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Chapter 11

Construction and Testing of the First Soviet Automatic Interplanetary Stations*

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Rocket-Carrier for Station Launching into Interplanetary Trajectories

After the launch of the first Soviet lunar rockets carrying Earth satellites, and a space probe to make photos of the back side of the Moon (Luna-3), the Experimental and Designing Bureau (EDB) of Sergei Korolev started, early in 1960, developing automatic interplanetary stations (AIS) for studying Mars, Venus and interplanetary space. These stations were planned for launch into interplanetary trajectories with the then-available R7 rocket, with new third and fourth stages also developed in Korolev's EDB.

One of the typical features of interplanetary flight is, that the angle formed by the carrier rocket velocity vector with the local horizon should be large enough by the end of the active trajectory portion for the AIS to be inserted into a heliocentric orbit, which ensures the station entry into the sphere of activity of the target planet, and touching it or passing near its surface. This reduced the admissible mass of the station along a continuous active portion of the orbit, because of the additional velocity loss due to the Earth's gravity field. To make

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the station mass larger, a new technique of launching into the interplanetary trajectory was developed. The essence of this technique is that the fourth stage of the AIS-carrying rocket was first inserted into the low orbit of the Earth satellite, at a certain point of which—depending on the target planet and the launch date—that stage engine was switched on, and the AIS was sent into an interplanetary heliocentric orbit. Soon that technique was also to launch the first Soviet communication satellites with 12- and 24-hour periods. The above-mentioned four-stage rocket to implement that launch technique was called Molniya (the lightening). The spacecraft intended for soft landing of an automatic research station (Luna-9) on the Moon was also launched with the same rocket.

It should be mentioned that to employ this new technique for spacecraft launching into interplanetary and lunar trajectories, as well as for communication satellite launches, the rocket designers at Korolev's EDB had to solve a new problem, that of switching of the fourth-stage engine in weightlessness. A special launch-support system was developed for this purpose, which featured solid-propellant engines with a small impulse for initial acceleration required for a reliable launch of the main engine of the fourth stage.

The lessons of development and testing of the first Earth satellites, of equipment—carrying containers mounted on lunar rockets, as well as of the Luna-3 spacecraft that made photos of the back side of the Moon, had been taken into account in Soviet AIS-designing. In particular, by the 1960s, Korolev's Experimental and Designing Bureau and its pilot production facilities already realized how to provide the required air-tightness of instrumentation containers and their testing. Principles of spacecraft thermal control were elaborated first; thermal environment chambers appeared for checking thermal modes of spacecraft on the ground; onboard systems were developed to supply the instrumentation with power and to provide the in-flight spacecraft control.

The development and testing of the above mentioned Luna-3 spacecraft helped very much in building the first AISs. For the first time Luna-3 employed an orientation system, solar panels as an electric generator common for all onboard systems, and a photo- and TV-device—that is, the systems and units without which no long-duration interplanetary flight and planetary investigations could be possible.

The designers of the first AISs were also to solve principally new engineering problems, above all those associated with the necessity to make trajectory corrections, with long ranges of radio communications and with the studies of planets. We shall deal in greater detail with trajectory corrections. The then-available means for rocket stages control produced—over the internal requirement of AIS insertion into the interplanetary trajectory—maximum deviation of this trajectory (0.5 to 1.0).10^6 km from Mars or Venus. Such a low accuracy for getting into the vicinity of the planet would neither permit hitting the planet itself or entering the orbit of its satellite, nor of making qualitative studies of the planet during the flyby.

The only correct decision was made: to measure parameters of the actual interplanetary trajectory after the AIS is placed on it, and to correct that trajectory by switching at an AIS trajectory. Since the correction process itself cannot be made perfectly accurate due to the errors in the measurements of AIS trajectories, orientations, and errors in engine operations control, sometimes two or even more corrections were necessary: the first—for preliminary removal of launching errors; the next—for correcting the errors of the previous corrections.

