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*How intelligence has monitored  
the Soviet program for lunar  
and planetary probes.*

## SEVEN YEARS TO LUNA 9

James Burke

On the evening of 3 February 1966 a Soviet spacecraft landed on the moon and began sending radio signals back to earth. This historic achievement was the culmination of a long, hard effort stubbornly pursued by the USSR over a period of years in the face of repeated mission failures. Our purpose here is to tell the story of how intelligence kept track of that effort through the collection and analysis of telemetric and other information.

This collection and analysis has required widespread contributions from the intelligence community, usually as a sideline to assigned tasks in support of national security objectives. Agencies of the Department of Defense, including NSA, Norad, the communications and support agencies, DIA, and particularly the Defense Special Missile and Astronautics Center, have joined with CIA's Office of Elint and Foreign Missile and Space Analysis Center in the creation of an integrated system. Several CIA and NSA contractors have supplied essential system analyses. Special credit is due to the operators in the field, who, working often under far from ideal conditions, have done a precise and demanding job with steadily increasing skill.

### *The Intelligence Product*

When the first radio signals from the moon arrived on earth, our collection systems were ready: we had kept track of the mission all the way from liftoff to arrival, and four stations were listening for the landed spacecraft's signal. Recordings from these stations were converted into a set of lunar panorama pictures (Figure 1) which were better than any released by the Soviets. These pictures were of great scientific interest and, having been proved genuine, constituted a powerful stimulant for the U.S. lunar program: they gave the first proof that the moon's surface is hard enough to support a spacecraft.

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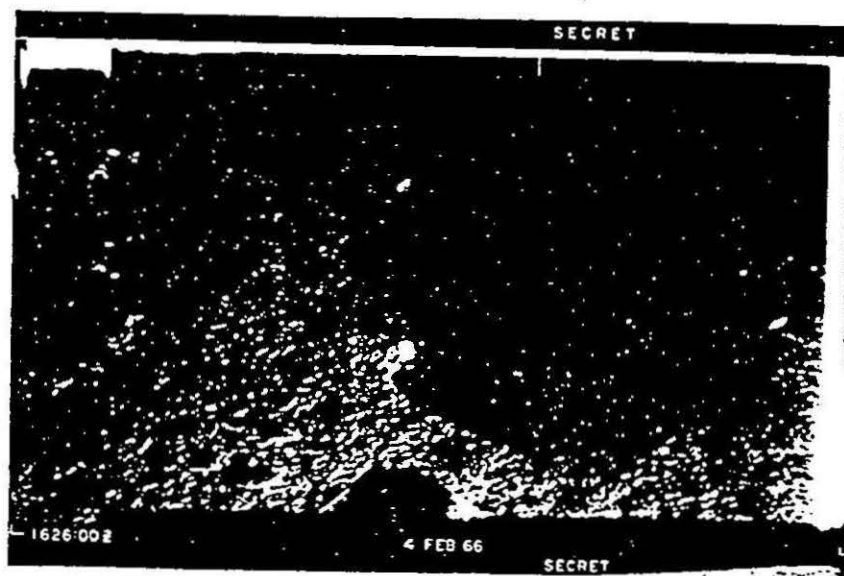


FIGURE 1. Samples of Panoramic Lunar Facsimile Images Produced From Intercepted Luna 9 Transmissions.

Top two pictures show how sun angle changed during mission and also indicate that capsule moved while resting on the moon.

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But the main product of our intelligence effort is not the pictures; it is the insight we have gained into the Soviet deep-space program as a whole. By some means unknown, Soviet space-flight enthusiasts have been able to obtain the support of their government for an unmanned lunar and planetary program much larger than that of the United States, although the total Soviet space program is smaller.<sup>1</sup> And this support has been maintained and steadily increased despite a continuing record of almost total mission failure.

The intelligence data leave no doubt as to the size of the Soviet commitment to deep space, but the reason for such a commitment continues to elude us. Only a deep penetration could reveal the decision process by which the USSR elects to keep on spending its scarce resources at such a high rate in pursuit of a non-military objective to which the United States, in spite of the pleas of scientists, has devoted only a limited effort.

