History of
Rocketry and Astronautics

Proceedings of the Seventh and Eighth History Symposia
of The International Academy of Astronautics

Baku, U.S.S.R., 1973

Amsterdam, The Netherlands, 1974

Kristan R. Lattu, Volume Editor

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AAS History Series, Volume 8

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 3

AAS Publications Office
P.O. Box 28130
San Diego, California 92128

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 1989

ISSN 0730-3564

ISBN 0-87703-307-2 (Hard Cover)
ISBN 0-87703-308-0 (Soft Cover)

Published for the American Astronautical Society
by Univelt, Inc., P.O. Box 28130, San Diego, California 92128

Printed and Bound in the U.S.A.

Chapter 14

THE CREATION OF THE FIRST ARTIFICIAL EARTH SATELLITE: SOME HISTORICAL DETAILS*

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In the course of his theoretical studies of the problem of interplanetary flight, Konstantin Tsiolkovsky forecast the creation of artificial Earth satellites, but while he was alive, humanity was not yet ready to launch them.

As a result of the successful completion of a number of five-year plans, the USSR created a highly developed heavy industry which provided the basis for the establishment of aircraft and rocket technology. An abundance of outstanding engineers and scientists made it possible for the Soviet Union to carry out, over a number of years, research and technical work leading to the creation of both the first artificial Earth satellite, and other forms of spacecraft.

In accordance with the program of the International Geophysical Year (IGY), a collective of scientists and engineers headed by Academician Sergei P. Koroloyov, working in close collaboration with the USSR Academy of Sciences, various other scientific establishments, industrial enterprises and construction teams, built a number of sputniks. The first of them, the simplest in design, was launched on 4 October 1957 and circled the Earth. This date has become one of the most glorious in the history of humanity.

By 1953, Soviet rocket techniques had reached such an advanced stage that it became possible to plan the development of artificial Earth satellites. On 30 January 1956 the decision was made to build a sputnik in 1957-1958. The first trial launching was to take place in 1957. During 1956, in the USSR Academy of Sciences, a number of conferences were held between scientists who specialized in fields connected with space exploration. Each conference was devoted to a single aspect of the problem, such as cosmic radiation, the ionosphere, the magnetic field, etc. But always there were present at each conference the following three fundamental questions: What will an artificial Earth satellite contribute to a given branch of science? What instruments should it carry? And who among the scientists would undertake its development?

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* Presented at the Seventh History of Astronautics Symposium of the International Academy of Astronautics, Baku, 1973.

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At the time our knowledge of the physical conditions of the upper atmosphere and space surrounding the Earth was quite inadequate. The subsequent discoveries of such phenomena as the radiation belt surrounding the Earth, the magnetosphere, and other findings only confirm this fact. Before the flights of the first sputniks, our various measurements of the density of the atmosphere several hundred kilometers from the Earth differed substantially from one another. Nor did we have a clear idea of the structure of the ionosphere, of how radio signals passed through it, or the extent of the danger presented by meteorites to spacecraft.

We also completely lacked experience of how to ensure the sputnik's pressurization, or how to control the internal temperature under conditions of space flight, how to supply its equipment with power over an extended period of time, how to control it when in flight, how to place it into orbit, or how to bring it back to Earth and land it safely. Practical solutions to these problems were the fundamental tasks of the planners and engineers of the first spacecraft. To these fundamental tasks were added the solution of the problem of how to place sputniks into orbit, the methods to be used by the ground stations to track and control them, and the question of communications.

Beginning in November 1956, Soviet scientists began to work out plans for the development of a sputnik capable of carrying a man. They also made preliminary calculations of what would be required to build a spacecraft capable of landing on the Moon. It was also at the same time that, on S. P. Koroloyov's initiative, work began on the actual construction of the first artificial Earth satellite. It was hoped that the successful launch of the first artificial Earth satellite would prove a most powerful stimulus for speeding up the rate of exploration and domination of space. Indeed, the first sputnik served as an impetus leading to the establishment of ambitious space exploration programs both in the Soviet Union and abroad.