Obviously, making trajectory corrections required that a system for trajectory measurements be developed, as well as a system providing practically any AIS attitude specified by a ground command during the operation of a corrective thruster; a system for engine operation control, the corrective thruster proper, which could be switched on several times in weightlessness, and finally a system for the onboard loading of the numbers determining the value and direction in space of each correcting impulse. It should be mentioned that for interplanetary trajectory corrections it was necessary to develop a theory of such corrections, helping to estimate optimal correction times, as well as the sought-for values and attitudes of correcting impulses. All of the above-mentioned theoretical, design, development and industrial problems had been solved in 1960/1961, in the Experimental and Designing Bureau of S. Korolev (an AIS orientation-system correction theory) and in Isaev's Experimental and Designing Bureau (corrective thrusters) and in other related organizations.

To have radio communications with AISs up to distances of (300 to 400).10^6 km, typical for flights to Mars, a new center for deep space radio communications was set up near the town of Evpatoriya. For several years this was the only center in the U.S.S.R. with two-way radio communications with interplanetary stations. Due to the 24-hour revolution period of the Earth, a single center could not ensure round-the-clock radio communications with AISs, hence, in several cases, trajectory corrections should involve not only corrections for the position of a station near the target planet, but also for the time of its approach to the planet, so that at this time the AIS could be within the radio visibility zone of such a center. Of course, it complicated the design theory and the strategy of correction procedures, as well as it brought about the necessity to have additional fuel for corrective thrusters.

Large distances of radio communications with AISs demanded that new onboard facilities be developed for receiving and interpreting control commands and numerical data, which is necessary to control AIS operations and to make trajectory corrections, as has already been mentioned. Besides, large distances of radio communications and limits on mass made it necessary to develop new onboard directional parabolic and omnidirectional antennas, which will be considered in greater detail below, when different types of stations are discussed.

Large distances from Earth to AISs resulted in sufficient time for radio signal propagation. For the sake of illustration, we emphasize that, during the flight to Mars, the longest interval from the moment a control ground command was sent, to the moment the control center obtained the confirmation that the command had been received and executed aboard the AIS, was 22 to 33 minutes (range: 200 to 300.10^6 km). This circumstance demanded that a new concept be developed regarding the combination of autonomous control systems (e.g. during trajectory corrections) with the ground-based control facilities and, as a result, that special-purpose onboard instruments be developed, in particular a programmed timer with several time intervals changed by ground commands. The situation was somewhat complicated, since at that time no reliable and small-size onboard computers were available.

As has already been said, the development of the first AISs relied upon the expertise that the designing and testing of Luna-3 had provided. This does not mean, however, that the orientation system and the solar panels that the spacecraft was equipped with could be installed without any changes onboard the first AISs. The Luna-3 spacecraft featured an omnidirectional solar panel, which supplied electric power to the onboard systems and ensured recharging of the chemical battery for any position of the spacecraft with respect to the Sun.

When the development of the first AISs had just started, it became evident that, since the onboard instrumentation of these stations consumed much more energy than Luna-3, the use of an omnidirectional solar panel would inadmissibly increase the mass of the stations. Besides, installation of such a battery considerably complicated the outer arrangement of AISs, in particular installation of corrective thrusters, of optical orientation sensors, sensors for scientific instrumentation and for thermal control system heaters. Means were then sought to provide permanent AIS orientation to the Sun, the error being within 10 to 15°, with which it was possible to mount a flat solar panel on the stations. Success crowned this search: the EDB, headed by S. Korolev, which was engaged in the development of orientation systems, managed to develop a principally new system of AIS's permanent orientation to the Sun. It was quite efficient economically in terms of power and working body consumption. As to the economic efficiency of this system, it is sufficient to mention that to ensure permanent Sun-orientation of stations, the mass of a station being about 1,000 kg, less than 300 g of gaseous nitrogen per month was needed, the latter used onboard these AISs as a working body in orientation microthrusters. Of course, this required from AIS configuration designers that they give serious attention to the only disturbing moments always affecting the station, that is, moments induced by light pressure forces.

