik-2's Orbit

Sputnik-2 was taken out to its orbit by means of a sectional rocket. While being taken out to the orbit the rocket rose to an altitude of several hundred kilometres above the Earth's surface and on reaching the end of take-out sector the last stage moved parallel to the Earth's surface at a speed of more than 8,000 metres a second, becoming an Earth satellite. By the time it reached the orbit the fuel in the rocket's tanks had been used up and the engine stopped. Thereafter Sputnik moved by kinetic energy gained by the rocket while it was sped up into the orbit.

The speed imparted to the rocket's last stage was higher than the speed needed for Sputnik's movement in the circular orbit at a constant altitude at which it entered its orbit. Sputnik does not therefore move in a circular orbit but in an elliptical, its farthest point from the Earth being roughly 1,700 kilometres, or almost double the highest altitude attained in launching Sputnik-1. Since the semi-major axis of Sputnik-2's orbit is larger than that of Sputnik-1, the period of its rotation around the Earth also proved greater, initially amounting to 103.7 minutes.

Owing to the greater period of rotation Sputnik-2 makes some 14 complete turns around the Earth in 24 hours, while Sputnik-1 in the initial period made about 15 turns. Because of the Earth's rotation the shift of Sputnik-2 with each successive turn is 1.15 times greater relative to Sputnik-1, and the distance on the Earth's surface between the paths of two nearest turns has grown to the same extent.

The resistance of the Earth's atmosphere acts as a brake on Sputnik, its orbit changing its size and shape. Owing to the fact that at great heights the atmosphere is very thin the braking force acting on Sputnik does not amount to much. At the point of apogee the Sputnik moves at such a great height that it is in outer space beyond the Earth's atmosphere, which according to theoretical calculations extends to an altitude in the neighbourhood of 1,000 kilometres above the Earth's surface.

The braking force operating against a satellite depends not only on the density of the atmosphere but also on the shape of the satellite and on the ratio of its wight to cross-section area. The greater this ratio the smaller the loss in speed.

Two satellites taken out to the same orbit but moving against different braking forces will after a certain period move along different orbits, since their orbits will vary with time at a different rate. And while the orbits are contracting it is mainly by decrease of the apogee height.

Sputnik-1 and its carrier rocket at first moved approximately in the same orbit and their periods of revolution differed slightly, being about 96.2 minutes for either. Later, owing to the fact that Sputnik-1 experienced less resistance than the carrier rocket their orbits began to differ materially.

The braking force operating against both the carrier rocket and the Sputnik has changed in time as a result of the change in the orbit's parameters. As the orbit lowered the braking force increased progressively. This is distinctly confirmed by the findings of the observations.

How long a satellite will survive depends on the braking force of the atmosphere. Obviously the greater period of revolution and the less braking force the longer it will survive. Estimates based on data obtained from the observations of Sputnik-1 and the carrier rocket suggest that ~~Sputnik will survive something like three months from the~~

~~[illegible]~~ Sputnik-1, will move in orbit apparently until January 1958. ~~[illegible]~~ The carrier rocket will not last as long, and it can be expected to burn up before Sputnik. The greater period of revolution of Sputnik-2 and the smaller braking force it experiences warrant the statement that Sputnik-2 will move in orbit appreciably longer than Sputnik-1.

When the trajectory measurements have been worked up it will be possible to establish fully the whole process of evolution of the parameters of satellites' orbits and to obtain important information on the distribution of the density of the upper atmosphere. Later on it will be possible realiably to predict how long artificial Earth satellites will survive.

IV. <u>WHAT MAKES SATELLITES MOVE</u>?

Modern celestial mechanics is based on the law of gravitation. The artificial satellites move around the Earth like <u>heavenly bodies</u>. The movement of the little "Moon" is subject to the same laws of celestial mechanics as that of the real Moon around the Earth or the movement of the Earth and other planets of the solar system around the Sun.

Satellites move around the Earth at great speed. If there had been no terrestrial attraction the satellites would be moving in a vacuum uniformly and in a straight line, and would disappear in outer space. The Earth's attraction distorts their path, making them circle the Earth and move around the Earth along its surface.

The force of attraction acting on the satellites is of a definite magnitude, and that is why they can make their circular movement around the Earth only at a certain and quite definite speed.

The Needed Speed

The approximate value of this so-called circular speed can be determined on the basis of the following reasoning. In order that a satellite moving around the Earth should continue at constant altitude it must every instant get as far away from the Earth as it gets nearer to it in its continuous dropping. In the first second a body falling freely to the Earth loses approximately 5 metres of altitude. Obviously in this second the satellite has to get away from the Earth the same five metres so that there is no change in the altitude at which it is moving. This makes it possible to build a right-angle triangle and making use of the Pythagorean theorem; to figure out the speed we want. For a satellite moving not very far away from the Earth's surface the speed is equal to roughly eight kilometres a second.

The question may arise why the speed is the same for bodies of any weight when the force of attraction acting on a heavier body is greater. At first sight it would seem that such a body should move around the Earth in a circular orbit at greater speed because of the action of force of attraction. However, if we bear in mind that it is harder to deflect a heavier body from movement in a straight line, and exactly as as many times more as it weighs more, it will become clear that the speed of a satellite's movement should not depend on its weight. The speed of movement of Sputnik-1 in its orbit therefore will be approximately the same also for other and heavier satellites.

It should be mentioned that to launch heavier satellites it is necessary to hurdle a number of other obstacles. That is why their launching will be a new and important stage in the development of science and engineering.

Altitude and Speed

The required speed of a satellite changes with altitude. The force of the Earth's attraction diminishes as the distance from the Earth increases, and therefore in a higher orbit a satellite must move at a lower speed. For satellites moving in different orbits lying about 1,000 kilometres above the Earth's surface the difference in the speed of motion is comparatively small. However, for satellites moving at considerably greater distances from the Earth the speed appears to be substantially less. For instance, the Moon, which is also a satellite of the Earth and is approximately 380,000 kilometres distant from it, moves around the Earth at a velocity of about one kilometre a second, that is, a speed roughly one-eighth that of a satellite flying close to the Earth. Bearing in mind that the Moon's path around the Earth is much longer than the path of an artificial satellite per revolution, it will become clear why the Moon revolves around the Earth not in an eighth of the time the Sputnik does but much more slowly.

In order to launch an artificial Earth satellite it has to be lifted to a great height and accelerated to the speed required for its movement in the orbit at that height.

No energy is expended as the satellite moves in its orbit. The satellite has no engine, moving solely at the expense of the speed imparted to it by the carrier rocket.

Because in a higher circular orbit the satellite moves at lower speed, it follows that when the satellite is taken out to such an orbit it has to be accelerated to a lower speed. This however does not mean that it is easier to launch a satellite on a higher circular orbit than on a lower one. The thing is that in launching a satellite the difficulties in lifting it to great altitudes are very great and the higher the altitude the greater the difficulties.

We pointed out before that at every height the movement of a satellite in a circular orbit has to proceed at a definite speed. If the speed is less than the one required, the Earth's attraction will deflect it more easily from a straight line; the path will be distorted in the direction of the Earth and the satellite will begin to drop. If the speed is only slightly less than required, the drop will be relatively small, and the satellite, after drawing closer to the Earth and gaining a certain speed thereby, will be able once again to rise to the earlier height, repeating the drop and rise periodically on each revolution.

If the difference in the speed of movement from the circular is somewhat greater, the drop may prove precipitate. The satellite will enter the dense layers of the atmosphere, and after losing its energy as a result of friction in the air it will not be able to climb again, and dropping lower and lower will grow terrifically hot and burn up in the atmosphere.

If the speed of the satellite at the point at which it enters the orbit is considerably greater than the circular speed required for its motion in the circular orbit at a constant height it will be harder for the force of gravity to deflect its course closer to the Earth's surface and the satellite will then be able to rise to a very great height, much higher than to which it was originally lifted by the rocket. Should the speed reach something like 11.2 kilometres a second or more the satellite will disappear in interplanetary space.