#### *The Early Lunar Program*

The deep-space efforts of both the United States and the USSR began in the late fifties. The Soviets started out using their early, big SS-6 ICBM with an upper stage that came to be called the Lunik stage.<sup>2</sup> This vehicle, flying a direct ascent path to escape speed over Siberia, gave a lunar mission payload of 600 to 900 pounds. A number of such rockets launched from Tyuratam failed, but three functioned correctly and yielded the first escape (Lunik 1, "Mechta," 2 Jan. 59), the first lunar impact (Lunik 2, 12-13 Sept. 59), and the first pictures of the moon's far side (Lunik 3, 4-7 Oct. 59; see Figure 2).

During this early lunar flight program the Soviets launched no other space missions. But they were readying the next big steps. The SS6-Lunik vehicle, retired from this field, became the reliable mainstay of the Vostok and photoreconnaissance earth satellite programs. Future deep-space missions were slated to use a new combination of upper stages on the SS-6—a combination that has been the greatest visible source of trouble in the entire Soviet program over the past six years.

<sup>1</sup> See "A Comparison of U.S. and Soviet Efforts to Explore Mars" by B. Murray and M. Davies, *Science*, Vol. 151, No. 3713, 25 Feb. 66.

<sup>2</sup> See Wheelon and Graybeal, "Intelligence for the Space Race," *Studies* V 4, p. 1 ff.

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FIGURE 2. Lunik 3 Photo of Eastern Part of Moon's Far Side.

### *The Heavy Vehicle*

On 10 October 1960, at the instant when Tyuratam was brought by the rotation of the earth into alignment with a minimum-energy path to Mars, an SS-6 lifted off carrying a far greater weight than any ever before lofted by rocket. Intercepted telemetry showed that the loaded upper stages weighed more than thirty tons. At SS-6 second-stage shutdown a new third-stage engine ignited, burned for a few seconds, and then failed.

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Only four days later, again at the exact moment for an optimum trajectory to Mars, another heavy vehicle lifted off, and again the third stage failed. These flights signaled the beginning of a huge new program. Since 1960 the Soviets have launched nearly forty of the heavy rockets, including double or triple shots at every Mars and Venus opportunity, several attempted launchings of high-apogee communication satellites, and over a dozen attempted missions to the moon. The calendar of lunar and planetary attempts is shown in Figure 3.

During the same time period, by way of comparison, the United States tried nineteen deep-space missions—five test shots, two missions each to Mars and Venus, and ten to the moon, culminating in the marvellously successful Surveyor soft landing on 2 June 1966. U.S. payloads were in the 500- to 2100-pound class; the Soviet spacecraft weighed 1400 to 3400 pounds. The U.S. program suffered from frequent revision of its scientific objectives, and its early lunar mission failures resulted in public criticism and long schedule delays. But because the reliability of U.S. flight equipment increased faster than the Soviet, some U.S. missions yielded high-quality data sooner than their Soviet competitors.

#### *Collection and Prediction Through 1961*

When the first Soviet ICBM tests began in 1957, it was necessary for us to expand upon the radar and telemetry collection techniques that we had evolved in previous years to monitor the testing of shorter-range missiles. Fortunately U.S. access to some of the countries bordering the Soviet Union was assured, and fortunately the Soviets elected to use the proven, simple telemetry systems that they had already developed. As a result, when the first Mars shots were launched in 1960, our understanding of the SS-6 and its subsystems was fairly far advanced.<sup>3</sup>

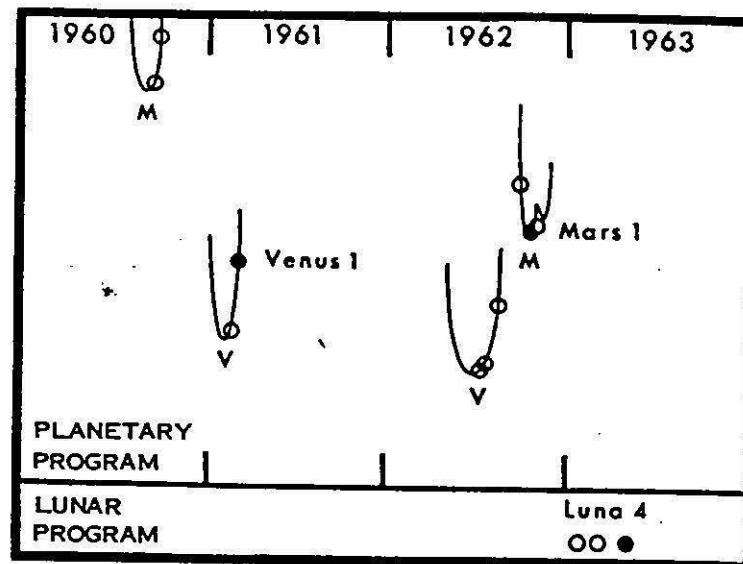
From the very slow acceleration recorded in their telemetry we could calculate immediately that the two October 1960 vehicles were by far the most heavily loaded ever launched. On the 14 October flight an unusually good, early intercept covering booster separation proved that the SS-6 is a parallel-staged rocket, with four large boosters attached around, rather than behind, a central sustainer

<sup>3</sup> See David S. Brandwein, "Telemetry Analysis," in *Studies VIII 4*, p. 21 ff.

