"Synopsis of a Report on the Development of a Conceptual Design of an Artificial Earth Satellite"

This document was signed by Sergey P. Korolev on 25 September 1956.
It is the detailed technical plan for the 'Object D,' the first Soviet satellite project. The program was approved by a decree of the USSR Council of Ministers on 30 January 1956 and envisaged the launch of a heavy scientific satellite in 1957 at the start of the International Geophysical Year.
The Object D program was a direct result of Korolev and Mikhail K. Tikhonravov's request to the government in May 1954 to launch an artificial Earth satellite.

Korolev's position at the time was:
Chief Designer and Chief of the Experimental Design Bureau No. 1 (OKB-1).

Source: Source: M. V. Keldysh, ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty* (Moscow: Nauka, 1980), pp. 362-368.

Synopsis of Report
on Development of Conceptual Design
of an Artificial Earth Satellite[1]

[1956]

The Decision of January 30, 1956, stipulates creation in 1957 - 1958 of a non-orientated artificial earth satellite on the basis of a missile under development (Object D), having the following basic characteristics:

⇒ satellite weight 1,000 - 1,400 kg

⇒ weight of scientific research hardware 200 - 300 kg

⇒ first test launch of Object D scheduled for 1957.

This report will discuss the basic results of development of the conceptual design of a missile to be used as satellite launcher.

It should be noted that development of this Conceptual Design had not been conducted by an accident: it is the result of all prior work of the organizations that had taken part in development of the RDD missile. Operations of these organizations included work on the turbopump rocket engines, control systems, a satellite tracking complex, a ground equipment complex, and gyroscopic instrumentation. A number of organizations of the USSR Academy of Sciences also took part: the V. A. Steklov Applied Mathematics Institute, the Institute of Automation and Telemechanics, etc. First works of M. K. Tikhonravov and his team and their participation in the Conceptual Design of the artificial satellite are of a special value.

During recent 5 - 7 years operations with DD missiles have been conducted by the OKB and by departments of the Head Scientific Research Institute with development of scientific and research themes, and a number of RDD missiles of increasing range have been built by effort of the whole industry. I am not going to discuss these operations in detail, because everybody here is familiar with these operations.

1. Basic Objectives of Explorations with the Help of the Satellite

The program of comprehensive scientific explorations envisaged to be carried out on board the first satellite is wide-ranging enough.

1. Measurement of density, pressure, and ion composition of the atmosphere at 200 to 500 km altitudes.

2. Investigations into the corpuscular radiation of the sun.

3. Measurement of the positive ion concentration along the orbit.

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[1] The design of Object D was implemented completely by launching the third Soviet artificial earth satellite on May 15, 1958.
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4. Measurement of the inherent electric charge.

5. Measurement of magnetic fields at 200 to 500 km altitudes.

6. Study of cosmic rays.

7. Study of UV and X-ray solar spectrum areas.

8. Studies of possibility of survival and life of animals during long-term residence on board a spacecraft[2].

To accomplish all this, the satellite has to accommodate on-board equipment of various types and for various functions for conducting scientific research as follows:

⇒ telemetry hardware for recording scientific data, having a programmable device controlling conduct of measurements;

⇒ a memory and a radio command line for sending commands from the ground and for transmitting the data recorded during conduct of the scientific research back to the ground for reception at the ground stations when the satellite is orbiting over the territory of the USSR.

In addition to the above-mentioned objectives of scientific research, launches of the first satellite will have to allow the following first experimental data to be obtained. It will be necessary in the future for development of an improved orientated satellite, which will be designed for orbiting at much higher altitudes and will have a much longer orbit life:

1) data on the character of movement of the satellite, its operation, and accuracy of measurement of coordinates and tracking data;

2) data on the character of the satellite's movements with respect to the center of gravity;

3) data on satellite braking in the atmosphere, bearing in mind scarcity of our knowledge in this respect;

4) data on the thermal conditions of the satellite in orbit;

5) data on the power supply problems.

Those are in brief our objectives concerning the satellite.

The operations aimed at creating the first artificial earth satellite represent, beyond any doubt, an important step in the way of mankind into the universe, and we are now entering a new field of the missile technology associated with development of the interplanetary missiles.

As a result of a thorough elaboration of the program of research operations to be conducted on board the satellite, the Commission of the Academy of Sciences chaired by Academic M. V. Keldysh has found that one option of the satellite is not enough, and it has been deemed reasonable to have three options with different sets of equipment.

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[2] These studies were conducted on board the second Soviet artificial earth satellite launched on November 3, 1957.

The weight of the satellite, based on components of equipment and bearing in mind availability of the existent power supplies, the radio telemetry system, tracking equipment, etc., is about 1,250 kg. This includes the weight of the shell of about 250 kg.

2. Specifics of the Satellite Design

1. Absolute tightness and air pressurizing to maintain a constant pressure.

2. Severe thermal conditions and the need of thermal control within +5 to 30°C (thus a temperature of 10 to 20°C is required for operation of the cosmic rays research hardware).