Thus, in order that the satellite may move in an orbit at the predetermined altitude its speed has to be quite definite. It is impossible to design another satellite to move in the same orbit at a different speed.

A speed of eight kilometres a second is called primary cosmic speed. It is the speed a satellite must attain to move in an orbit close to the Earth. A speed of 11.2 kilometres a second is called secondary cosmic speed, and an interprlanetary vessel launched near the Earth must have it to overcome the Earth's attraction and to begin to move in interplanetary space as a new planet of the solar system. Speeds between the primary and secondary cosmic speeds will make it possible to launch a satellite moving in elliptical orbits whose perigee will be near the Earth and apogee considerably distant from it. The orbits will be the more extended and farther away from the Earth the greater is the initial speed imparted to the satellite by the carrier rocket.

If a satellite's orbit can be made to pass at all points at altitudes in the neighbourhood of 1,000 kilometres or more above the Earth's surface, the satellite will move virtually in a vacuum and continue so for an indefinitely long time. With present progress in the building of rockets it is quite realistic to speak of launching a satellite to survive scores of hundreds of years, and such a satellite will be practically a perpetual satellite of the Earth.

V. OBSERVATIONS OF THE SPUTNIK'S MOTION

A very important element of the research conducted with the aid of satellites is the observation and recording of their motion, treatment of the records and forecast of their further motion on this basis.

During the first period of the sputniks' motion the scientific stations conducted observations with the aid of radar and radio direction finders and by means of optical instruments and photographing their motion. Since the radio transmitters have stopped working the observations have been conducted mainly by the latter two methods.

All data obtained by the stations and the observations of amateurs are collected and analysed and electronic computing machines are used to work up the data. How valuable will be the geophysical observations by the scientists will depend on how correct and precise are the data obtained in observing the Sputniks as they move in their path. For example, to determine the Earth's exact shape for geodetic purposes the orbit of the satellites' motion has to be determined accurately within a few seconds in the arc and a few milliseconds in time.

Many of the ground stations measuring the position of the Sputnik in its path transmit the results of their observations to a central station, where the orbit is determined, and the more observations are made the more accurate will be the determination of the orbit. Radio amateurs have been very helpful in the collection of radio observations; in particular, thousands of Soviet radio amateurs have conducted observations of the sputniks using ordinary radio instruments as well as radio receivers designed specially for the purpose. Diagrams of the receivers and of the direction finders with which they are equipped were published in "Radio", a Soviet popular-science magazine in the field of radio engineering, long before Sputnik-1 was launched.

Used too for observing the Sputnik are ground radar stations, which irradiate the Sputnik and receive signals reflected from it, the same as radar stations designed to detect planes in the air at high altitudes, or which make it possible to receive signals reflected from the Moon. However, as the Sputniks and their reflecting area are relatively small, these special stations must have a very large pulse radiation capacity.

Optical observation of the Sputniks is possible mornings and evenings on cloudless days, when the Earth's surface where the observer works from is all in darkness and the sputnik, very high up, is lit by the Sun.

Since the transmitters on the Sputniks have ceased working, optical observations have been widely used. Besides, optical observations in conjunction with radio methods have made it possible the better to ascertain the actual path of the Sputniks, and to make geographical calculations much more exact.

Wide-angle optical instruments are best for these observations. But the satellites can be seen also through an ordinary binocular or a wide-angle prism spyglass.

It should be mentioned that observations of the Sputniks with the aid of astronomical instruments present a certain difficulty; they are not similar to observations of regular heavenly bodies, as the Sputniks move very fast across the sky, at an average speed of approximately one degree per second.

To make sure that the observations are reliable, each optical station has one or two sets of optical instruments placed as a barrier on the meridian and along the vertical circle perpendicular to the apparent orbit of the Sputnik. In addition, the method employed in searching for the Sputnik is based on the so-called "local-time rule". This method turns to account the fact that the Sputnik's orbit is not involved in the rotation of the Earth, and the Sputnik itself passes through a given latitude in local sidereal time, which changes slowly as the orbit revolves in absolute space around the Earth's axis, owing to the divergence of the gravitational field from central. Therefore, with respect to a given station the satellite will in the course of its motion pass successively through the points in the celestial sphere which may be called waiting points. If the axis of the optical instrument is regulated so as to be directed to the waiting point next in order in the celestial sphere as figured out in advance, then sooner or later the satellite will inevitably be detected, and when detected the time of its passage should be noted with the aid of a chronometer or by radio time signals. In this way the accuracy in determining the time the satellite passes through their range of vision will not be above a second. Among other things, the Soviet amateur astronomers at 66 optical observation stations and all observatories have at their disposal many special improved wide-angle optical instruments. The observation stations also have sets of equipment making it possible to fix the Sputniks in the celestial sphere as accurately as within one degree in position, and one second in time.

Optical observations of the satellite and following it up will be more precise and thorough if the optical instruments are fitted out with special photographic and photoelectric apparatus registering the position of the satellite and the azimuth and quadrant angle of the instrument's optical axis. The purpose of the optical follow-up is to obtain a relatively exact position of the satellite in the celestial sphere (during twilight hours). All along the time of each recorded position of the satellite in the orbit should be determined precisely.

The satellite can be followed up by instruments with a focal distance of 0.6 - 1.0 metres. In such an instrument, as the satellite passes through its range of vision, the rate of movement of its image is 1-2 centimetres a second. A particularly important part will be played by the optical observations of the satellites at the last moment of the final stage of their passage, when they make the last spiral movements before entering the atmosphere's denser strata and when they begin to burn up.

~~At the present time the optical observations have shown [illegible] carrier rocket varies in brightness [illegible] space. The [illegible] recorded period of brightness variation [illegible] seconds.~~

Along with visual observations, photographic observations of the carrier rocket and Sputnik-2 are conducted. The photographs taken by observatories in the Soviet Union and other countries have made it possible to define the orbits of the Sputniks and of the carrier rocket with considerably higher precision.

In using the special cameras for photographing satellites highly sensitive plates are required. The shutters should permit very small exposures and the lens should have an aperture ratio of 1 and the sight at least

30 degrees. Exact pictures of the position of the Sputniks in the orbit will make it possible to determine their geodetic position in space in relation to the Earth's centre with an error of about 10-15 metres. When we have a number of these positions for 10 to 15 regions of the Earth's surface it will be possible to determine the Earth's figure more accurately than has been done up to now. As a result we shall be able to refine the continental geodetical system. These observations will also enable scientists to understand better the distribution of masses in the interior of the Earth.

In fact the Sputniks move in the gravitational field of the Earth and this field in turn is determined by the distribution of the masses in the Earth's interior and its crust. Studying the movement of the Sputniks we can highly refine our knowledge of the gravitational field of the Earth and thereby arrive at interesting conclusions on the Earth's structure. True, revolving around the Earth is also the real Moon, but a study of its motion gives us information only about those parts of the terrestrial gravitational field which are relatively far from the Earth, as the distance from the Earth to the Moon is some 380,000 kilometres. Of course at such a distance the terrestrial gravitational field depends much less on the distribution of the masses in the interior of the Earth. The study of the Moon's motion can therefore furnish only very meager information on this question. Artificial satellites, however, launched something like 1,000 kilometres above the

Earth's surface, offer many more opportunities in this respect.

Thus, not to mention the telemetric measurements of different quantities in following the artificial Earth satellites in their orbit, simple observations with the aid of radar, optical instruments and photography will furnish scientists abundant geophisical data widening and refining our knowledge of our planet.