Along with providing constant AIS orientation toward the Sun, the orientation control system of those systems was also intended to implement other, novel-for-that-time, tasks. It has already been mentioned—in particular, in connection with the discussion of the problems of trajectory corrections—that prior to such corrections it may be necessary to point the corrective-thruster axis in a given, or practically any, position in space. To meet that problem, two astronomic references could be used: either the Sun or one of the brightest planets (Canopus was chosen as such or, as a "stand-by," Sirius). To search for these reference stars and track them, one of the allied organizations developed (on S. Korolev's EDB argument) a novel sensor with solar and stellar lenses, whose orientation, according to the numerical data transmitted from the Earth, ensured the given corrective-thruster axis attitude before this thruster was switched on. The onboard electronics of the attitude control system implemented the specially elaborated star-search logic, which practically excluded false orientation, say, to small particulates separated from the AIS.

Besides, the attitude control system provided a parabolic antenna pointing to the Earth during the operation of the high-speed radio-link. Generally speaking, the attitude control system of the first AISs was possibly the most sophisticated and multifunctional among all onboard systems, and its installation aboard the station required the greatest attention from the EDB and production.

The scope of this presentation does not permit a detailed consideration of new engineering problems associated with the investigations of the planets themselves. These are the designing of the load-bearing unit and heat protection of descending spacecraft that enter the atmosphere of Venus and Mars at second cosmic velocities of these planets; of chute systems permitting descent in the planetary atmospheres, and of the means to control these systems; designing of the means ensuring the functioning of descenders or their parts on the surface of the above planets, as well as the development of equipment and units intended for scientific planetary research. It should only be emphasized here that the development of all listed systems, instruments, and structural elements was considerably complicated by a series of uncertainties in the parameters of the atmospheres and surfaces of Mars and Venus, as they were known in the early 1960s. In fact, it is for removing such uncertainties that these means were developed.

To conclude this section, we will discuss the problems of ensuring the AISs' functioning reliability and their survivability during emergencies. In the early 1960s, there was not complete enough information about the effects of new conditions of spacecraft maintenance, which other fields of technology had never experienced. These conditions were the vacuum of outer space and its effect on the behavior of materials and on the functioning of mechanisms, long-duration weightlessness and radiation doses, large and typical of space; planetary conditions, etc. The situation was further complicated since, practically simultaneously with the development of the first AISs, a ground-based experimental base was underway in the U.S.S.R. Besides, there was also no experience in inflight spacecraft control. For the reasons mentioned above, emphasis in the development of the first AISs was given to the problems of ensuring reliability. Certain measures to improve AIS reliability and survivability had been implemented in the very first spacecraft, others were implemented later, when the results of the test were analyzed. Below we list some of these measures:

- For the already mentioned mode of permanent AIS pointing to the Sun, a back-up was provided, a passive gyroscopic stabilization of the spacecraft, transition to which was made automatically in case of main mode malfunctioning.
- Onboard automatic equipment permitted corrective thrusters to be switched on only when a star entered the focus of the stellar lens of a respective sensor, whereas the star-search logic almost completely prevented orientation on false references, as has already been mentioned. It should be clarified here that the corrective thruster switching when the spacecraft is not in the proper position in space, is one of the "most unpleasant" emergencies, since, on the one hand, if the trajectory is not corrected, it becomes even worse, and on the other hand, the corrective thruster fuel is wasted, though it is badly needed for further trajectory correction.
- A number of redundant instruments and units were envisaged: receivers, transmitters, and fan motors in pressurized bays.
- In automatic interplanetary stations intended to land on a planet, and in descenders, transmitters were necessary for data transmission from the descent path and from the surface of the planet. The onboard automatic equipment envisaged the possibility of using these transmitters along the Earth-to-planet trajectory, as well as in the event an emergency occurred in the main bay.
- The logic of onboard AIS systems control by radio commands was developed so that a ground command sent at the wrong time would not create a situation onboard the station which could not be corrected. When this could not be done, for instance when a communication session was initiated prior to the entry into the atmosphere of the planet, at whose beginning a descender was jettisoned from the AIS, two commands were envisaged, that is "enable" and "execute." Here the fact that the first command was received aboard the station was telemetered and, in case a false command was passed, its execution could be prevented.

o Two-way communication with the first AISs was controlled by the deep space radio communication center (see above). In some extreme meteorological conditions, the center could not send control commands. Besides, the possibility of emergencies at the center itself could not be excluded. Hence, initiation of some processes onboard the station, "tied" to some specific time (in particular, trajectory correction and a communication session before entering the planet's atmosphere) were duplicated by the onboard programmable timer already mentioned above.

