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Chapter 8

The "Burya" Intercontinental Cruise Missile*

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The problem of building intercontinental means to deliver nuclear warheads to the target was very acute in the Soviet Union in the 1950s, as the United States had aviation bases on the European continent, while the Soviet Union had none on the American continent. It was clear that the problem could be solved by building either intercontinental ballistic missiles or intercontinental cruise missiles. The data which would allow the choice of one variant was very scarce then, and as a result the work started in both directions. This article will be devoted only to the cruise missiles.

At the end of the 1940s and the beginning of the 1950s, an extensive cycle of theoretical and experimental research was completed. It proved the potential possibility of designing such a missile. Research work was carried on in the field of supersonic inlets for various Mach numbers, the process of burning in ramjet combustors, the process of fuel atomizing and many other things. This work was carried out under the general supervision of academician M. V. Keldysh.

Originally the center, headed by S. P. Korolev, was charged with the mission of designing both types of combat missiles. As a result, in 1953-1954, the

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work of designing an experimental cruise missile started there. Afterwards, it was planned to start work on combat missiles. An experimental missile was to have have a flying range of 730 kilometers and a speed characterized by Mach 3. For the first stage a ballistic missile R-11 was to be used (the mass of the fueled missile was 6,390 kg), for the second stage—a cruise missile with a ramjet (starting mass of 1,484 kg, weight of fuel 300 kg). Since the center headed by S. P. Korolev had a great amount of work on the intercontinental ballistic missile, it was decided, in 1954, to transfer all the work on cruise missiles to the center headed by S. A. Lavochkin. They started immediately on the combat missile, neglecting the experimental missile. This decision was based on the fact that, by that time, the aviation industry had already accumulated vast theoretical and experimental data on the issues of inventing supersonic ramjets. The flying range for the combat cruise missile was defined at 8,000 kilometers. It was preliminarily called "Burya" [Storm].

Work started in 1954 and was carried on rather intensively. By 1957 a sufficient number of cruise missiles was constructed, and after several launchings, when the boosters and their interaction with the cruise missile had been tested, the full range flights started. The launchings took place, starting in June 1957, in the region from the Volga delta up to the eastern shore of Kamchatka. Altogether there were five such flights made. They were all successful. At the beginning of 1958 all the work on "Burya" was abolished, and all the remaining missiles were destroyed. The reason for this was the successful testing of the intercontinental ballistic missile R7 in 1957, designed by S. P. Korolev; in those years such a weapon was called "an absolute weapon." Compared to the R7, "Burya" had one ineradicable drawback—it flew very low (flying altitude at the beginning was 18 kilometers, at the end—23 kilometers). That is why it was rather simple to fight against it: as it was unpiloted and was flying with a constant speed, it could easily be destroyed by anti-missile rockets, which could be specially designed for this purpose. Moreover, the defense against the cruise missile was simplified by the fact that "Burya's" flying time to reach the target exceeded two hours, while the ballistic missile could reach the target in less than an hour. Also, the latter was characterized by high altitudes beyond the atmosphere and by very high speed. At that time it was believed that such characteristics excluded the usage of anti-missile rockets in the struggle against the R7.

In all probability it was for the same reason that they stopped the work on the "Navaho" cruise missile in the U.S.A. If we compared the work on "Navaho" and on "Burya," we would discover a lot of similarities. It does not seem to be surprising at all, as both missiles had practically similar goals. It would be of interest to compare technical solutions used in the U.S.S.R. and in the U.S.A., for example to assess the effectiveness of different schemes of inlets for the big Mach numbers, which were used on both cruise missiles, and to evaluate other differences, but this is not the purpose of this paper. The only fact that should be noted here is the completion of work on "Burya." It differs from "Navaho" in that the project was executed to the full extent, including flying tests. It so happened that only "Burya" went down in history as an example of a flying vehicle of the "intercontinental cruise missile" class.

"Burya" was an unpiloted aircraft with a supersonic ramjet. This aircraft was launched at a given initial flying altitude with the help of two boosters with liquid rocket engines, moreover the vector of its flying speed by the time the boosters were switched off was of the necessary direction (horizontal) and dimension (Mach 3.2). When the ramjet started working, the boosters were separated. The effect of the requested flying range demanded a great amount of fuel reserve and consequently a rather perfect design. This perfection can be seen from the following figures: the fuel stock constituted 71% of general weight, the missile itself constituted 22%, and the warhead 7%. The main construction material was titanium sheet. By its design "Burya" can be considered as a rather simple aircraft with a delta wing of 60 square meters and a cylindrical fuselage with a length of 19 meters (not considering the protruding part of the inner body of the high Mach number inlet.)

The selected design system allowed the creation of ideal conditions for the ramjet, that is in that the multishock air inlet, where the air pressure increases, was connected to a conductor with the help of a straight cylindrical duct, and which consequently had no additional losses of pressure.