VI. RESEARCH WITH THE AID OF THE SPUTNIKS

The Upper Atmosphere

In studying the heavenly bodies around us and the outer space in which the Earth moves, scientists have encountered considerable difficulties due to the fact that the observatories and scientific stations are situated at the bottom of the air ocean surrounding the Earth, hundreds of kilometres deep. This ocean is the Earth's atmosphere, which lets through to us only some narrow regions of the spectrum of electromagnetic oscillations emitted by the Sun, stars and other heavenly bodies. Scientists have therefore always dreamed of extra-atmospheric observatories, as are artificial satellites, which open up new possibilities for carrying out all kinds of scientific experiments that earlier seemed unrealisable.

What is meant by the upper atmosphere today is the region above 30 or 40 kilometres high. It is of great practical interest, as it is the medium through which artificial satellites will travel and the routes of future interplanetary ships will pass. Besides, the upper atmosphere is the medium in which radio waves are propagated. The strata and regions with high ionisation forming in it reflect or scatter the waves, thereby creating the requisite conditions for their propagation over great distances. At the same time, under certain conditions, the upper atmosphere sometimes becomes a medium in which radio-waves are absorbed.

The processes going on in the upper region of the atmosphere are characterised by a great many features which are not usually intrinsic in its lower parts. Among them are the features related to the continuous chemical conversions of the atmosphere's molecules and atoms and their ionisation which occurs when they are irradiated by the penetrating ultra-violet, X-ray and corpuscular emission of the Sun (corpuscular radiations of the Sun are the fast-moving elementary particles: electrons, protons, neutrons, alpha-particles, etc.). Besides, in the higher parts of the upper atmosphere the change of its relative atomic composition becomes significant. Here the lighter molecules and atoms predominate owing to the force of gravity. The circulation of the ionised atmosphere, which is an electrical conductor, in the Earth's constant magnetic field is accompanied by the generation of electric currents which cause different kinds of variation in this field.

Valuable information on the circulation of the upper atmosphere has been obtained by the observation of the drift of meteoric trails by means of optical instruments and radar, and the observation of the tides in the atmosphere caused by the Sun and Moon. We know of the high and low tides of the seas, yet these phenomena have been observed to be much more intensive in the upper atmosphere. From the observations approximate characteristics of the upper atmosphere have been derived; the temperature in the upper part was estimated to be several thousand degrees and the density about 1,000 million molecules and atoms per cubic centimetre (at an altitude, of some 300 kilometres). It should be mentioned that the air density at the Earth's surface is more than 10,000 million times as much.

It had been believed that in the upper atmosphere there were three or four distinct ionised strata. However, the information gained about the penetrating ultraviolet and X-ray radiation of the Sun which is absorbed by atmosphere and does not reach the Earth's surface, was until recently rather hypothetical. The dynamics of the upper atmosphere related to the photo-chemical changes and ionisation remained unclear. Too little is known also about corpuscular emission,which causes auroral displays and anomalous ionisation.Without exact knowledge of these disturbing factors it is difficult to build up a general theory of the dynamics of the processes going on in the upper atmosphere.

Of late there has been considerable development of the study of emissions, that is, certain forms of radiations of the upper atmosphere. Many valuable data have been obtained in this way. For instance, by using spectroscopes it has been established that the Earth's atmosphere about 100 kilometres above the surface is colder over the equator and warmer over the polar regions. That is a very important factor for the origination of circulation. The higher temperature in the polar regions leads to a highly original structure of the highest regions of the atmosphere, called the exosphere. As is known the ionised particles in highly rarefied medium can move only along magnetic lines of force, and therefore projections of ionised particles or columns are formed over heated areas and they are sometimes discovered in the twilight hours when the exosphere is lit. These are the so-called high radiant structures of polar auroras. Interesting information about ionisation was obtained by investigations of the auroras by means of radar.

Meteors greatly influence the properties of the upper atmosphere. Their falls lead to the formation of readily ionisable nitrogen oxides and shock sound waves, which cause variations in the density of the medium. This phenomenon occurs in the upper atmosphere also when sub-audio waves produced by winds and the disturbances of the ocean surface and so on, penetrate up there from the atmospheric strata near the Earth. Thus, to employ a figurative expression, the outer part of the atmosphere suggests somewhat the agitated foaming water surface during a storm.

In recent years new and important results have been obtained through the use of rockets in investigations of the upper atmosphere. A lower density and lower temperatures have been found above 150-200 kilometres. Exceptionally valuable results have been obtained in determining ionisation; it was found that there is a gradual and smooth rise in ionisation with a large number of very shallow peaks, which it is difficult to identify with the sharply defined simple strata assumed earlier. Then, the real ionosphere proved to be lower than had been believed, and the penetrating ultra-violet and X-radiation of the Sun has been measured directly.

The measuring of absorptions of the penetrating solar radiations has made it possible to bring out the fact of the lower density of the upper atmosphere. However, a material shortcoming of rocket investigations was the short time they lasted.

Artificial satellites can ensure long and continuous observations over different localities of the globe, and therein lies their chief advantage. Most important is the observation of the penetrating ultraviolet, X-ray and corpuscular emission of the Sun.

On Sputnik-2 instruments for investigating the Sun's radiation were installed. Three special photoelectronic multipliers set up at an angle of 120 degrees to each other serve as the radiation receivers. Each multiplier is successively covered with several filters made of thin-metal and organic plates and also of special optical materials, which make it possible to separate different ranges in the X-ray region of the solar spectrum and the hydrogen line in the far ultraviolet region. The electric signals produced by the photomultiplier trained on the Sun were magnified by radio circuits and transmitted to the Earth by telemetric system.

Owing to the fact that the Sputnik has continuously changed its orientation in relation to the Sun and part of the time was in the sector of its orbit lit up by the Sun, to economise on power the electric circuit was switched in only when the Sun landed in the range of one of the three light receivers. It was switched in with the aid of photo resistors lit by the Sun simultaneously with the multipliers and the system of automatic control.

Parallel with the observations of solar radiation from the Sputnik, observations of the Sun are also conducted by the whole network of the "solar service" ground stations under the IGY programme. By comparison of all the observations it will be possible to arrive at the preliminary deductions on what connection there is between the Sun's ultraviolet and X-radiations and the processes going on in the chromosphere and the Sun's corona and the state of the Earth's ionosphere; these data will serve as a basis for the regular observations to follow.

Outer space is full of cosmic dust, the nature and characteristics of which it has heretofore not been possible to study directly. Science had only conjectures on its origin and characteristics. With the artificial satellite serving as a laboratory it will be possible to begin direct study of this problem too. What makes it important is the presumption that cosmic dust is the material out of which planets are formed.

Since Newton's days scientists all over the world have been pondering over the physical nature of terrestrial gravitation and of the force of inter-action between material bodies in general. But it was only Einstein's theory of relativity which slightly lifted the weil from the mystery of these phenomena and hence attracting the attention of the vast majority of scientists throughout the world.

So convincing is Einstein's conception that today it is the only rational theory explaining many cosmic phenomena. However, in some respects it has to be refined and checked by experiments. Artificial Earth satellites launched to move in high altitudes can help to check experimentally some of the theses of this theory, one of the fundamental theories of modern science.

It is known that the Metagallaxy possesses a definite luminosity and its value should be in agreement with the general theory of relativity. It is difficult to measure the luminosity of the Metagallaxy from the Earth's surface because of the night-sky air-glow, but with the aid of an artificial satellite it will be easier to solve this problem. When we have measured the luminosity of the Metagallaxy we shall solve an important cosmic problem and verify certain theses of the general theory of relativity.

Finally, in astronomical observations by telescope from the Earth's surface magnification of 900 times is ordinarily the limit because of interference caused by tiny air streams in the atmosphere (twinkling of stars, breaking up and blurring of the images of the heavenly bodies in the telescopes, etc.). On the other hand beyond the atmosphere magnification as high as 10,000 times is possible so that objects 12 metres in diameter will be seen on the Moon from a satellite , and on Mars areas measuring approximately 1.5 kilometres in diameter will be observable.