3. A large quantity of structural elements of equipment, modules, mounting assemblies, etc.

4. Numerous pickups on board the satellite, each having its own lines, etc.

To insert a satellite of the necessary weight into orbit, it is necessary and advantageous to modify operating conditions of the propulsion unit of the central module by bringing them closer to those optimal for a given product, based on the available power data of the missile. It is assumed that the central propulsion will be throttled down to about 60 tons of the pull beginning with the lift-up moment. V. P. Glushko will give a more detailed information on the experimental studies aimed at building the propulsion.

3. Choice of the Orbit Parameters

For these power conditions and for the missile parameters for a given weight of the satellite, the satellite can be inserted into different orbits. The choice of reasonable orbit parameters was made first based on the need to achieve a long enough orbit life (close the maximum), and second, based on the perigee altitudes that are not too small (> 200 km). This is especially important if the density of the atmosphere proves greater than expected.

The projects assumes the procedure of propulsion deactivation by means of an integrator set up two times below the guaranteed propellant reserve (with respect to the nominal reserve).

In this case, the propulsion will be deactivated by the integrator for 90% of all launches, with the velocities at the end of the active leg for the above-mentioned 90% of the products (7915 ± 20 m/s) being 65 to 70 m/s higher than the velocity occurring with the nominal guaranteed reserve. The rest of the products (10%) will have a scatter of velocity within the above mentioned range of 65 to 70 m/s (7850 to 7915 m/s).

This gives the following orbit parameters for two cases, respectively:

a) with deactivation by the integrator, using 50% guaranteed residues $G_{guar.} = 0.5^{nom.}{}_{guar.}$ (90% of launches);

b) with deactivation after burning out propellant in the worst case (corresponding to $v_n = 7850$ m/s).

It should be noted that about 190 m/s are added owing to the earth rotation during launch to northeast, taking into account the launch point latitude (azimuth 35°).

For each of these two cases, the nominal values of the orbit parameters can be determined (in the event there is no scatter of the parameters at the end of the active leg) ,and the limit values of the orbit parameters can be determined (corresponding to the worst combination of scatter of the parameters at the end of the active leg).

The ultimate parameters were calculated on the basis of the following deviations:

$\Delta v_n = \pm 20$ m/s; $\Delta \vartheta_n = \pm 0.6°$; $\Delta h_n = \pm 6$ km.

It should be noted that the satellite life span values were calculated based on the Mitre data on density of the atmosphere as recommended by the GeoFIAN.

Based on some other data (e.g., according to Spitzer), density of the atmosphere at 200 to 230 km altitudes is several times as great in comparison with the Mitre data, and it is 10 to 100 times as great at the altitudes of 300 to 400 km. At the same time, the object life span is approximately inversely proportional to the density at the altitudes of 200 to 250 km.

For these reasons, the drag for the object in determining the life-span was assumed to be two times as short as the calculated time so as to have the upper limit value assessment, bearing in mind a potential inaccuracy of the theoretical calculation of aerodynamic coefficients at such altitudes. It will be required to have a perigee altitude of at least 200 km.

A greater fraction of the reserve could be used, or the engines could be even run without deactivation by the integrator, but in such case the scatter of the orbit parameters would increase (the scatter of the one revolution period is seven minutes for the case of deactivation upon propellant burn-out).

4. Specifics of Separation of the Stages

Throttling down the central propulsion impairs the separation process and can result in a risk of collision of the separated stages because of the relatively low acceleration values. This problem is resolved by delaying separation until a high altitude is reached and by throttling down a side-mounted propulsion (to 75% of the initial pull) about 17 seconds before separation. Throttling down the side-mounted propulsion reduces the dynamic head at separation from 145 to approximately 100 kg/m^2, but it also results in the velocity v_n being decreased by about 15 m/s. At the same time, throttling down the side-mounted propulsion reduces loads during separation and allows the central object propellant module to be retained.

Therefore, the main differences in the modified product are as follows:

- ⇒ the central propulsion pull is lowered to about 60 t (in the vicinity of the earth); the side-mounted propulsion is throttled down about 17 seconds before separation;
- ⇒ the radio control hardware is removed (weight saving of about 300 kg);
- ⇒ the radio module is replaced by an adapter module for attachment of the product to the satellite;
- ⇒ the rocket-based measurement system is minimized.

With all the above modifications, the product can be launched with a steady flight, the stages can be separated, and the satellite with a preset weight can be inserted into an orbit with the errors of ; $\Delta\vartheta_n = \pm 0.6°$; and $\Delta v_n = \pm 20$ m/s.

The pressurization value and the thickness of all load-bearing shells remain the same.

5. Brief Characterization of the Orbit

The satellite orbit will extend over a large area of the earth. The flight altitude and the time of flight over the USSR, North America and especially in the region of Mirny settlement for passage over the region of the magnetic maximum are given in the Table.

