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Chapter 15

UPPER ATMOSPHERE RESEARCH AND THE FIRST ROCKET EXPERIMENTS IN THE USSR*

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On 24 May 1949, scientific instruments were lifted for the first time in the Soviet Union by a rocket to an altitude of 110 km for measuring atmospheric pressure and sampling of air.

Almost the whole mass of the Earth's atmosphere is concentrated in its lower 30 km layer. The higher layers contain only 1-2 percent of the whole air mass. Nevertheless, it is precisely this region of the Earth's gas envelope that has attracted the attention of scientists for a long time. The reasons for this are extremely important both from the scientific and the practical points of view.

To begin with, the upper atmosphere serves as the first barrier along the path of the solar radiation to the bottom of the air basin, the terrestrial biosphere. As it impacts this barrier, the radiation not only undergoes considerable changes in itself but also causes a radical reconstruction of the atmosphere's structure. Aurora and luminescence of the night sky occur, as do disturbances of the magnetic field of Earth. It is known that the state of the upper atmospheric layers, primarily of the ionosphere, affects the nature of radio wave propagation.

Some information about the upper atmosphere is provided by study through ground methods. However, it is extremely difficult and sometimes impossible to obtain a number of most important data by ground methods. This includes data on the short-wave ultraviolet radiation of the Sun as well as on the nature of its corpuscular radiation; of ionization above the reflecting layer of the ionosphere; of composition, density and temperature of the upper atmosphere; etc. This type of information requires penetration of research instruments to an altitude of 100 km and above. At present the attainment of such an altitude is routine and surprises no one, but not so long ago it seemed formidable.

The only technical means to reach 100 km or more was the rocket. In the Soviet Union, the first rocket designed for scientific research was constructed in

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1949 under the supervision of S.P. Korolev. From that moment, an entirely new stage began in the study of the upper atmospheric layers.

Rocket research in USSR and in U.S.A. began almost simultaneously and subsequently developed quite independently of each other. The principal feature of our experiments has been that the whole scientific apparatus designed for measuring the parameters of the atmosphere at high altitudes was located in a robot-container, separable from the carrier rocket.

The fact is that the rocket body is not fully hermetic and in the rarefied atmospheric layers there is an intensive emanation of air, filling it prior to takeoff with remains of unconsumed fuel, combustion products of fuel, etc. The "parasite" gas surrounds the rocket by a unique cloud, which may distort the picture being observed and even ruin the experiment. This is highly prominent at altitudes above 80 km, where the pressure drops below 10^{-4} Hg mm.

In the Geophysical Institute of the USSR Academy of Sciences (GEOFIAN), new trends were devised for the research of the upper atmosphere (1946-1949). The scientific apparatus for this research was designed under the supervision of B.L. Dzerdzievskii and E.M. Reikhrudol. It was here, too, that the idea of the separable container was born and, moreover, that a new hermetically sealed container of this type -- FIAR-I (physical research of atmosphere by means of rockets) was constructed. The institute was initially under the direction of O. Yu. Schmidt and later of G.A. Gamburtsev.

Being an absolutely new sphere of research, rocket experiments in the upper atmosphere raised one problem after another. How would the vibrations generated by rocket engines, it was asked, affect the scientific apparatus, which includes brittle thin-walled glass cylinders, electric instruments, clock mechanisms, storage batteries, etc.? What about the performance of instruments and how they would it be affected by their overheating due to aerodynamic braking? How would one conduct the recording of instrument readings (portable autonomous telemetric systems did not as yet exist)? And how would one set up the power supply accessories and what exactly should they be? Should the whole container be hermetically sealed or only a section of it? In what shape should the container itself be? Cylinder, sphere, or parallelpiped?

In the first launchings of FIAR-I, whose length was about 1 m, diameter about 40 cm, and weight 85 kg, the feasability of the direct research of the high atmospheric layers by means of the rocket-container system had to be experimentally established and confirmed. This required separation of the container with its instruments from the rocket at a rigidly prescribed moment of flight and to ensure its descent and landing by parachute. The latter was an independent and complex engineering problem -- to lower the container carefully from an altitude of 100 km onto the ground and preserve the scientific apparatus. The problem was being solved for the first time. It should be mentioned that the parachute system for the FIAR-I container, just as the rocket itself, was devised and tested by the specialists at the Design Bureau headed by S.P. Korolev.