Of considerable interest is the study of electric fields at great heights (in the neighbourhood of 1,000 kilometres) and solution of the problem whether the Earth and its atmosphere constitute a charged or a neutral system. Along with indirect studies of the ionosphere, by observing the passage of radio waves, the programme of investigations on satellites envisages direct measurements of ionic concentration at different altitudes, and later the chemical composition of the ionosphere by mass spectrometry. If the present ideas that there are no negative ions at great altitudes are correct, these experiments will furnish complete information on the composition of the ionosphere.

Of great interest for science is the study of the radiation arising from the disturbance of the atmosphere by a body moving at cosmic speed. This radiation will become especially interesting when the satellite will be somewhat slowed down by the breaking force and will get into the lower strata, behaving like an enormous artificial meteor which excites and ionises the molecules and atoms of the surrounding medium. It will be particularly valuable if all these observations are conducted simultaneously with those from the Earth's surface as provided for under the current IGY programme.

It goes without saying that a complete solution of the problems enumerated above will require many satellites equipped with various equipment of high degree of perfection. And the data thus obtained will of course give birth to a great many new problems.

Cosmic Rays

Cosmic rays come to us from outer space. These radiations are a stream of nuclei of the atoms of different elements travelling at velocities very close to the velocity of light. They are the heralds of the gigantic processes as a result of which the nuclei of atoms of elements are accelerated to very great energies. The cosmic rays produced in this way offer the possibility of studying the cosmos at great distances from the Earth and even from the solar system.

In most cases the energy of the particles of cosmic radiation amounts to thousands of millions and even tens of thousands of millions of electron-volts. Some of the particles, however, attain an energy millions of times greater. Up to now particles have been found with an energy of as much as a billion billion electron-volts. This high energy of cosmic ray particles makes it possible for physicists to use them effectively to "bombard" atomic nuclei, and to study the laws operating only at the extremely high energy of the colliding particles. The study of cosmic rays, especially with the aid of instruments mounted on a satellite, will make it possible considerably to simplify some of the studies which when conducted on the ground require highly powerful accelerators such as a cyclotron or proton synchrotron. We might mention incidentally that the world's biggest proton synchrotron, made in the Soviet Union, can accelerate to an energy of "a mere" 10,000 million electron-volts.

Not many particles of cosmic radiation reach the Earth. On the average a square centimetre receives one particle a second. Despite the great energy of the individual particles the total energy of cosmic radiation is therefore small, being equal approximately to that brought to us by the light from the stars.

That is a trifle compared with the energy entering the Earth from the Sun. However, far away from the Sun the cosmic rays play no small part in the general energy balance.

The question naturally arises how cosmic rays come into being? There can be no doubt that as a rule they start out far from the Earth and even from the solar system. Sometimes, though extremely rarely, the Sun itself is the source of cosmic rays, and in such cases explosive processes have been observed on the Sun.

Cosmic rays produced on the Sun consist of particles possessing little energy, which shows that the scale of phenomena taking place on the Sun is very small compared to that which cause the formation of cosmic rays.

Where then in the Universe do these gigantic processes occur? To answer this question it is first necessary to study the composition of primary cosmic radiation. When colliding with the nuclei of the atmosphere's atoms the particles of cosmic radiation impart a portion of their energy, sometimes a very considerable portion, to secondary radiations, and owing to the high energy of the particles of cosmic rays a good many generations of secondary particles appear. For this reason, what we are studying on the Earth's surface and in the stratosphere too is not the primary radiation which came from cosmic space but in the main its numerous offspring.

In order to study primary cosmic rays scientific apparatus has to be lifted beyond the Earth's atmosphere.

Until now we could lift instruments to considerable heights by means of sounding balloons, stratostats or rockets, but in the first two cases primary radiation is masked by a secondary, while in the case of rockets the time of measurement is limited to a few minutes.

Artificial Earth satellites make it possible to study fully the composition of primary cosmic radiation. We shall very likely succeed in finding new components of cosmic radiation which will reveal many of the universe's secrets.

Physicists have long tried to establish the age of cosmic rays, to find out how much time has passed since the particles of cosmic radiation have obtained their great energy and began their wanderings through the universe. This question, however difficult it seems to be, can nevertheless be answered if we turn to account the fact that the longer cosmic rays travel in the universe the more times they collide with the atoms of interstellar space.

In such collisions the atomic nuclei of heavier elements in cosmic rays will break up and out of their fragments nuclei of lighter elements will be formed.

In cosmic rays we find nuclei of the atoms of different elements. The more nuclei of the atoms of a particular element there are in the cosmos the more of them will become accelerated and gain high energy. Experiments have shown that the composition of cosmic rays corresponds, in the maih, to the distribution of the different elements in the universe. Though there is very little of some elements in the cosmos, lithium, beryllium and boron, for instance, yet the nuclei of these elements are ofteh produced when heavier nuclei decay.

Consequently if such nuclei are found in the composition of primary cosmic rays it will mean that cosmic radiation travels a long time in the universe.

To find the nuclei of atoms of different elements in the composition of cosmic rays is a very difficult problem.

It may be successfully solved by using special counters, which register the Vavilov-Cherenkov radiation.*)

*) The "Vavilov-Cherenkov effect" (named for the Soviet scientists who discovered it) is that charged particles fly through matter at a velocity greater than the velocity of light, producing an original lightwave similar to the sound-wave produced by a plane flying at supersonic speed.

The greater the specific gravity of the element the more intense the radiation of the atomic nucleus passing through the counter. As shown by experiments carried on by the Soviet scientists L.V. Kurnosova, L.A. Razorenov and M.I. Fradkin, this is a good way to analyse primary cosmic radiation and especially to try to find out if it has the nuclei of lithium, beryllium and boron. In the same way the nuclei of the atoms of many other elements, particularly heavy elements, can be searched for in cosmic rays. The large opportunities offered by the satellites will permit undertaking new attempts to find among primary radiation electrons, and photons, the tiniest material particles of light. If these new components were found even in very small quantities our knowledge of the origin of cosmic rays would be considerably advanced.

This will be evident, indeed, if we recall that there are magnetic fields in outer space. While passing through the Earth's magnetic field the cosmic-ray particles are greatly deflected in the field, and as a result the primary particles of cosmic radiation, possessing as they do an an electrical charge, follow a considerably distorted path. Observing these particles on the Earth we cannot tell where they came into being since the original direction of their motion was completely lost owing to the deflection in the magnetic fields.

Photons, on the contrary, move practically in a straight line. If, therefore, we succeed in finding them they will better than any other radiation indicate to us where in cosmic space are to be found the sources of cosmic rays.

Thus, study of the composition of primary radiation will make it possible to discover a number of phenomena occurring in cosmic space and to shed light on the origin of cosmic rays, and in particular to check some consequences of the hypothesis put forward by the Soviet scientist V.L. Ginzburg to the effect that cosmic rays are formed on supernovae outbursts.

With the aid of artificial Earth satellites long observations of primary cosmic radiation can be conducted affording the possibility of discovering even relatively little variations in the intensity of the different components of this radiation.

In every particular case it is very interesting to find out the nature of those particles of cosmic radiation, which have changed in number. The use of satellites will make this possible.

Among other things, the number of primary particles can be registered to this end and simultaneously the ionisation caused by them. In this way it will be possible to separate the variations in the intensity of the main component of cosmic rays consisting of the nuclei of the atoms of hydrogen, namely, protons, from the changes in the number of nuclei of the heavier elements. Instruments on the Earth's surface cannot effect this separation, but satellites offer an altogether new approach to analysing the processes going on with cosmic rays.

The number of primary particles can be measured with the aid of a counter of charged particles. As has been shown by experiments conducted in the USSR (by N.L. Grigorov, Y.I. Logachev, A.M. Charakhchyan and A.E. Chudakov), it is now possible to design an instrument which will use electricity viery economically.