AISs Built in 1960/1966 and Some Results of Their Flight Tests

The first launches of spacecraft intended for flyby near Mars, and for scientific investigation of interplanetary space, the Sun and planets, commenced in October 1960, with the new four-stage Molniya rocket. The designation of the spacecraft was IM. It featured an attitude control system which realized the mode of permanent solar orientation, Sun/star orientation before the corrective-thruster switching, and spacecraft pointing to the Earth during the high-speed radio link operation; a liquid-fuel rocket engine for trajectory corrections; a flat solar panel; a photo-TV device; and scientific instrumentation. Two Molniya rockets, with the above-mentioned spacecraft, were launched; however, both launches were unsuccessful, since the third stage of the rocket failed. Note that the development of the IM spacecraft took about twelve months. This was obviously insufficient, in view of the new engineering problems to be solved in the development of the first AISs, even though they worked very hard at the Korolev EDB and its pilot production. Hence, the above mentioned spacecraft had a number of shortcomings, both in the onboard systems and in structure, some of which were already detected during ground testing, and some later on in the development and flight tests of the succeeding spacecraft. In particular, the body construction combines the mounting seats of Sun/star orientation sensors, of the gyroscope controlling the spacecraft attitude during the corrective thruster and of the engine itself. With the insufficient rigidity of the construction, pressure changes in the pressurized bay, caused by the instability in the temperatures of gas filling the bay, and of the body of the bay itself, as well as by some leakage in the pressurized bay, led to angular mismatching of up to several minutes among the above-mentioned mounting seats. This added more errors to trajectory corrections. The AISs that followed no longer had that drawback in structure.

From the end of 1960 until February 1961, the next AIS (designated IBA) was designed and manufactured. It was envisaged for the flight to Venus in the then nearest favorable period of time in terms of the position of the planets, February 1961. The idea of that launch was to reach Venus and to conduct scientific investigations along the Earth-to-planet trajectory, and along the planet approach portion of the trajectory. The objective of contact studies of the planet itself, in particular, of its atmosphere and surface, was not put forward for that spacecraft. A dropable message bag, in a spherical envelope with heat protection to preserve it during the entry into the planet's atmosphere at the escape velocity, was placed aboard the IBA.

The IBA spacecraft was similar to IM in the set of onboard instrumentation and its characteristics. Some typical features of this spacecraft will be discussed below, in the analysis of the results of its flight tests.

The Molniya rocket carrying the IBA spacecraft was launched on February 12, 1961. The rocket fully performed its task, and the spacecraft was inserted into the interplanetary trajectory. Ballistic calculations relying upon the results of trajectory measurements made in the first communication session immediately after the completion of the fourth-stage operation and spacecraft detachment from the rocket showed that, in case the trajectory corrections were successful, the spacecraft might hit the planet. After this information was obtained the launch of the spacecraft was announced and it was officially named Venera-1.

However, the very first communication session demonstrated some failures in the spacecraft operation, in particular in the operation of its constant solar orientation system (CSO system). To update the status of the onboard systems, another short communication session was conducted, which also recorded unstable CSOS operation. According to the logic of the onboard systems operation, when the constant solar orientation failed, the instrument again oriented itself on the Sun and, after the orientation process was over, the instrument was spinning about its "solar" axis. Then the orientation system was switched off and, to save electric power, the onboard receivers were also switched off—those responsible for receiving control commands aboard the spacecraft. In the above-mentioned case, the next communication session was already autonomously switched on with the onboard timer, 5 days after the previous session began. In this session transmitters were turned on and housekeeping and scientific TM information was relayed. Besides, onboard receivers were also turned on during that session, that is the spacecraft again became controlled. According to the operation logic offered here, the next "stand-alone" communication session was started on February 17, 1961.

The operation again confirmed the inability of the CSO to operate, which meant that the next communication sessions could only be "autonomously" switched on. However, the February 17, 1961, session was the last communication session with the Venera-1 spacecraft; the "autonomous" sessions that followed have not been received on Earth. The failure of the onboard timer on the "autonomous" sessions, after the CSO failure and the receivers turning off, was assumed to be the most probable cause of this spacecraft loss.