Scientists were working on the problem of building an artificial Earth satellite in a number of countries outside the Soviet Union, but the difficulties encountered by them prevented them from solving the problem in 1957. However, when the first (non-Soviet) artificial Earth satellite was built abroad, it was considerably smaller and lighter than the first Soviet sputnik.

The following guidelines formed the framework of the planning for the first (Soviet) sputnik:

1. The artificial Earth satellite was to be of maximum simplicity and reliability, so that it would have the best possible chance of completing the tasks assigned to it. At the same time, technical solutions to the problems of ensuring its pressurization and thermal control were to be of a kind that could be used in the planning of more complex spacecraft.

2. The body of the artificial Earth satellite was to be spherical in order to determine, as accurately as possible, the density of the atmosphere along the orbital flight path of the unguided of sputnik.

3. The artificial Earth satellite was to be equipped with radio equipment working without interruption on at least two wavelengths, and with sufficient power to ensure the reception of its signals over great distances by a large number of radio tracking

stations and amateur receivers in order to obtain statistical data on the propagation of radio waves through the ionosphere under varying conditions.

4. The antenna system of the artificial Earth satellite was to be designed to exclude the effects of spinning of the sputnik on the intensity of the received signals.

   In order to work out a method for using radar to measure the orbit by means of passive reflection of the signals, angle reflectors were to be installed on the body of the carrier-rocket. The carrier-rocket was also to carry equipment for recording cosmic radiation.

5. The equipment aboard the sputnik was to obtain power from batteries with a high-energy output capable of ensuring the functioning of the equipment for at least two-to-three weeks.

6. The positioning of the sputnik on its carrier-rocket and the method of separation were designed to ensure that there would be no failure at separation nor at the moment when the antennas were deployed.

The radio transmitting equipment aboard the sputnik was to ensure:

1. One watt transmission on frequencies of about 20 to 40 megacycles (MHz).
2. Transmission of two telemetry signals recording pressure and temperature inside the sputnik by means of a form of frequency modulation.
3. Power supply from silver-zinc batteries.
4. Continuous operational life of 14 days and nights.

The radio equipment was to be a separate unit. The temperature of the gas inside the satellite would vary between minus 40 and plus 50 degrees centigrade, and the pressure between 100 mm to 1.2 atmospheres. The humidity was to be 80 percent.

The objectives of the first sputnik were:

1. To test the method of placing artificial Earth satellites in orbit and their separation from the carrier-rocket.
2. To supply data on the density of the upper atmosphere, essential for calculation of the lifetime of a satellite in orbit.
3. To test radio and optical tracking techniques of orbital measurement.
4. To understand the propagation of radio signals of varying frequencies through the ionosphere.
5. To check the principles of pressurization control under the conditions of space flight and the efficiency of the hermetic seal used.

The first Soviet artificial Earth satellite had a pressurized body in a spherical shape, 580 mm in diameter. It was made of an aluminum alloy and consisted of two hemispheric casings held together by a frame. The hermetic seal between the two casings was assured by a reinforcement ring made of rubber, which was placed in the annular groove of one of the frames. The hermetic frame was held together by screws. The front half-casing was of a smaller size, and was covered by a semi-spherical shield in order to protect its thermal balance. Four fittings in the half-casing served as reinforcements for the projections holding the antennae. The rear half-casing acted at the same time as a (thermal) radiation surface for the pressurization system. The pressurized body was filled with dry nitrogen at a pressure of 1.3 atmospheres.

The fueling was done by means of a special valve. Inside the first artificial Earth satellite were the electrochemical sources of power (batteries), the radio-transmitting equipment, the ventilating fan and air duct of the pressurization (and thermal) control system, the commutation system, the temperature and pressure transmitters, and associated wiring. The power source unit consisted of three silver-zinc batteries. The unit had the shape of an octagonal prism 450 mm wide and 270 mm high, and had a central right-angled channel 170 mm by 130 mm, in which was installed the radio equipment. The shape of the unit ensured the symmetrical circulation of the nitrogen gas inside the pressurized body of the craft and the best use of the heat (even distribution) produced by the radio transmitters. The power unit was fixed to the junction frame of the front half-casing at eight points. Two batteries supplied power to the radio equipment; a third battery supplied power to the ventilating fan of the pressurization control system and the commutation system.