Considerable difficulty is presented in measuring ionisation produced by cosmic radiation beyond the atmosphere. However, the measurement can be managed by employing a method developed by Chudakov, as follows: owing to the ionisation, the instrument travelling outside the atmosphere accumulates an electric charge, and when the charge is removed an impulse emerges which is radioed to the Earth, and the ionisation produced by the cosmic rays can be judged from the value of the impulse.

The orbits of the Sputniks girdle almost the entire globe, and this makes it possible to study the dependence of the intensity of cosmic radiation on latitude and longitude. This dependence is due to the deflection of the primary cosmic rays in the Earth's magnetic field. By utilising the Earth as a huge measuring instrument the composition of cosmic radiation can be analysed, and the distribution of the radiation over the globe makes it possible to investigate our planet's magnetic field.

Instruments for studying cosmic rays were installed on Sputnik-2.

The particles making up cosmic radiation were registered on the Sputnik with the aid of charged-particles counters. When an electrically charged particle passed through the counter a spark was produced which supplied an impulse to the radio circuit incorporating semi-conductor triodes, the purpose of which is to add up a number of cosmic-ray particles and signal when a certain number has been counted. After transmitting the signals that the particular number of particles had been added up registration of cosmic-ray particles began again and when an equal number of particles had been counted another signal followed. Dividing the registered number of particles by the time in which they were counted we get the number of particles passing the counter per second, or, in other words the intensity of cosmic rays.

The preliminary analysis of the data on the cosmic rays transmitted from the Sputnik has shown that the instruments function normally. It has been definitely shown that the number of particles of cosmic radiation depends on the geomagnetic latitude, and the analysis of the many measurements of the energy spectrum of the primary cosmic particles makes it possible to study the variation of the spectrum with time and compare it with the processes going on during that time in the space around it.

There can be no doubt that in time the instruments set upon the Sputniks will provide the possibility for a continuous observation of the primary cosmic radiation.

In this way cosmic rays will become a powerful means of studying the Universe.

The Secrets of the Ionosphere

The characteristics of the atmosphere at altitudes above 200-250 kilometres have been little investigated. Especially interesting is the study of the fine structure of the ionosphere, that is, the part of the atmosphere which contains a vast number of electrically charged particles -- electrons and ions. Science today possesses few data on the circular electrical currents in the ionosphere and other related phenomena, as until now the principal information on the ionosphere has been obtained by studying the paths of the radiowaves sent from the Earth and reflected from the ionised strata. Moreover, this method makes it possible to get an idea of the ionosphere only up to the level of maximum ionisation (F2 layer), that is, up to a height of roughly 250-300 kilometres. This is because the ionosphere reflects or lets through radio signals, depending on the frequency used in transmitting them. For instance, greater density of ionisation is required to reflect signals sent on high frequency waves.

The greatest frequency at which radio waves are reflected from a given layer of the ionosphere when they fall vertically on it is called critical frequency. The greatest critical frequency is observed in the F2 layer. Radio waves of a greater frequency than the critical frequency of the F2 layer pass through the inonosphere and do not return to the Earth. Thus, in order to study the higher layers of the ionosphere it is necessary to have radio-wave sources placed considerably higher than the F2 layer, and it is such sources that the Sputnik carries. However, radio waves from the Sputnik falling on the ionosphere from the outer side and not from the side of the Earth can also be reflected and not get to the Earth. To avoid this, the Sputnik's radio transmitters had higher frequencies than the critical frequency of the F2 layer, with a range of 10-15 megacycles, depending on the season of the year.

Radio Waves Emitted from the Sputniks Made it Possible to Get Signals from an Area in the Ionosphere in which Radio Waves Travelling from the Earth Cannot Penetrate

Radio observations were conducted from points in different geographical latitudes and longitudes by radio direction-finder stations, radio clubs and thousands of radio amateurs.

Of very great importance are the measurements of the field intensity of radio signals received from the Sputnik. The measurements were made by continuous automatic recording as well as by separate measurements at certain fixed instants, and so much material has been obtained that at this time only a preliminary analysis has been completed.

The results of receiving the radio signals from the Sputniks and measurement of their levels have shown that the signals transmitted on a 15-metre wave-length rose very high up, far exceeding the direct vision range.

Of special interest is the fact that while moving in the elliptical orbit the Sputniks occupy a varying position in relation to the main maximum of electronic concentration in the terrestrial atmosphere. While in the Southern Hemisphere the Sputnik travels above the ionosphere layer in the Northern Hemisphere at certain moments it is above the peak ionisation of that stratum, at other moments under it, and at still others, near the peak. These conditions make for a great many ways of propagation of short waves over great distances. One of these ways is the reflection from the Earth's surface of the radio waves which have come from above through the whole mass of the ionosphere, followed by a single reflection of it from the ionosphere in the regions where the critical frequencies are sufficiently high. In other cases the radio waves falling on the ionosphere from above at a certain angle are considerably refracted by it and as a result penetrate into a region lying beyond geometrical direct visibility.

The position of the Sputnik near the area of maximum ionisation of the atmosphere creates especially favourable conditions for the propagation of radio waves by means of ionospheric radio-wave guides. In some cases, as the observations have shown, radio waves came to the receiving point not the shortest way but rather travelled about the globe over the longer arc of the great circle. In some cases the phenomenon of round-the-globe echo of the radio signals has been observed.

There can be no doubt that the final analysis of the great amount of material obtained through the radio observations of the Sputniks will provide very valuable information on the specific features of ionisation of the upper layers of the ionosphere and the absorption and propagation of radio-waves in them.

The Earth's Magnetic Field

There is a natural magnetic field around the Earth. Its properties, for instance, its directional effect on the magnetic needle, have long been utilised in practice, though the nature of the field and its origin still remain obscure. The Earth's magnetic field affects the motion of charged particles coming from the Sun to the Earth through outer space, particles formed in the upper layers of the atmosphere when the latter are ionised by the Sun's ultra-violet rays. This is the explanation for the geomagnetic effects such as the latitude distribution of the intensity of cosmic rays and the frequency of auroral displays, the polarisation of the radio waves reflected from the iono-sphere and many other things.

Until recently the Earth's magnetic field was measured either on the Earth's surface or close to it (from aeroplanes); it was only lately that several measurements were taken from rockets at altitudes exceeding a 100 kilometres. The mathematical analysis of the measurements made on the ground has led to a number of interesting deductions. It turned out that the field observed near the Earth's surface should be regarded as consisting of two parts: one due to sources in the interior of the Earth, and the other to sources outside the Earth.

Although the share of the outer sources is very small (one to three per cent), its value lying close to the limits of the error involved in the mathematical analysis, there is no doubt that it exists in reality. The existence of an external field is confirmed by the rapid changes taking place in the Earth's magnetic field, changes that are known as diurnal magnetic variations, magnetic disturbances and magnetic storms. These changes are closely related to many phenomena occurring outside the Earth's surface, such as solar activity, the state of the ionosphere, auroral displays and cosmic rays.

A mathematical analysis of the changes shows that their sources lie outside the Earth's surface. Unfortunately, the analysis of the data obtained from ground observations will neither indicate the exact spot where the field's sources are to be found nor define their nature. Other data have to be found for this purpose.

Investigation of the daily variations, magnetic storms and the phenomena related to them have led scientists to assume that an external magnetic field may be produced by systems of electrical currents outside the Earth's surface. The most likely place where such currents might originate is the upper conductive layers of the Earth's atmosphere, namely, the ionosphere.

It is also suggested that there may be currents beyond the ionosphere too. They may possibly be due to charged particles and corpuscles, ejected by the Sun and captured by the Earth's magnetic field and revolving around the Earth in the plane of its magnetic equator several tens of thousands of kilometres away from the Earth. These extra-ionospheric currents increase when during magnetic storms the Earth finds itself in the midst of intensive corpuscular streams ejected from the Sun's active regions. At such time their magnetic field shifts the zones of auroral displays closer to the equator and reduces the intensity of cosmic rays.

The presence of sources of a magnetic field in the ionosphere is confirmed today by direct magnetic measurements conducted from rockets.