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○ Launch failure ● Launch success, mission failure  
★ Mission success

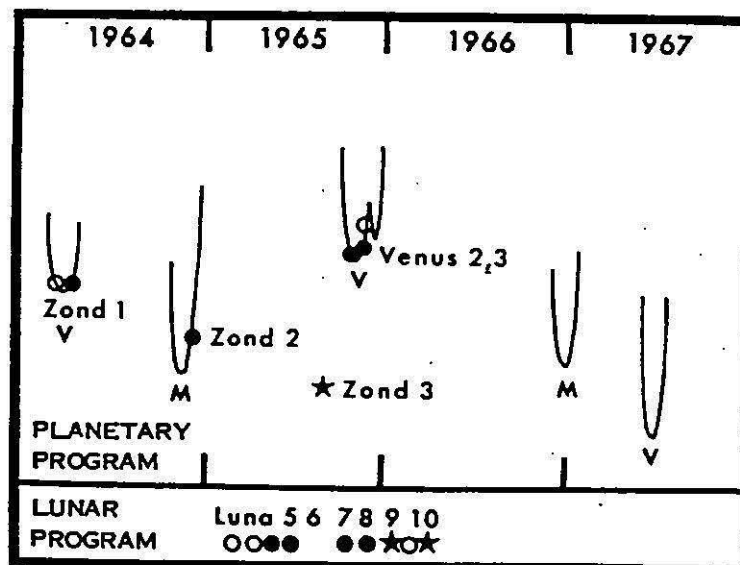


FIGURE 3 SOVIET LUNAR AND PLANETARY LAUNCHINGS SINCE 1960. CURVES SHOW ENERGY REQUIRED TO REACH PLANETS (M-MARS; V-VENUS) DURING EACH LAUNCH "WINDOW". PAYLOAD POTENTIAL IS GREATEST ON MINIMUM-ENERGY DAY.

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stage. On both flights the third-stage telemetry showed that the propellant pumps started up but failed to attain stabilized operation at full speed.

How did we know that these were Mars shots? Our knowledge would have been only suspicion but for a peculiarity of Soviet practice. From the beginnings of their respective programs the United States and the USSR have manifested a gross difference in launch operations philosophy. At Cape Kennedy, large rockets are placed upon their launch pads weeks or even months beforehand and are subjected to elaborate on-pad tests. For deep space missions, U.S. designers strive hard to provide on each of many days a "launch window" of several hours during which the vehicle can lift off and still, with the aid of variable guidance settings, arrive at its target.

Soviet designers, on the other hand, insist that the rocket be on the pad for at most a few days before liftoff, and they have never tried to provide a "window"; they simply demand that the vehicle be launched at the very instant optimum for the mission. Each approach has its merits, but this one surely makes the intelligence problem easier: the launch times of Soviet deep space missions are predictable almost to the minute.

Thus we were able, immediately after the October 1960 failures, to forecast an attempt on Venus in late January or early February 1961. The two shots were launched on schedule, and this time they worked better. The first placed in earth orbit a satellite which the Soviets promptly announced as history's heaviest—14,295 pounds. The second did the same, but after this satellite had coasted almost once around the world, a fourth propulsion stage ignited, ejecting itself and its payload from the "parking" orbit into a path toward Venus (Figure 4).

This rocket pioneered the concept which both the United States and the USSR now use to fling spacecraft away from the earth. Placing the interplanetary launch platform in a low earth orbit allows the maximum payload for a given launch vehicle and avoids some geometrical constraints imposed by launch site location and the motions of earth and target. But the required techniques of guidance, control, instrumentation, and propulsion are complex, and failures in the parking orbit and ejection phases continue to plague the Soviet deep-space effort even in 1966.