The radio equipment consisted of two transmitters operating on frequencies of 20.005 and 40.002 megacycles. The wavelengths were 15 and 7.5 meters. The vacuum tube-type transmitters had an (intake) power of 1 watt. The signals on both frequencies were in the form of telegraph transmissions lasting from 0.2 to 0.6 second. One set transmitted during the working pauses of the other one. As the circuits of the pressurization control pickoff (barometric relay tuning of p = 0.35 atmospheres) and the temperature pickoff (pressurization relay tuning T1 = +50 degrees centigrade, T2 = 0^{o}) opened or closed, there was a change in the frequency of the telegraphic signals and the relationship between the duration of the signals and the intervening pauses.

The radio equipment was in the form of a unit 100 x 130 x 390 mm in size, fixed with the aid of a shock absorber to the central joint of the front half-casing. Its central position in the axial channel of the power unit and the absorption of side loads was secured by six springs.

The antennae system consisted of four metallic projections, two with a length of 2.4 meters and two with a length of 2.9 meters. These projections, which were fixed to insulators, would spring into position following separation of the sputnik. When the sputnik was mounted on the final rocket stage, the antennae were folded inside a conically shaped adapter, which had an angle of 46 degrees, and were held in position by eight catches. After separation, the angle between the opposite projections increased to 70 degrees, which insured the best possible performance of the antennae system.

The thermal control system maintained a constant temperature level within the sputnik despite the changeable outside temperatures between the sunny and sunless sides of the Earth. This included a switch operated by a thermocouple controlling a ventilator. This ventilator was switched on when the temperature reached more than 30 degrees centigrade, the circulating nitrogen gas transmitting the heat to the rear half-casing, whose outer surface had a radiation coefficient E = 0.35-0.4 as against an absorption capacity of solar radiation with a coefficient of A_S - 0.23-0.27, and it acted as a radiator, radiating the surplus heat into space.

On the outer shield the ratios of the (optical) coefficients were A_S = 0.2-0.25, E = 0.05-0.1, while on the inner surface they were E = 0.8-0.9. When the temperature of the nitrogen gas dropped to between 20 and 23 degrees centigrade, the ventilator was switched off, which resulted in a marked rise of the heat resistance between the radiation surface and the inner volume of the sputnik and prevented a further lowering of the temperature.

The switching on of the power supply of the radio equipment and the pressurization system after the sputnik had been placed in orbit was effected by a commutator, by means of a switch, which went into action when a circuit closed at the moment of separation of the sputnik from its carrier-rocket.

The separation was effected by pneumatic pressure at a speed of 2.73 meters per second. To prevent failure, a parallel pyrotechnical system was also installed, producing separation at a speed of 1.54 meters per second. At the same time, a spring ejector effect (at a speed of 0.643 meter per second) the separation of the dome, or conical shield, which protected the sputnik from aerodynamic and heat effects while it was traveling through the denser layers of the atmosphere on its way into orbit.

To avoid a collision between the last stage of the carrier-rocket and the sputnik after separation, the last stage was braked by jets, produced by the escape of gases from an opening in the top of the oxidant containers, drawn from the remaining pressure inside the containers.

The weight of the first sputnik was as follows:

1. The body of the sputnik: 13.9 kg
   a. Upper half-casing 5.8 kg
   b. Lower half-casing 5.9 kg
   c. Shield 1.6 kg
   d. Other parts 0.6 kg
2. Equipment, wiring, and power sources: 58.4 kg
   a. The power source unit 51.0 kg
   b. Radio transmitters 3.5 kg
   c. Remote control switch 1.6 kg
   d. Ventilator 0.2 kg
   e. Diffuser 1.2 kg
   f. Commutator unit 0.7 kg
   g. Pressurization ducts and pyrotechnical switch 0.4 kg
   h. Reinforcements 0.8 kg
3. Antennae 8.4 kg

4. Other parts 0.3 kg

Total 81.0 kg

The flight of Sputnik I was followed by a network of radio tracking stations. The head of the (launching) operation was L. A. Voskresensky and the director of the operation team was Nosoc. The launching was set for 4 October 1957, and indeed the carrier-rocket took off at 22.28.04 hours (Moscow time) on 4 October 1957. After separation from the carrier-rocket, the radio transmitters aboard Sputnik I came to life. The angle reflector on the last stage opened and enabled tracking of the flight of the carrier-rocket.

