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ALTERNATE STAGE OF THE SOVIET
SPACE PROGRAM

CONTROLLED DESCENT OF AS "ZOND-6" FROM
THE PATH EARTH-MOON-EARTH

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Highlights of the Column in
Newspaper "PRAVDA" No.329 (18376)
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Unsigned Article

SUMMARY

The very recent flight of ZOND-6 around the Moon and back to solid ground in the USSR is described in detail. Emphasis is given to the solution of the more complex problem, that is, the guided descent of a spacecraft flown past the Moon, as compared to that of ZOND-5, which returned to Earth along a ballistic trajectory, splashing down in the Indian Ocean. The entire flight trajectory is divided in three parts: 1) placement into intermediate orbit of a rocket-spatial" complex with the aid of a multi-stage carrier rocket, including the station itself; 2) blast-off from the intermediate orbit and placement on the course to the Moon, returning to Earth after flying around the Moon; 3) separation of the descending device, which enters into the Earth's atmosphere and lands in the preassigned spot of the Soviet Union.

The flight problems are discussed in detail and the significance of the successful flight of the station ZOND-6 is commented.

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The flight data of ZOND-6 were the object of a TASS communique (refer to ST-PR-10776 of 22 November 1968); therefore this section will be only summarized. We should recall that the perigee was of 185 km and the apogee of 210 km; the orbit inclination was 51°4'. Once in orbit, the rocket complex performed the required angular maneuvers and the stabilization of its position in space.

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The second switching on of the rocket engine of carrier's last stage was performed by onboard command at 23 hours 18 minutes 30 seconds, so as to impart the station a velocity close to the second cosmic of 11.2 km/sec, which was required for the flight to the Moon. As the computed velocity was attained its automatic switching off was accomplished and the station separated from the last stage of the carrier-rocket.

All subsequent flight of the AS was at constant orientation at the Sun of solar cell panels, assuring its supply of electric energy. As a result of de facto motion of the station, the trajectory was close to the computed. However, in order to ensure the flight at a prescribed distance from the Moon, trajectory correction had to be made.

The correction time had to be chosen in accordance of a series of conditions. Correction at relatively short distance from Earth results in great spreads in the region of the Moon, whereas correction near the Moon may be either ineffective, or requiring substantially higher energy consumptions for assuring the optimum flight trajectory around the Moon. This is why, the correction of motion trajectory of ZOND-6 was performed at a distance close to 250,000 km from the Earth. The required initial data for the correction, such as the magnitude and direction of the correcting impulse and the switching on time of the motive power were performed by the ground coordination and computation center. Prior to correction ZOND-6 was oriented in space by the Sun and the star Sirius. All the ground data were fed to the onboard memory device, in accordance with which the station performed the further necessary angular stragglings with the aid of low-thrust engines. As a result of these maneuvers the station was oriented in space according to the computed position.

As a result of the correction, ZOND-6 flew past the Moon at a distance of 2420 km from its surface. During that time, all scientific investigations and measurements of physical characteristics of the near-lunar space were carried out.

After flight around the Moon and in order to eliminate the perturbations induced by its gravitational field, a second trajectory correction was performed at 09 hours 40 minutes on 16 November at the distance of 236,000 km from the Earth's surface (see Fig.1). Still one more trajectory correction was performed on 17 November at 08 hours 36 minutes so as to allow a more accurate entry of the descending device into the Earth's atmosphere.

These corrections assured the hitting by the descending device of the atmosphere entry corridor, whose computed width constitutes ± 10 km for a nominal value of the height of conditional perigee of 45 km. It should be stressed that in order to assure the landing at the preassigned point of USSR territory, it is necessary to hold not only the height of the conditional perigee with exceptional accuracy, but also the time of station approach to Earth. A time departure by $\pm 5 - 10$ minutes from the computed one results in a 300 km error in the return direction to Earth!

As the station approached the Earth, initial data were transmitted for the realization of the descent regime. Astro-orientation and other required station's maneuvers were performed on command from onboard program devices. Then, separation of the descending device from the instrument compartment of the station. The stabilization system of the dd quenched the angular perturbations having arisen during separation and placed it in the required position for the realization of the necessary angle of attack (angle between the device's longitudinal axis and the velocity vector), assuring the creation of the required magnitude of lift at descent.

CONTROLLED DESCENT AND LANDING

In order to accomplish landing in the calculated region of the Soviet Union, the dd must fly some 9000 km after entering the dense layers of the atmosphere, inasmuch as the station approaches the Earth from the Southern hemisphere. Generally the entry can be performed from either side, from the North ("northern entry variant") or from the South ("southern entry variant"). As far as USSR is concerned, only the "southern variant" is applicable. This is explained by the fact that at entry from the North, the point of entry lies practically in all cases on the southern boundary of USSR territory. The "northern variant" could be used in exceptional cases, whereupon it would be attended with exceptionally high overloads. There is another extremity in the "southern variant", namely that the entry point is remote from the southern boundary of USSR by several thousand km. These distances can be overcome by the dd only at controlled descent.