It was possible to state unambiguously why the CSO aboard the Venera-1 failed, from the structural analysis that followed and from the IM data received. The optical sensor of the CSO was not pressurized, whereas the Korolev EDB specialists responsible for the thermal mode of the spacecraft, its units and instruments chose special coatings on the sensor body providing only the required mean temperature of the sensor, and they did not calculate or estimate the local temperatures of its individual elements. The TM data received from the spacecraft showed that the sensor body temperature was close to that expected (about 60°C). The theoretical analysis of the sensor configuration, however, showed that in this situation the temperature of its sensitive element might reach values exceeding the maximally admissible value, which evidently did happen and which resulted in the failure of the sensor, and therefore in the CSO failure. This was a design error, as it was called at that time, rather than a random failure.

Along with the above mentioned failures and errors, the Venera-1 activation also revealed some other, though not so principal, defects. In particular, inaccurate operation was reported of the mechanical shutters of the thermal control system, which changed the effective area of the radiative spacecraft surface.

The "negative" lessons of the first automatic interplanetary station functioning have been used in the development of the spacecraft that followed. In particular, the institution developing sensors for the orientation system changed the configuration of the CSO sensor and made it pressurized—to make equal the temperature fields of its elements and body; the development of the onboard programmable timer, previously developed by an institution manufacturing the radio/TM system, was made a responsibility of one of the departments of Korolev's EDB, which had expertise in the development of such instruments; a decision was made not to use onboard the next automatic stations mechanical shutters outside the spacecraft; finally it was decided that in the future onboard receivers would never be switched off, so as not to make the spacecraft uncontrollable even for a short time.

Late in January 1961, during the prelaunch activities with the IBA spacecraft at the Cosmodrome, the development of a series of unified spacecraft began, which could—with minimal changes in their configuration and onboard system—be used in flights to Mars and Venus with different goals (flyby or touching) and different scientific payloads. The very idea of developing a series of uniform spacecraft belonged to S. P. Korolev, Chief Designer. He envisaged the prospects of conducting interplanetary investigations aboard unmanned space probes. He saw possible achievements and failures, but he wanted to reduce, as much as possible, the expenditures needed for the interplanetary studies program, while in no way curtailing it. The idea of the Chief Designer was implemented in a series with the plant index 2MB. The development of spacecraft within this series took into account the requirements to provide for maximum uniformity of the structure and onboard systems, relying on the lessons of designing and testing the previous IM and IBA automatic interplanetary stations.

The first spacecraft of the 2MB series launched into a Martian trajectory was the one named Mars-1. It was launched on November 1, 1962, with the same Molniya rocket. The spacecraft was to fly close to Mars and on, to make photos of its surface and to study the interplanetary space along the Earth-Mars trajectory and the vicinity of that planet, and to make measurements of its magnetic field.

Note that the mission failed; because of an emergency the spacecraft did not fulfill the task set. The emergency consisted of the depressurization of the actuator subsystem in the orientation control system, because several days after the launch the whole store of gaseous nitrogen necessary for the working of this subsystem was lost. Analysis of the telemetry data, and examination of another similar spacecraft in pilot production, showed that dirt on the seat of one of the valves of the subsystem caused depressurization.

Among the measures taken on Earth to sustain communication with this spacecraft, were the timely transfer to the gyroscopic stabilization mode of the expected characteristics of light pressure moments, to be performed by the onboard automatic equipment; and the development of spacecraft motion theory, so as to provide efficient control of the spacecraft during the flight. As a result of all these measures, the Mars-1 experiments made it possible to carry out scientific investigations of interplanetary space, to control functioning of the Deep Space Communication Center up to 106.10^6 km to check operation of the onboard systems, such as a radiotelemetry system, a thermal control system, onboard automatics, and so on, during 140 days.