Considerable attention is given in the International Geophysical Year to studying the varying external magnetic field and its relation to solar and other geophysical phenomena. The changes in the magnetic field will be registered continuously at a great many stations. It is also planned to measure the magnetic field from satellites and rockets. Magnetic measurements on satellites make it possible to survey the magnetic field around the Earth at great altitudes. Their purpose is to check the existence of extra-ionospheric currents, to find out the system of ionospheric currents and learn more about the main part of the fild, i.e, the part due to the Earth's interior sources. By means of satellite measurements it can be checked whether the streams of the Sun's particles are neutral or consist of electrically-charged particles of either sign.

Data on the field portion created by external sources can be obtained by comparing the measured values of the field with the theoretical calculations based on the assumption that the field is produced only by sources in the interior of the Earth. Knowing the field produced by the external sources at high altitudes it will be possible to appraise better the part it plays in particular geomagnetic effects. It is not impossible that in some cases it plays a considerable part. In particular, the recently revealed difference in the position of the Earth's geomagnetic equator as found from the data obtained by magnetic measurements on land and by measurements of the intensity of cosmic rays, may possibly be caused by the action of the field's external sources on the charged particles of cosmic rays.

Observing that the intensity of the large magnetic anomalies decreases with altitude we shall be able to judge whether the sources of these anomalies lie near the Earth's surface or far out in space.

Weather Forecasting

It is close to 75 years since the first attempt was made to carry out geophysical investigations simultaneously on a worldwide scale. That was the first international polar year. Its task was to study the influence of the Arctic on the weather, and to investigate the Aurora Borealis and the Earth's magnetic field. The second attempt was made 50 years later, in 1932-1933, when the second international polar year was organised. The object of that attempt was to study the ionosphere and its effect on the propagation of radio waves, and to conduct meteorological observations by an extended network of stations.

The meteorological maps compiled following the observations of the second international polar year (for the Earth's

Northern Hemisphere) served scientists as a basis for developing a thermo-hydrodynamic method of long-range weather forecasting, and to verify whether the experimental hydrodynamic long-range forecasts were justified.

The next international meteorological observations were planned for 1982-1983, but the rapid rate of development of science and technology in the middle of the 20th century made it necessary to change the schedule and fix the IGY for 1957-58.

Participating in the IGY are 64 countries, with the USSR taking an important part in carrying out its programme. Some 300 meteorological ground stations and some 100 aerological stations were set up on Soviet territory. The work done under the IGY programme will be extremely important for meteorology, especially for weather forecast, which is the principal problem in this science. For the first time the results of observations by a wide network of meteorological stations will be received from both hemispheres of the Earth.

This will be the first time that meteorological conditions in the Antarctic and equatorial regions will be widely analysed, an analysis that meteorologists are so badly in need of. Vast material will be collected for meteorology, during the year, and by using electronic fast computing machines the material will be analysed in brief time. The calculations, which formerly would have taken scores of years, can now be done in a few hours.

The automatic meteorological stations set up on the Sputniks operating beyond the Earth's atmosphere will lead to fundamental changes in the theory and practice of weather forecasting. Many meteorological phenomena hidden from observers on Earth will become obvious when observed from the Sputnik. Today meteorologists are forced to collect most of their data from an extremely limited number of ground observations. However, making use of a satellite it will be possible, for instance, to photograph at once all clouds over the Earth's surface at least several times in 24 hours. It will also be possible to obtain data on ice conditions and information on other factors influencing the weather all over the world.

Many problems of meteorology are already in the process of solution as a result of the observations of the first two satellites; for instance the distribution of the density of the air in the upper layers of the atmosphere along longitude and latitude, etc. In future satellites will help to solve a vast number of meteorological questions.

The successful launching of the Sputniks has afforded the possibility for the first time in the annals of meteorology to conduct extended observation of the Earth's atmosphere "from above."

By equipping the Sputniks with special sensitive photocells, scientists will get a picture of the distribution of clouds over extensive regions of the Earth's surface and simultaneously get a picture of the distribution of the gigantic planetary and atmospheric waves (more than 1,000 kilometres long), which play a part in shaping the weather over large distances; scientists will be able to watch jet currents, that is, a pronounced belt winding among the cyclons and anti-cyclons which block it, like a river winding between islands, and many other things. In short, the Sputniks will furnish a picture of the distribution of the air currents, a picture of total air circulation over wide expanses.

It has been proved that for short-range forecasts (24 to 48 hours) it is necessary to know the initial field of meteorological elements for a relatively small area, surrounding the particular region for which the forecast is made. However, as the time for which the forecast is made grows longer the territory to be elucidated by the initial data increases sharply. In the case of long-range forecasts for some point in the Northern hemisphere the initial data have to cover the entire Northern Hemisphere as a minimum.

A dense network of stations to take observations and complete information from the stations are essential for making more accurate forecasts. There are still however, large areas on the Earth's surface in which there are few stations or none at all. Thus, while on the Atlantic Ocean daily observations are conducted on a few stationary vessels belonging to the meteorological and aerological service, practically no obeservations are conducted on the Pacific Ocean. Here observations from the Sputniks will render indispensable service, They will cover vast areas including the oceans, on which no regular observations of the state of the atmosphere have been conducted.

VII. TOWARDS THE CONQUEST OF OUTER SPACE

Problems Involved in Study of Animals Travelling in Outer Space

Soviet scientists began the conquest of space by implementing a broad programme of medical and biological investigations of animals on their flights in rockets to 100-200 kilometres above the Earth's surface.

From the biological standpoint a flight in the upper layers of the Earth's atmosphere has much in common with a flight in outer space. A living organism in that case too, will be affected by a whole series of factors not found in the usual environment, such as the effect of cosmic radiation, the long gravity-free dynamic state and, under certain conditions, the virtual absence of atmospheric pressure and molecular oxygen.

Some of these factors can be produced artificially and studied in laboratories, and others during brief flights in rockets. A good many papers deal with the study of their effects on the organism. Airflight medicine today has enough experimental and theoretical data which reveal more than merely the physiological effects of the influence of this kind of factors. At its disposal are preventive and protective measures to safeguard the living organism; these are hermetically-sealed chambers, space suits and so on.

The effects of weightlessness, of primary cosmic radiation, corpuscular and ultra-violet radiation of the Sun have as yet practically not been studied from the medico-biological angle. Their biological effects and perhaps also other factors we still know inadequately can be found out only by long flights in the upper layers of the atmosphere.

To conduct such investigations, considerable difficulties as regards design and method have to be overcome. All apparatus in such cases must operate independently over a long period, ensure automatic recording of the needed data and be highly resistant to the action of overstrain, vibrations and variations in pressure and temperature. At the same time the apparatus has to be compact, weigh little and consume little electricity.

No less are the difficulties arising in providing conditions to enable animals to survive in the flight. For instance, the efficient systems of air regeneration used ordinarily are unsuitable for the hermetically-sealed chambers because of their bulk and large weight.

New and more efficient systems had to be designed. Obviously the ventilation system had to be a forced feed system since the gravity-free state precludes the air exchange usual for conditions on Earth. Because of this, the heat exchange in the chamber and protection of the animal from the considerable variations in the temperature have to be specially designed.

A special system had to be worked out to provide the animal with water or liquid food, as in conditions of weightlessness liquids in a free state can possibly disperse throughout the chamber.

It was necessary to work out a whole system of rather complex automatic equipment to ensure that the conditions required to keep the animal alive are maintained. Scientific instruments are used which are designed to investigate a number of basic physiological functions of the animal and hygienic conditions in the chamber (temperature, air pressure, etc.). For this purpose particular physical values are converted into electrical, then they are coded into different kinds of radio impulses, which are transmitted by radio and automatically recorded on Earth with the aid of special recording devices.

Even this by far incomplete enumeration of the problems is enough to give an idea of the variety and complexity of the tasks due to the specific conditions of the experiment.