Early in 1961, however, the parking-orbit departure was a major technical "first," and the Soviets, justly proud of their achievement,

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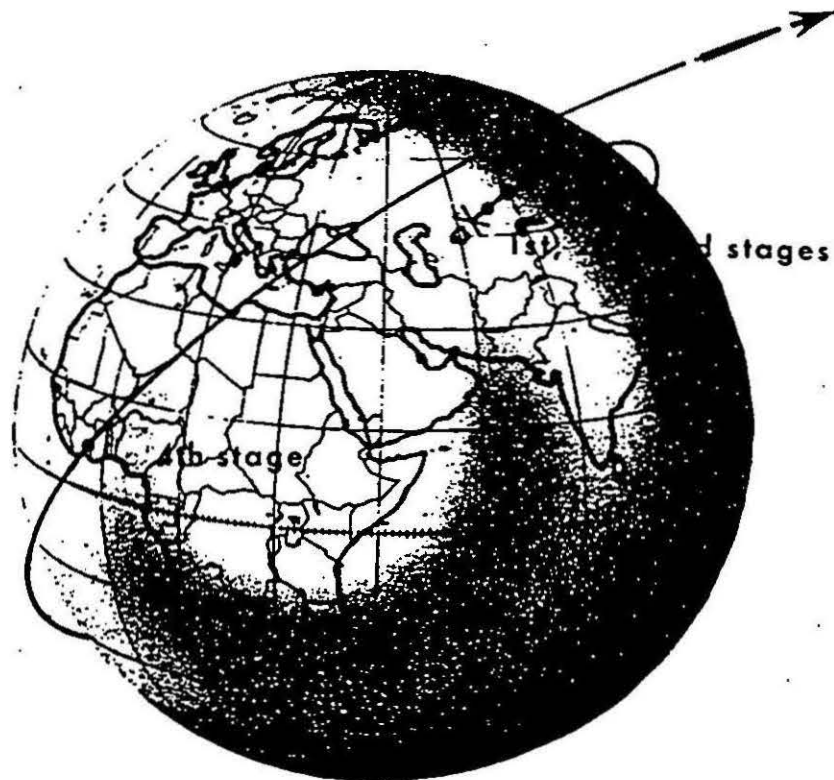


FIGURE 4. PARKING ORBIT DEPARTURE PATH

published a description of the launch, orbit, and ejection phases that was completely in accord with our intercepted data. They also released drawings and photos purporting to show the Venus spacecraft (Figure 5), and they began to issue bulletins on the progress of the flight.

We were not able to confirm or contradict these latter statements because our collection systems, being primarily oriented toward the Soviet ballistic-missile threat, included no sensors capable of following a weak spacecraft signal out into deep space. The Jodrell Bank radio-astronomy observatory in England did track the spacecraft for several days, and public announcements were made by its director, Prof. A. C. B. Lovell. The spacecraft apparently failed before the end of February, after completing only a small fraction of its three-month journey to Venus. During the period of the expected planetary

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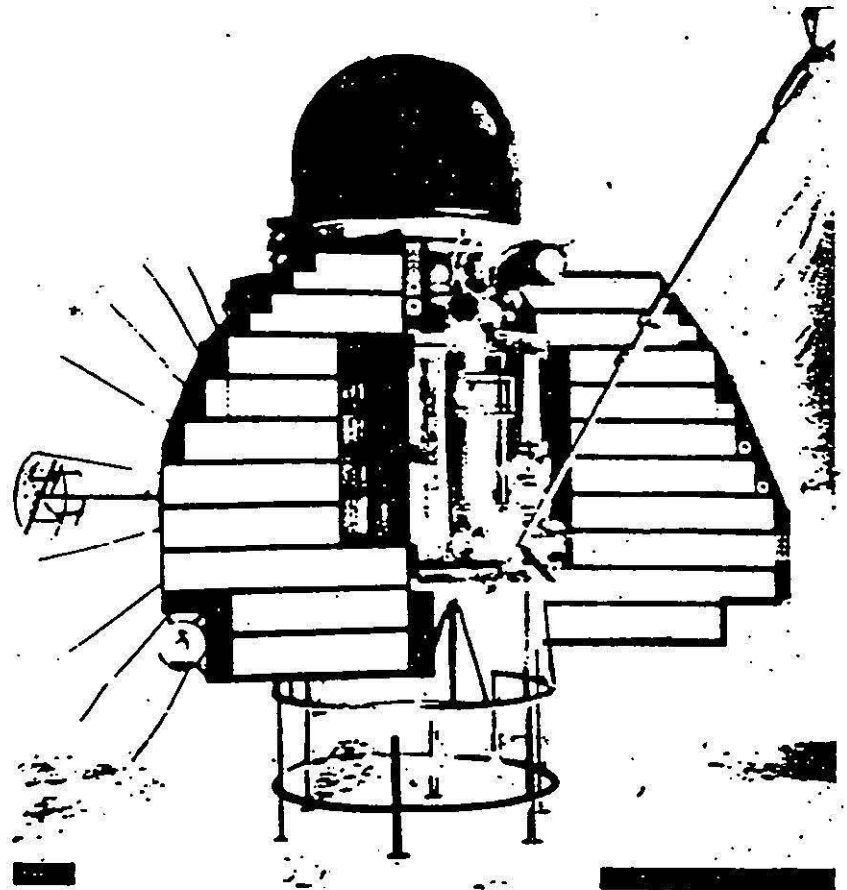
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FIGURE 5. Venus 1961 Spacecraft.