The first Soviet geophysical rocket IRA (academic) was based on the R-I ballistic rocket, with certain changes in construction of its tail and head as well as in the control system. The first launching of IRA took place, as mentioned at the beginning of this paper, May 1949. At 4 hours 40 minutes, the rocket rushed upward along an almost vertical flight path, carrying with it scientific apparatus weighing about 200 kg.

At a prescribed time after engine cutoff, on command from the program device, the containers FIAR-I, two symmetrically arranged tail compartment mortars, were ejected; and, having obtained some additional velocity (with respect to the rocket), accomplished an independent flight.

Due to the fact that the axes of mortars formed a certain angle with the rocket axis, the containers went sideways from it and, outstripping it, left the zone, where the composition of the atmosphere could have been highly distorted by "parasite" gases. The ejection of containers was carried out prior to the rocket's attaining the altitude of sampling. This was done so that the containers would move out as far as possible from the rocket's body, being thus "ventilated" and freed from the remaining contaminating gases. Having attained the ultimate altitude, the containers began their descent suspended by parachutes.

In the first first flights it was established that the apparatus for the direct physical study of the atmosphere was efficient at all the stages of ascent, ejection and descent of containers and also withstood the accelerations and vibrations. During these flights, measurements were conducted of pressure and density of the atmosphere at altitudes 35 to 115 km and air samples were taken at altitudes of about 100 km. The process of recording on the film showed that atmospheric pressure at the apex of the rocket's flight path was 8.10^{-4} Hg mm.

As regards research on the samples' chemical composition, special methods were devised for this using spectral analysis under laboratory conditions.

On the basis of atmospheric pressure gauging, it was possible to plot temperature curves calculated from the barometric formula.

The successful determinations of the physical parameters of the upper atmosphere, implemented during the first rocket flights, have raised the question of organizing this kind of research on a large scale. S.P. Korolev, who played a significant part in setting up this research, always met the needs of experimenters with great willingness, participated directly in conducting all the tests on rockets, and discussed and analyzed the results obtained jointly with the scientists.

The method of air sampling (and its subsequent laboratory analysis) was later replaced by gas analysis method, carried out by means of radio-frequency mass-spectrometer directly during the flight. The first device of this type in the USSR (and one of the first in the world) was made by V.G. Istomin in 1956-57 and was successfully used in container FIAR-2 for research up to altitudes of 200 km. Now the method of mass-spectrography is inseparable from experiments on structural parameters, determination of the terrestrial atmosphere, that of other planets, and of the cosmic space.

From 1951 to 1956, on assignment by the USSR Academy of Sciences, several modifications were devised on the base of the R-1, one of the geophysical rockets used for regular research of the upper atmosphere. The program of geophysical investigations, conducted under the supervision of Academician A.A. Blagonravov, was considerably extended.

However, it was inexpedient to use powerful rockets for mass launchings to negligible altitudes. In this case, small meteorological research rockets could be quite suitable as they could be launched in tens and hundreds annually for a quick meteorological analysis of the state of the stratosphere and ionosphere, as well as for solving geophysical problems.

These operations were conducted by another group of scientists on meteorological rocket MR-1, which was launched in 1951 by specialists of the Central Aerological Observatory (G.I. Golyshev, A.M. Kasatkin, B.T. Shvidkovskii, G.A. Kokin, et al). MR-1, of lower weight and smaller size, probed the atmosphere up to an altitude of 80 km.

The first rocket experiments, which we have described, provided a lot of new information regarding the upper layers of the atmosphere. The obtaining of air samples and their analysis have, for the first time, clearly shown that for the physics of upper atmosphere boundary-turbopause (above it is the region of molecular intermixing of atmospheric gases) the very important region is not at the altitude of 50-70 km, as previously assumed, but at altitude of 90-100 km. This was later repeatedly confirmed by many investigators. The study of the variation of pressure and temperature in relation to altitude made it possible to determine clearly the deep temperature minimum (about 150^{o}K) at altitudes of 80-90 km, which has previously been surmised from indirect observations. Very high velocity winds were discovered high in the atmosphere (100 m per sec and above), forcing revisions to be made to the question on dynamics of the upper atmosphere.

Besides research of the upper atmosphere and ionosphere, the rockets also served as a basis for solving a number of applied problems connected with perfecting the cosmic-rocket technique.

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