Observations of the animal's behaviour on Sputnik-2 made it possible to find out the effect on the organism of factors which could not be studied in laboratory conditions or in high flights on aeroplanes.

Biological Phenomena in Cosmic Flights

For the purpose of studying a number of medico-biological questions a special hermetically-sealed chamber was fixed up on Sputnik-2 in which the animal (a dog called Laika) was placed, also instruments to study the physiological functions of the animal, equipment for regenerating the air, for feeding the animal and removing the products of its physiological activity. In designing the equipment account was taken of the need of the utmost economy in the size and weight of the instruments and of minimum consumption of electricity by them.

Functioning for some considerable time, the apparatus ensured with the aid of radio telemetric system the registration of the animal's pulse and respiration, its arterial blood pressure, the bioelectrical potentials of the heart, the temperature and air pressure in the chamber, and so on.

It is perfectly natural that the first "passenger" on the Sputnik was a warm-blooded animal -- a dog -- the normal physiology of which had been thoroughly studied. It may be that to clear up special questions it will be necessary to use anthropoid apes, rodents, mollusks and insects. Insects will afford opportunities for genetic studies.

Laika, the passenger on Sputnik-2, was a small dog weighing approximately five kilogrammes. Unfortunately its genealogy is not known. It was a phlegmatic animal; while living in the vivarium it never quarrelled with its four-footed neighbours. The information obtained from the Sputnik shows that during the space flight too it did not lose its calm disposition.

Before sending it on the Sputnik, Laika underwent preliminary training. It was gradually accustomed to long stays in a small hermetically-sealed room wearing a special outfit, and to the gauges attached to different parts of its body for registering the physiological functions, and so on. The animal was also trained to stand the effect of overstrains, and in the laboratory it was determined how far it was proof against the effect of vibration and certain other factors. Following long training the animal calmly endured several weeks in the hermetically-sealed chamber, which made it possible to conduct the needed scientific investigations.

The study of the biological phenomena of a living organism travelling in outer space became possible as a result of extensive preliminary investigations on animals in short flights in rockets to altitudes of 100 to 200 kilometres, investigations conducted in the USSR over a number of years.

This is the story of one of the flights.

... Five minutes before sunrise a cigar-shaped silver grey rocket was zooming up to the stratosphere. In the forward part was fixed up a non-hermetically sealed compartment in which catapulting trolleys had been placed. Attached to the trolleys were special outfits -- oxygen supply instruments, containing 900 litres of oxygen, a parachuting system and apparatus for recording the physical functions in flight.

The catapulting trolley weighed 70 kilogrammes, and the parachuting system ensured a vertical landing speed of about six metres a second. The rocket quickly reached a height of 110 kilometres, at which the head part fell away from the body and began its free fall. At an altitude of 80-90 kilometres the first trolley was catapulted at a speed of some 700 metres a second; three seconds later, the parachute system began to work and the animal dropped down to Earth from a height of 75-85 kilometres, the descent taking an hour.

In the last five years Soviet scientists carried out many similar rocket flights for the purpose of studying the high layers of the atmosphere and their effect on living organisms.

Unlike earlier investigations, the flight of an animal on the Sputnik makes it possible to study the effect of zero gravity over a long period. Before this the influence of weightlessness could be studied only on an aeroplane for a few seconds at a time, and during the vertical launching of a rocket for a few minutes. On the Sputnik, however, it was possible to study the animal's organism in gravity-free state for several days.

The experimental data obtained in the medico-biological investigations are now being studied thoroughly and in detail. It may be said already now that the animal stood well the long action of the accelerations as the Sputnik was taken to its orbit and the gravity-free state which followed for several days. The data show that throughout the experiment the animal's state was satisfactory.

VIII. LIFE ON A SATELLITE

Without Atmosphere

Animals and human beings can travel in outer space only in hermetically-sealed chambers, where the air composition and pressure are close to those prevailing on Earth. In order that the organism could breathe the space ship must have a supply of oxygen, and most expedient is liquid oxygen. One litre of liquid oxygen yields 800 litres of oxygen gas as it evaporates. However, the required amount of oxygen dissolves in the blood only at a certain barometric pressure; if there is not enough barometric pressure, even if the organism breathes pure oxygen it will not get all it needs.

If the barometric pressure drops (in outer space there is practically none) the gases dissolved in the blood pass out. This brings about grave consequences, and sometimes a complete disturbance of the vital activity of the organism is the result.

Liquids' boiling temperature depends on the surrounding pressure. The lower the pressure the lower the temperature at which a liquid begins to boil. At a pressure of 47 mm. of mercury (which corresponds to 19 km. above sea level) the liquid begins to boil when its temperature barely reaches 37°C. This is the blood temperature of a human being, and the "boiling" of the blood would inevitably bring serious consequences.

When could such disorders arise? They could occur if something unforeseen happened to the hermetically-sealed chamber. If a meteorite traveling at a terrific speed collided with the space ship and pierced the chamber and the astronaut was not wearing protective clothing he would faint in 15 to 30 seconds. For this reason, besides hermetically sealing the chamber, space or special high altitude suits are provided. In the space suites the required barometric pressure is maintained and in the special altitude suits the pressure is produced by tensioning the fabric of the suit which tightly fits the human body. Both hermetically-sealed chambers and space or altitude suits are used.

Flights of animals in satellites will make it possible to check up how reliable are the hermetically-sealed chambers and the space and altitude suits and to work out ways to enable the organisms to take food and water under these conditions, and to solve a number of other questions.

An important requisite for the normal life of living beings is the adequate temperature of the surrounding medium. The first experiment of launching a satellite with a dog on board has shown that Soviet scientists have correctly solved the problem of producing the required temperature inside the satellite; the animal behaved calmly in flight and its general state was satisfactory.

The Sun Is Not All Life

It is extremely important to study with the aid of satellites the effect of the different kinds of solar and cosmic radiation on living organisms. The intensity of the ultra-violet radiation in the upper atmosphere and beyond is so great that it is fatal for the living cells. However, protection against the action of the Sun's ultra-violet rays is no difficult problem, since most materials, including ordinary glass, do not let through this part of the solar spectrum.

Solar radiation also contains the so-called X-rays. While at first their influence on the organism is quite unnoticeable, in may later lead to very unpleasant consequences. Therefore an effective protection against X-rays must be secured.

Cosmic rays, or cosmic particles, as they should be called more properly maybe even more dangerous. Possessing enormous kinetic energy these particles, on encountering molecules of other substances, cause their disintegration into ions. Molecules become ionised also when cosmic particles penetrate into the tissue of the organism; that leads to the destruction of the cells, to unhealthy symptoms like those caused by gamma radiation, which occurs in nuclear reactions.

The question naturally arises: how can the organism be protected against cosmic particles? While there are no finished plans on this score as yet, published data indicate that this protection is faced with considerable difficulties, and the launching of satellites carrying animals will make it possible to obtain highly important information on this question.

Sputnik-2 is equipped with measuring instruments for studying all "radiant" effects of outer space: the Sun's short-wave ultraviolet and X-ray radiation, and cosmic rays.

A few words should be said about the danger from meteorites.

It has been established that more than 8,000 million meteorites enter the planet's atmosphere every 24 hours, their total mass being approximately one ton. Possessing an immense speed of movement -- 30 to 50 kilometres or more a second -- they become hot from friction in the air and burn away in the upper strata of the atmosphere;

we see them as "falling stars." Meteorites do not, as a rule, penetrate below 70-100 kilometres. However, the higher a satellite moves the more likely it is to meet a meteorite. It is important to establish how much this possibility depends on the height of the orbit, the time of the year, and so on.

The very first weeks of the Sputniks' flight have shown that the Sputniks have not been hit by a meteorite of destructive force. It may well be that the chance of colliding with meteoric particles will turn out to be no greater than the chance of an automobile accident.

What Is Weightlessuess?