On the following day the events, which on 4 October had taken priority in the world press, gave way to reports on this historic achievement of Soviet science and technology. Nobody had expected Soviet scientists and engineers to score such a brilliant success in such a short time.

Monitoring throughout the first five orbits showed that the signals sent by the radio transmitters aboard the sputnik were well received. Sputnik I passed over Moscow at 0148 hours Moscow time on 5 October 1957. It took the sputnik 96.3 minutes to orbit the Earth; the orbital angle was 65 degrees.

The radar tracking stations continued to plot the trajectory coordinates until the end of November 1957. A large number of stations tracked the sputnik until November 5, but afterwards this was done by only 10 stations. The signals ceased on November 15, probably due to the disintegration of the lining of the angle reflectors on the carrier-rocket.

Two stations took fixes of the ionized trail in the upper layers of the atmosphere caused by the passage of the carrier-rocket, which itself had become an artificial Earth satellite. Two sputniks were plowing through the sky! People could observe the spacecraft with their naked eyes, for it was quite clear in the sky, and, at each of the passages over Moscow, many people gathered in the streets, in particular outside the Planetarium, to watch.

Soviet scientists carried out observations that allowed them to determine the coefficient of absorption of radio waves in the ionosphere and the effect of the ionosphere on the diffusion of radio waves. They also examined methods of determining electronic concentrations above the maximum layer F_2. The signals of the transmitter, operating on 20 megacycles, were tracked at a distance of 6000 to 8000 kilometers, the maximum distance of reception being 16,000 to 17,000 kilometers. This could be done because of the free diffusion of the sputnik's signals.

Optical observations made it possible to determine the parameters of the trajectory of the carrier-rocket. They were carried out with AT-1 telescopes operated by amateur astronomers recruited from among university students and the staff of astronomical observatories. Their observations made it possible to determine the star magnitude of the sputnik, which turned out to be magnitude 5 to 6 in the case of the sputnik, and up to magnitude 2 in the case of the carrier-rocket. To compute the elements of the orbits, observers made use of forecasts of the movements of the two satellites and also of data provided for the needs of more precise optical instruments.

As the first sputnik slowed down in its flight through the atmosphere, the time taken to orbit the Earth decreased by approximately 1.8 every 24 hours, or 15 orbits. The first sputnik lasted as a celestial body for 92 days and nights, and during that time executed 1400 orbits of the Earth. On 4 January 1958 it reentered the lower layers of the atmosphere and ceased to exist.

The higher air resistance (drag) met by the carrier-rocket was responsible for the fact that it existed as a satellite for only 58 days and nights. By 30 November 1957 it was observed taking much less time to orbit the Earth, and that it was flying much lower than the sputnik. On December 1 the carrier-rocket dropped markedly in the sky when flying along a course passing over Irkutski, the Chukotka Peninsula, Alaska, and down the western coast of North America. The carrier-rocket had begun its descent into the lower layers of the atmosphere and soon burned up.

The launching and flight of the first sputnik made it possible for Soviet scientists to accumulate an invaluable store of knowledge on the laws governing the movements of artificial Earth satellites, the density of the upper layers of the atmosphere, and the ionosphere. They learned much about the temperatures in which the sputnik was operating, and it was established that while the radio transmitters aboard the sputnik were working, i.e., during the first fortnight of its flight, there were no punctures caused by meteorites and no damage to its pressurization.

The flight of the first artificial Earth satellite created by the Soviet people opened the way to further sputniks, to the flights of space rockets and man himself into space. The flight of the first Soviet-made sputnik 16 years ago marked the beginning of the Space Age that holds out to man fantastic prospects for exploring interplanetary space for the benefit of future generations of mankind.