encounter, however, in mid-May 1961, Jodrell Bank heard possible probe signals and reported them to Moscow.

There followed a unique event: Prof. Alla Masevitch and Dr. Yu. K. Khodarev came to Jodrell Bank to assist in the search for signals.<sup>4</sup> They talked by telephone with people in the Crimea who were sending commands to the spacecraft trying to turn it on. They discussed both the flight and ground radio systems in some detail. Clearly they were not under any severe security strictures. At no other time in their deep-space program have the Soviets shown such a tendency to operate in an open, scientific atmosphere. Perhaps

<sup>4</sup>D. S. I. Report No. 200 (Secret): Visit of Prof. Masevitch and Dr. Khodarev to Jodrell Bank, 9th-17th June 1961.

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during this first venture no firm security policy had been established. Public releases on the later flights mostly indicate that the Soviets are still caught between a desire to brag about partial successes and their habitual inability to be candid about failures.

#### *U.S. Deep-Space Collection Plan*

After the 1961 Venus attempt a year and a half went by without another launching of the heavy four-stage vehicle. We computed its payload potential—1800 to 2100 pounds to Mars and Venus, more than 3000 pounds to the moon—and waited apprehensively for the formidable missions made possible by these great weights. This was a period when the United States was revising its deep-space objectives downward, eventually abandoning the 1962 Mars mission altogether.

There were pro and con arguments on the importance of preparing a system for collecting intelligence from Soviet deep-space probes. It was hard to show a direct connection between such intelligence and national security. On the other hand, it was recognized that possible future efforts of both countries, particularly flights to the moon, could bring on a requirement for a high-quality collection effort. The decision was not a minor one: in order to intercept and record signals from deep space it is necessary to have a large antenna similar to those used by radio-astronomers, a highly sensitive receiver, high-quality recording devices, a local environment free of radio noise, and highly skilled personnel supported by a communication and computation network to make prompt and accurate predictions of the location and transmitting frequency of the target. The cost of a single such station amounts to millions of dollars.

Initially, a three-station collection network, giving round-the-world coverage, was proposed; it would have been directly analogous to the existing NASA Deep Space Instrumentation Facility. Budget limits ruled this proposal out. The three-station net, it turns out, may not have been really necessary anyway; subsequent data indicate that Soviet probes, unlike U.S. spacecraft, transmit during only a small fraction of their flight and only when over the Soviet Union. It was decided to build one station on essentially the same meridian as the Soviet transmitting and receiving sites in the Crimea.

The site selected was Asmara, Ethiopia, and it proved to be an excellent choice. Initially it was planned that the station would have one high-precision 85-foot antenna, with appropriate receivers and data-processing equipment; to be ready late in 1965. Later it was

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decided to add a 150-foot antenna of lower surface quality but simpler construction, which could become operational late in 1964.

*Soviet Planetary Shots in 1962*

All doubts about Soviet intentions toward the planets vanished with the massive assault on Venus and Mars in 1962. Three flights were launched for each planet: 25 August, 1 September, and 12 September for Venus, and 24 October, 1 November, and 4 November for Mars. All six attained earth orbit, but only one, the middle one to Mars, ejected into its interplanetary course. The flights followed one another so closely that there must have been little time even for diagnosing the failures, let alone trying to correct them.