The guidance of the flying craft is most rationally assured by the use of the aerodynamic lift and drag. This form of descent, called "controlled descent", was used for the first time by ZOND-6. By comparison with the ballistic descent it is much more complex, for it requires two dd dippings into the Earth's atmosphere. This requires the availability of an especially accurate guidance system. The one chosen on ZOND-6 was based upon the regulation of the aerodynamic lift at the expense of variation of the direction of its action. The aerodynamic lift ratio to drag is called the aerodynamic quality. The greater the aerodynamic quality, the more slanting the descent trajectory, the greater the flight remoteness and the wider the maneuvering possibility of the dd.

Fig.2 shows the descent trajectory with their various portions. The main problem of the system over the portion of initial dipping into the atmosphere is the guarantee with high precision of such values of flight velocity and inclination angle of the trajectory that would assure the computed range prior to the beginning of the portion of the second dipping. Over the last portion of flight deceleration takes place from 11.2 km/sec to ~ 7.6 km/sec at the expense of aerodynamic drag, provided specific limitations are observed in respect to overloads and thermal regime. The maximum values of axial overloads over the sector of the first dipping are mainly dependent on the height of conditional perigee, and constitute 4 - 7 units. The controlling action of the aerodynamic lift prevents over this portion of trajectory its distortion along the direction toward Earth, occurring as a result of aerodynamic braking, preventing the device to descend below the calculated height.

SKETCH SHOWING THE MANEUVERING OF THE DESCENDING DEVICE (DD)
OF THE AUTOMATIC STATION "ZOND-6" IN THE EARTH'S
ATMOSPHERE

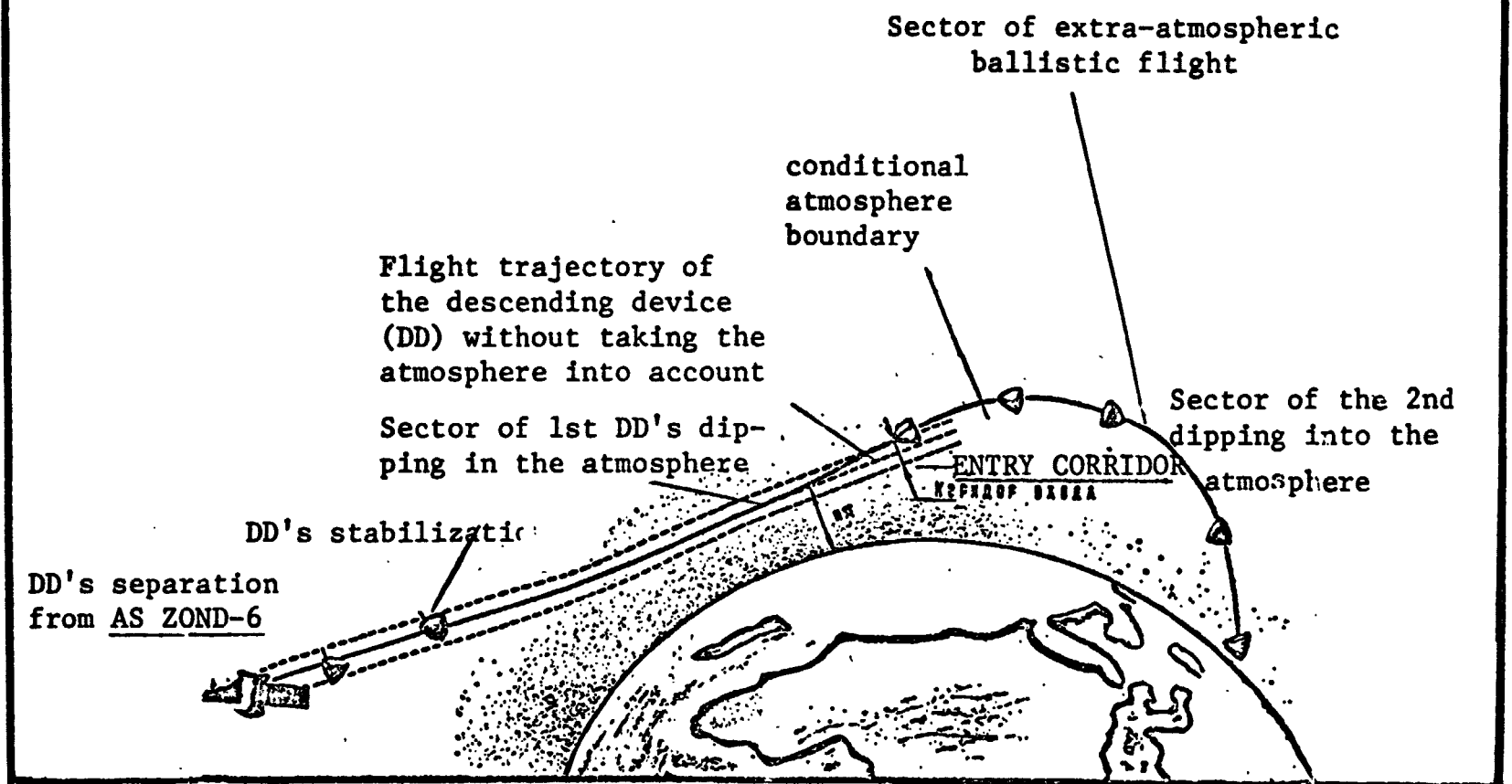


FIG.2

After that, the device emerges from dense layers of the atmosphere and performs a noncontrolled flight along the ballistic trajectory.