Concurrently with the Mars-1 operation, the space design department of Korolev's EDB and its other departments, together with the related organization, started to develop an improved series of uniform interplanetary vehicles with the plant index 3MB. Space vehicles of this series differed from the 2MB specifically by:

- A stand-by subsystem for the orientation system actuators as a "compensation" for emergency depressurization aboard the Mars-1 spacecraft.
- A shifting of the solar plane relative to the spacecraft center-of-mass, that ensured better characteristics of the light pressure moments.
- Slight changes in onboard automatic equipment.

During the 3MB spacecraft flight tests, some insignificant changes aimed at improving the reliability were introduced in the design and electric circuits of the spacecraft and their instruments. Specifically, after the programmed timer of the Zond-2 spacecraft failed (see below), the stand-by programmer designed only for switching on the thermal control system was changed.

From spring 1964 to autumn 1965, five spacecraft of the 3MB series were launched by the Molniya rocket carrier to heliocentric orbits. These spacecraft were designed and manufactured in the EDB of Korolev. Four of them were positioned to touch the planet or to pass by close to it; one spacecraft called Zond-3 was inserted into an orbit crossing the Martian orbit. This spaceship was designed only to study interplanetary space and to make photographs of some parts of the far side of the Moon when leaving the Earth.

The launch dates of the mentioned spaceships, the launch tasks, the reasons for the non-fulfillment of these tasks and some features of the missions and spaceships' functioning are summarized in the table at the end of this article. Information given in the table should be explained.

The Zond-1. Analysis of the telemetry data, and this spacecraft's motion relative to its center-of-mass, made it possible to determine the place of gas leakage from the orbital module. It turned out that the glass astrodome of the Sun/star tracker was depressurized. Two reasons were considered to be most likely—either a defect in the astrodome glass, or glass residual stresses due to inaccurate tracker assembling or mounting on the spaceship, resulting in glass damage due to overloads at the injection trajectory portion. The second emergency on this spaceship mentioned in the table was due to depressurization and inaccurate control. It seems likely from the telemetry data, that the transmitters of the depressurized module were switched on at the most hazardous instant from the viewpoint of possible gas discharge onset in the high-voltage circuits, when the module pressure was about 5 mm Hg. Maybe it would be better to wait for the module pressure to go down to a safe level, which could be determined during special ground-based tests.

Failure of some onboard automatic devices drastically complicated the experiments that finally brought about the spacecraft's loss, In spite of the Zond-1 emergencies, it had been possible to perform two trajectory correction sessions that allowed for the first time checking of the operation of the spacecraft orientation control system before thruster ignition, using the Sun/star tracker only in the mode of accurate solar attitude control, of the stabilization system using the gyroscopic device as the thruster was operating, and of the thruster itself.

The Zond-2. As the table shows, the solar panels were not fully deployed because of a design defect in the deployment mechanism not detected in the ground-based tests since these tests, were not complete. Because of this, the spaceship energy characteristics were significantly impaired.

The task of the programmed timer, which failed immediately after the spacecraft insertion into the interplanetary trajectory, was also to ensure starting up of the thermal control system between the radio communication sessions (in the waiting mode) with preset relative pulse duration. The programmed timer failure resulted when, in the waiting mode, the required thermal mode of the instruments was not sustained in both modules of the spaceship. The programmed timer featured the generators which duplicated each other and set up the initial frequency; however, the efficiency control of each of them was not envisaged. Analysis of the programmed timer storage duration and modes was made after the Zond-2 launch, to show that obviously this spacecraft used the device in such a way that only one of the three generators could operate.

The two emergencies described above were responsible for the premature communication loss with the Zond-2, but note a certain positive effect of this spacecraft launch. On board, an experimental system of plasma engines was mounted for generating the impulse to control spacecraft orientation to the Sun. Though this system did not provide stable orientation, and after two tests was switched off, the experience of its development and operation made it possible to create a new version of the plasma engine system, which was successfully used on many spacecraft with different applications several years later.

The Zond-3. As is mentioned in the table, this spacecraft has fulfilled all of its tasks. Particularly, during the mission it became possible, for the first time, to make trajectory corrections by accurate spacecraft pointing not only to the Sun, but also to the star (trajectory stellar monitoring).

The system of spacecraft pointing to the Earth, and functioning of the high-speed radio link via the parabolic antenna, were checked as the results of the Moon's far side photographing were transmitted from the Zond-3. The photographs were of high quality.