To have a satellite get out to its orbit a speed of some 8,000 metres a second has to be imparted to it, and this involves a considerable acceleration over a long period. The effect of acceleration depends on its magnitude, period of action, the rate of increase and the direction of the motion in which the force producing the acceleration acts on the body of the human being or animal.

The effect of the accelerations, or overstresses, as they are also called, on the organism of animals and human beings has been studied quite intensely in recent years, since modern high speed planes are subject to considerable accelerations over long periods.

If the acceleration acts upward from a person's feet to his head it will cause a redistribution of the whole mass of the blood, and there will be more blood than usual in the lower part of the body and not enough in the upper.

If the acceleration is strong enough the blood circulation in the brain may be less than the regular, and this will lead to a disturbance in the functions of the central nervous system, including the loss of consciousness.

If the acceleration does not act on a person along his body but perpendicularly it can be withstood much easier. The special suits also help to protect from over-strains, as they envelop the different parts of the body tightly, not letting the blood accumulate in them. These questions too will be checked in the experiments with animals.

A few words on the speed of movement the organism can stand. Uniform speed does not affect the organism. We certainly are not troubled in the least by the Earth's rotation on its axis. Neither are we disturbed by the Earth's motion around the Sun, at a velocity of more than 100,000 km. an hour. We may state definitely that the human organism can safely stand any uniform speed. However, at a certain speed of movement there comes a point when man's sense organs cannot supply the brain with exhaustive information because the information is transient and incomplete. Space flights will therefore be controlled chiefly from land stations by means of electronic computing machines with a stored programme. Astronauts in space flights will be released from having to control their flight themselves, which is literally beyond man's capacity.

Let us now pass on to the question of weightlessness, which travelers in space are bound to come up against.

The effect of weightlessness has been studied in recent years on both animals and human beings. True, the observations were of effects lasting but several scores of seconds. Undoubtedly the effects of being a considerable time in a gravity-free state will be quite different. That is just what satellites carrying animals should establish. Dogs clad in special space suits on their brief flights in rockets also experienced a state of wightlessness. Automatic instruments recorded the animals' respiration, measured the blood pressure and pulse, and an automatic motion-picture camera took photographs. No material changes in respiration or heart activity were found. However, such experiments were limited as to time.

Interesting results have been obtained in studying the effect of zero gravity on human beings. Weightlessness occurred in a specially programmed flight by aeroplane and it continued for 30 to 45 seconds. Of the 14 persons who took part in those flights eight said that they had felt well. The scientist who conducted the study and who took part in the flight stated that the zero-gravity state was the best form of relaxation for a human being. Five of the fliers, however, experienced illusory sensations during the gravity-free state: they had the feeling that they were in a state of free falling or that they were flying "upside down." And one showed symptoms of health disturbance very much like the sick feeling one gets during air sickness.

It has been established that after repeatedly experiencing weightlessness in flight the human organism adjusts itself to it, and a person who has experienced it several times retains a sufficiently good orientation in space and is capable of making precise coordinated movements.

The dog's flight on the Sputnik, in which the gravity-free state continued for a considerable time, makes it possible to study the effect of prolonged weightlessness on the organism and to solve the problem to what extent centrifugal forces should be created on a satellite to take the place of gravity.

There can be no doubt that weightlessness also affects the organism's functions of breathing, blood circulation, body temperature, and so on. Observations have shown that weightlessness causes some drop in blood pressure.

Under the action of accelerations there is increased gas exchange in the organism, and the consumption of oxygen and evolvement of carbonic acid gas rises severalfold. During the gravity-free state a drop in the gas exchange may be expected, at least after the organism had become adjusted to this state. These facts are important for ensuring a supply of oxygen for the animals and for determining the capacity of the air-conditioning apparatus.

Another important reason why satellites should be launched with animals on board is the saving of crews of future space ships. It may happen that unforeseen circumstances will force pilots to abandon the cosmic vessel, and provision should be made to save the people in such cases. Naturally, such experiments should first be conducted with animals. Besides, for scientific purposes it would also be highly desirable to save the animals after the satellite has completed its movement in the orbit.

Where Are the Biological Limits?

The height of the orbit above the Earth is important for flights of satellites; the greater the altitude the longer will the satellite survive. But what about satellites carrying animals? Is there any reason to limit the distance of its orbit from the Earth? There appears to be no difference, for animals have the same chance for survival at any of the heights to which a satellite can be launched.

The thing is that already at very low heights our atmosphere begins to lose rapidly its properties which are essential for a living organism.

At eight or nine kilometres above sea level the effect of insufficient barometric pressure is felt, and at 19,200 metres, where total barometric pressure equals 47 mm, of mercury, measures have to be taken to protect the organism against the liquids beginning to boil.

At 36 to 37 kilometres up lies the boundary where heavy particles of cosmic radiation are absorbed; above that level in the atmosphere one must be protected against cosmic particles. Above 42-43 kilometres begins the region which as regards the ultraviolet part of the solar spectrum is equivalent to interplanetary space.

Meteorites generally burn away at an altitude of about 100 kilometres.

At 122 kilometres above the Earth's surface and higher sound cannot propagate in the atmosphere. At that altitude the distances between the air's molecules are approximately equal to the lengths of sound waves apprehended by the human ear. Above this limit the free path of the air's molecules is longer.

Approximately at these heights the intensity of cosmic particles begins to increase sharply.

However, the region in which a satellite can survive for a long time is considerably higher than these outside limits.

IX. Man in Outer Space

Today we may already say that in a very few years satellites will be built to revolve around the Earth at a distance of several thousand kilometres from the Earth's surface and they will be equipped with apparatus for every kind of scientific measurement. One of the next steps should be the development of a rocket capable of breaking away from the sphere of the Earth's attraction, get close to the Moon and fly around it. Such a rocket would give us abundant information on the nature of the Moon's surface and on the structure of the Moon's hemisphere which we never see.

We can say that a flight to the Moon is a matter of the not distant future. The carrier rocket of the world's first artificial Earth satellite imparted to it an orbital speed of some eight kilometres a second, and the second satellite was imparted an equal speed. And to send up a space ship to the Moon it will need a speed of only three kilometres more, or slightly more than 11 kilometres a second. In the latter case the space ship will travel in a drawn out ellipse, and entering the sphere of the Moon's attraction will after a few evolutions land on the latter's surface.

The whole trip will take no more than five days and a minimum of fuel will be consumed. A route has been figured out to make the flight in less time. If the space ship will fly faster than 11 kilometres a second it will be able to reach the Moon in 24 hours. Such projects too have been worked out by Soviet scientists.

Soviet scientists are also working on projects for flights to Mars. One of the projects envisages the assembly of 10 space ships each weighing 1,700 tons on flying stations. From their circular orbit around the Earth they will get out via the transitory orbit to an ellipse and will move towards Mars in the sphere of the Sun's attraction without using fuel. The trip to Mars will take 256 days. For the return flight the travelers will have to wait on Mars or its artificial satellite until the position of Mars and the Earth in relation to each other is again such as will favour the start of the return flight. This waiting period will equal 440 terrestrial days. The whole trip will thus take 952 days, or nearly three years. Scientists believe that such flights will be made towards the end of the present century. There are also projects under which a path has been figured out for a flight to Mars in less time.

At first, space ships will make their flights without people on board. The development of present-day automation and electronic computing machines provides a theoretical basis to build equipment which besides taking measurements will be able also without human intervention to figure out exactly which measurements should be taken and how they should be arranged in view of the findings of the earlier measurements. The radio makes it possible automatically in short time to transmit to the Earth the results obtained in the vast number of observations and measurements. Theoretically it is possible also to transmit pictures visible from the ship.

It will thus be possible to obtain enough scientific data without sending people out into outer space.

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Considerable technical difficulties are still to be overcome before man will be able to fly in outer space. However, the progress made and the continued hard work by scientists give us grounds to believe that before very long man's flight in outer space will become a fact.