The position of a high efficiency spike inlet in the front part of the fuselage was also optimal, as the air which was going inside it was perfectly undisturbed. As is known, the supersonic inlet is most effective in the case where the vector of flying speed is parallel to the axis of symmetry of the inlet. Any other position of the inlet, relating to flying direction, diminishes its effectiveness. Therefore, this requirement should be strictly followed during the flight. However, the above-mentioned also means the constancy of the angle of attack of the wing. Besides, the high efficiency of the supersonic inlet demands that the flying velocity remains unchanged (the Mach number must be constant), that is it remains the same for what its geometric shape is calculated to be. As the weight of the aircraft was noticeably reduced during the flight (more than three times by the end of the flight), the preserving of the angle of attack and velocity constant was possible only on account of changing the density and consequently the flying altitude. This resulted in the increase of flying altitude by five kilometers at the end of the flight.

Fuel (it was kerosene) was stored in a ring-shaped tank around the duct which connected the inlet and the combustor. The supersonic ramjet used with the combustor, made from heat-resistant stainless steel, was designed and built under the supervision of M. M. Bondaryuk. This ramjet was the result of experimental and practical work for many years, which was carried on on specially designed experimental stands. The experience obtained during the tests of other ramjets for different goals was also used when this ramjet was built. As a result of the undertaken efforts, it became possible to create a high efficiency ramjet. A multishock air inlet, installed in the front part, was also the result of theoretical and experimental research by the specialists in the field of gas dynamics, which was headed by G. I. Petrov for many years. Finally, by the joint effort of many scientists and engineers, it became possible to build a supersonic ramjet, which created favorable conditions for the record flights of the cruise missile "Burya."

The boosters were located under the wings, and they were of traditional construction, similar to the construction of ballistic rockets. A combination of kerosene and nitrogen acid was used for the fuel. At the back side of each booster there were installed four liquid rocket engines with a thrust of 20 tons each, designed by A. M. Isaev. Thus, the total thrust of both boosters constituted 160 tons, which was quite sufficient to launch vertically and boost the cruise missile, the initial weight of which was 126 tons (the weight of the cruise missile was 32 tons at the launching, each of the boosters also weighed 32 tons initially).

The control over the angle attitude was obtained with the help of gas rudders, and while the velocity was being gained common air rudders became active. The flying control system consisted of two main parts. The inertial guidance control system was used for an immediate control of both the boosters and the cruise missile. This system was based on the use of a gyroscopic platform and double integrating accelerometers similar to those used for the ballistic missiles. This part of the control system was designed under the supervision of G. N. Tolstousov. The adopted decision was quite reasonable, as the launching of the missile to the given altitude and rendering to it a given vector of velocity is an ordinary task for the ballistic missiles. As far as the main flying of the cruise missile was concerned, here the task of gyroscopic devices had a very simple task to accomplish, that is they were to act as automatic pilots.

The second part of the unified control system were the optical devices for astronavigation. The primary task of this group of devices was the constant introduction of corrections into the gyroscopic devices, as it is known that they gradually deviate from the right directions. If the control system works for the short period of time, then the mistakes are insignificant. However, "Buryas" were supposed to fly very precisely for over two hours, and during this time the gyroscopic devices could deviate inadmissably from the right directions. Therefore they should be corrected constantly during the main flight. It is evident this was not needed during the boosting time.

The work of creating the systems of astronavigation started in 1947. In 1952-1953, the tests of the designed devices were conducted on aircraft. In 1955, the created system was fully tested on the TU-16 aircraft, where the signals from the astronavigating devices were transmitted to the automatic pilot of the aircraft. The testing continued for more than four hours, and the deviation of the aircraft from the predicted route was no more than four kilometers. All this testifies to the fact that, by the beginning of work on "Burya," the system of astronavigation was, in general, ready. In the process of its transfer from the aircraft to the cruise missile, specific additional difficulties occurred. One of the difficulties was the protection of optical devices from the heat, which appears during the flight with Mach numbers over 3. The effect was reached by special flat optical glasses, which successfully protected the optics.

The system of astronavigation consisted of a gyroscopic platform on which a star tracker was installed. This gyroscopic complex allowed a local vertical and the tracking of two stars to determine the location. For the navigating stars any suitable pair of stars of second magnitude (or even brighter stars) could be used. Tracking of both stars was made with the same star tracker and with a mirror that turned from one star direction to the other every five seconds.

Five above-mentioned flights of "Burya" took place in the following way. During the first flight the working capacity of the whole complex was tested. The length of the route where astronavigation functioned was limited to 1,500 kilometers, then, according to radio commands, the missile changed its flying direction to the opposite. The total length of the flight was 4,000 kilometers. As the results of the first test were satisfactory, the remaining flights were done for the full range. The first four flights were executed at night. This was done in order to facilitate the work of the star tracker. During the fifth flight the working capacity of the star tracker in daytime was checked. The results achieved during the tests showed that the system may successfully function both in the daytime and at night. All this work was carried out under the supervision of I. M. Lisovich.

Summary

In 1954-1957, the intercontinental cruise missile "Burya" was designed, built and successfully tested in the Soviet Union. Despite the fact that further work in this direction was abolished, the experience gained during the creation of "Burya," found a vast application in other spheres of engineering activities. Such spheres as supersonic inlets, ramjets, control systems, the use of titanium sheets etc., can be mentioned here. All this is used to a certain extent in modern aviation. The experience shows that the outstanding achievements are not only important for themselves, but their role in the acceleration of the development of other spheres can hardly be overestimated.