The Venera-2 & Venera-3. It should be added to the above that the ground-based experiments showed that poor command passage to the spacecraft was associated with overheating of some individual elements in the command receiving and decoding units. The latter was caused by the increase in gas temperatures in the modules, due to the violation of the technology of 40 thermal coating applications on the thermal-control-system radiators. It was found that considerable regular deteriorations in the impairment command passage are correlated with higher solar activity.

Note also that the ground-based experiments and analysis of the above spacecraft made it possible to correct the program of ground-based tests of onboard instruments of future space vehicles to take into account the weightlessness conditions.

From the table it is inferred that six spacecraft of the 2MB and 3MB series were launched to interplanetary trajectories in three years, and five spacecraft of the 3MB series in 18 months. It should also be added that the number of carrier-rocket launches with the AIS were higher since, because of the failures of the fourth stage, some stations did not reach the required trajectory. In essence, the carrier and the AIS itself were simultaneously tested.

Obviously, preparation for the launch of each space vehicle is a rather time- and labor-consuming process, including revision of the technical documentation taking into account the objective of the next launch and experience of the previous one; manufacturing of the space vehicle and its components and instruments at the plants of S. Korolev's EDB, in the related organizations, and of ground-based tests; preparation of the service forms and records (including manuals on control, etc.); and finally spacecraft preparation activities at the Cosmodrome.

The above account shows that the preparations and launches of the first AISs, particularly of the 3MB series spacecraft, were rather difficult. Analysis of the results of the first AIS flight tests shows that, for the most part, malfunctioning of the onboard systems and designs of 2MB-and 3MB-series spacecraft resulted from insufficient ground-based tests, and from failures in the manufacturing technology of these spacecraft.

However, note the obviously positive aspect of the first AIS launches. First, the knowhow acquired in designing, manufacturing, testing, and operating these spacecraft allowed a fairly rapid development of the next AISs at the EDB of G. Babakin, which became responsible for interplanetary programs after 1965. The Venera-4 AIS, designed in this EDB, was launched on June 12, 1967, and its descender made the flight on its parachute in the upper atmosphere of Venus, measuring its characteristics. The onboard systems and design of this spacecraft were similar to those developed in S. Korolev's EDB, except for the thermal control system which used a gaseous, rather than a liquid heat-transfer, agent.

Second, all first AISs launched into interplanetary trajectories from 1961 to 1965, carried out scientific investigations of the interplanetary medium (cosmic rays, micrometeorites, plasma, and so on), whereas the Zond-3 completed photography of the Moon's far side, started by Luna-3 in 1959.

Table 1

Launch Date	Spacecraft Name	Mission Objective	Specific Features of Spacecraft Functionings and Mission	Reasons of Nonfulfilled Mission Objectives
2.4.64	Zond-1	Venus touching	- Two trajectory corrections. - Radio communication during 2 months via the descender transmitters.	- Orbital module depressurization after the spacecraft was inserted into the interplanetary orbit. - Failure of the orbital module transmitters and malfunctioning of the automatic devices because of improper switch-on of the transmitters (corona discharge).
30.11.64	Zond-2	Pass-by near Mars	- Radio communications during 1 month. - Checking of the experimental system of attitude plasma engines.	- Non-complete deployment of solar panels. - Malfunctioning of the programmed timer.
18.7.65	Zond-3	Mission to Martian orbit	- Taking photographs of the Moon far side (part of it). - Trajectory stellar monitoring. - Checking of the system of spacecraft pointing to the Earth and high-speed radio link. - Radio communications during 7.5 months.	-Fulfilled.
12.11.65	Venera-2	Pass-by near Veunus	- Poor passage of commands. - Radio communications during 3 months (ceased 17 days before passing near Venus).	-Overheating of the solar panels and higher gas temperature in the modules because of failures in thermal-control-coating-application.
16.11.65	Venera-3	Venus touching	- Trajectory correction to ensure hitting the planet on 1.3.66. - Poor passage of commands. - Radio communications during 3 months (ceased 11 days before hitting the planet).	-Overheating of the solar panels and higher gas temperature in the modules because of failures in thermal-control-coating-application.