During the recurrent (second) dipping into the atmosphere, the choice of the descent program for this sector is made by the automatic guidance system with assurance of landing at the preassigned place of Soviet Union territory with very high precision. Over this sector the thermal flows are substantially less than during the first dipping, and do not exceed those taking place during descent of artificial Earth's satellites. However, the fact that the thermal insulation is subject to heat for the second time complicates the reliability of thermal shielding, implying its complex structure that includes a special selection of heat-resistant materials.

The dd of AS ZOND-6 entered the dense layers of the atmosphere on 17 November 1968 at 1658 hours. As the velocity was about 200 km/sec at the altitude of 7.5 km, the parachute system was switched on and the device landed.

SCIENTIFICO-TECHNICAL PROBLEMS OF FLIGHT

Many scientific problems connected with radiation hazards in a period of increased solar activity were tackled, especially with emphasis on their effects on living beings. In this regard, ZOND-6 pursued the program started by ZOND-5 with the use of biological objects.

At the same time experiment was conducted with a photoemulsion chamber, permitting to obtain data on the multi-charge component of primary cosmic rays at great distances from Earth (of the order of several hundred thousand kilometers), which is in the region of high charges.

A registration device of meteoric particles was also installed on board of ZOND-6. Its interest centered in the passage of the station on its return journey through the Leonides meteoric shower, with its well known, particularly high encounter velocity with the Earth (about 72 km/sec). This stream, which is one of the most remarkable natural phenomena that people observed more than once in the form of a bright shower of "falling stars", has this time apparently shifted in space probably on account of Jupiter attraction. Obviously, only the forthcoming data processing can tell us the extent to which this encounter actually took place.

Of particular interest is the prospective study of the film with the image of lunar surface taken from heights from 10000 to 3500 km. This film, with high resolution, permitted the obtaining of high quality photographs, especially by comparison with the photo-television pictures obtained from LUNA-3 and ZOND-3. The good quality of pictures is explained by the absence of the usual interferences taking place when these are transmitted by radio channels. The photographs obtained have a 13 by 18 cm cadre dimension and the objective had a 400 mm focal distance. Obviously, a detailed analysis of this material will require some time, but, as of now, it is already permitted to speak in terms of large volume of new and valuable information delivered to laboratories.

The technical achievements during the flight of ZOND-6 consist in the further improvement of the flight itself along the route Earth-Moon-Earth and of the system of controlled (guided) descent during atmosphere entry with the second cosmic velocity. The guidance itself is based upon the overload variation at atmosphere entry.

Indeed, over the nominal, computed trajectory the overloads vary in a strictly specific fashion, so that a program can be assigned of overload variation, for example, according to time of descent. In a real flight, by measuring the acting overloads and comparing them with the program overloads, one may obtain a representation on the character of motion. Thus, for example, if overloads exceed the programmed values, this means that the device proceeds over a trajectory below the computed one.

One should particularly stress that the operation of the guidance system is not controlled from the ground, since the descending device is surrounded by a sheet of ionized air, making the communication with Earth impossible. This imparts additional and peculiar requirements to guidance system reliability and renders the automatic flight exceptionally complicated from the technical viewpoint.

Finally we should mention the working off in flight conditions of the aerodynamic shape and characteristics of the descending device.

The most appropriate for the latter is the application of axi-symmetric segment-conical shapes for the protruding parts. For the realization of the aerodynamic lift for such devices, it is necessary to compose them in such a fashion that the center of gravity be displaced relative to symmetry axis. Then, during its motion in the atmosphere the device will have an angle of attack, the so called balancing angle, and the incident air flow will come at an angle to the device's axis of symmetry. The asymmetric streamline flow past a symmetrical body assures the onset of the aerodynamic lift.

SIGNIFICANCE OF ZOND-6'S FLIGHT

The successful performance of ZOND-6 has clearly shown that Soviet engineers and scientists made still one more step forward on the difficult path of mastering space routes with return of spacecrafts to Earth. It has completed the tasks assigned to preceding Zond series and allowed to obtain a series of important experimental data on the construction of onboard systems and on the instrumentation of piloted spacecrafts for manned flights to the Moon. The Soviet Union materializes in sequence the scientifically founded program for the study of the Moon, considering it as a very important object of research.

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Translated roughly and rapidly

by ANDRE L. BRICHANT

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