Satellite Altitudes and Flight Time over the Territory of the USSR, People's Democratic Countries and North America

	Parameters	Orbit revolution No.																Total in 24 hours
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	163 minutes (11%)
Flight over USSR and People' Democratic Countries	Flight time, minutes	20	18	19	13	16	10	6	4		"Mimy"		-	8	16	17	17	163 minutes (11%)
																12 rev.		Total about 15 rev.
	Altitude, minimum, km	230	230	230	240	240	260	280	280	-	-	-	-	230	230	230	240	
	Altitude, maximum, km	290	310	320	310	310	350	330	300	-	-	-	-	240	260	270	280	
Flight over North America	Flight time, minutes	-	-	-	-	-	-	10	17	14	12	19	20	16	13	3	-	124 minutes (8.5%)
																9 rev.		
	Altitude, minimum, km	-	-	-	-	-	-	220	240	250	230	230	230	240	240	250	-	
	Altitude, maximum, km	-	-	-	-	-	-	240	250	330	260	300	320	340	330	260	-	

Total flight time over USSR over 24 hours is 137 minutes (9.5%).

Note: The data correspond to the nominal orbit during the first 24 hours and to the nominal propellant reserve.

6. Basic Problems in Satellite Design

Provision of the required temperature conditions on board the satellite (0 to 30° and 10 to 20° for certain instruments).

On-board hardware power supply.

On-board hardware operation control (according to a preset timed program).

Provision of a radio telemetry system with a memory.

Provision of a tracking complex.

Sealing of the satellite for a prolonged period.

Provision of a system of omnidirectional antennas.

7. Specifics of the Thermal Conditions

The thermal conditions are characterized by material changes in the thermal exposure factors: solar radiation, solar radiation reflected by the earth, and substantial heat release from the on-board hardware.

The components of the thermal balance sheet are as follows:

⇒ direct solar radiation [about 1160 kcal/(m^2·hr)];

⇒ solar radiation reflected by the earth (about 40% of the direct solar radiation);

⇒ earth radiation;

⇒ atmospheric air friction;

⇒ heat of recombination of atomic oxygen on the satellite surface;

⇒ heat release from operating on-board hardware (from 200 to 1600 kcal/hr).

The thermal conditions are controlled by means of a radiation wall of the sealed module, irradiating heat into space owing to a high degree of opacity ($\varepsilon>0.8$) in the infrared spectrum area (ε is the coefficient of opacity for the overall normal radiation). A special coating of this wall assures low absorption of the solar radiation (the coefficient of absorption $A_s \leq 0.3$ for the visible and ultraviolet areas of the spectrum, in which the solar radiation energy has its peak value).

Transfer of internal heat release is assured by forced circulation (by a fan) of nitrogen in the sealed module through a passage adjacent to the radiation wall. When temperature decreases, this passage is closed by a valve to cause a material reduction of heat removal to the space environment. An additional thermal control device is in the form of louvers on the radiation wall. Weight of the thermal control system of the main sealed module is 60 to 70 kg together with power supplies.

Bearing in mind special requirements imposed upon cosmic ray research hardware, a special thermostatic module is provided and isolated from external exposure.

The sealed module surface will be protected on the insertion leg against aerodynamic heating by means of a drop shield with panels. The thermal conditions of the satellite on the launch pad will be controlled by ground equipment because there are no weight resources for an additional on-board device.

The above mentioned coating ($\varepsilon > 0.8$; $A_s \leq 0.3$) is crucial for assuring the thermal conditions. It is necessary to investigate its properties in orbit. Research in this area has not been very extensive.

The calculation shows that preset thermal conditions can be realized with the chosen layout of the satellite.

8. On-Board Hardware Power Supply

Power supply is assured by using electrochemical current sources: silver-zinc storage batteries and mercury oxide batteries.

At the same time, the weight characteristics of the power supply system are poor (a weight of up to 450 kg) and the operation time is short. The reason is both a low power capacity of the batteries (50 to 70 W·hr per 1 kg on the average) and high energy consumption of the on-board hardware.

It is necessary to expedite development of a solar array and to work for lowering energy consumption of the hardware.

9. Experimental Debugging of the Satellite Design

1. Experimental debugging of functioning of all hardware and telemetry equipment.

2. Debugging of sealing, lead-outs, etc.

3. Experimental debugging of thermal control:

⇒ building a full-scale thermal mock-up with real operating hardware;

⇒ experimental investigations into heating of the satellite structures in the insertion leg;

⇒ experimental investigations into properties of special coatings for the radiation surface.

The thermal mockup for studying the internal thermal conditions will be tested in a special plant assuring the design temperature of the sealed module shell, thus reproducing the internal thermal conditions within the satellite.

The external thermal radiation exposure factors that determine temperature of the shell can be calculated accurately enough.

4. The experiments aimed at studying properties of special coatings in orbit are also crucial, bearing in mind high vacuum, collisions with molecules and ions of rarefied gas at velocities greater than 10 km/s, ultraviolet radiation of the sun, etc. These experiments can be conducted by specialized institutions of the USSR Academy of Science.

5. Debugging the electrochemical power supply sources (hydrogen release and explosion safety.