The lone spacecraft to depart from earth was labeled Mars 1, and nothing was said about the failures, even though they were promptly announced in the U.S. press. Pictures of the Mars 1 spacecraft

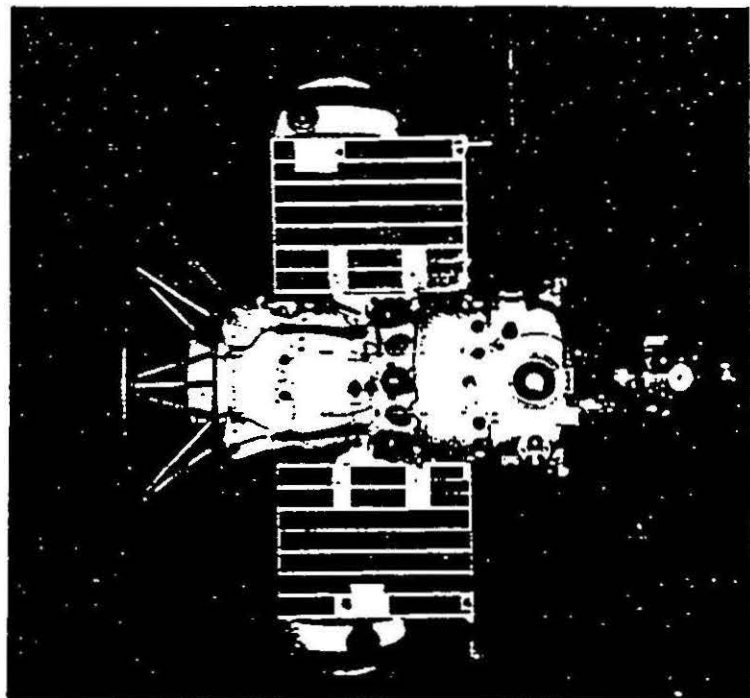


FIGURE 6. Mars 1 Spacecraft.

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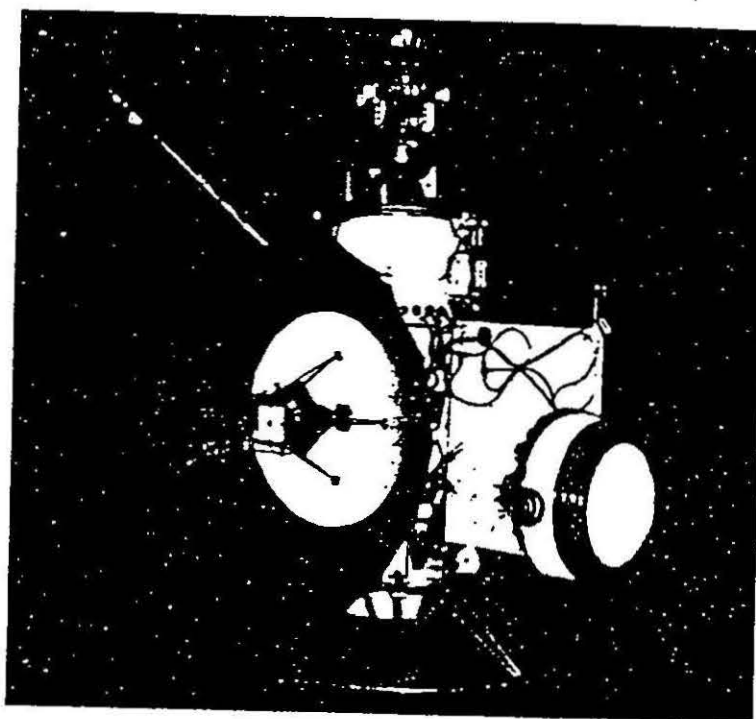


FIGURE 7. Mars 1 Spacecraft, Second View.

(Figures 6 and 7) and a relatively complete description of its mission were released. The published data included a description of the instrumentation to be used at the planet, though normal Soviet practice is not to reveal such intentions until after the fact.

The intercept history of Mars 1 was much the same as that of Venus 1. No U.S. facilities heard it after it departed from earth. The Jodrell Bank observatory reported occasional contacts on one of the four transmission frequencies made public by the Soviets. After more than three months of travel, when the probe was 66 million miles from earth, the Soviets announced that its orientation system had failed. The spacecraft had functioned long enough to have completed a Venus mission, but it was only half way to Mars.

#### *Renewed Lunar Program*

On 4 January 1963 came the first of the long-awaited lunar missions using the heavy four-stage vehicle. The launch platform achieved earth orbit, but again ejection failed. The data we collected

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enabled us to tell some things about the intended trajectory: the launch time was correct for an 80-hour transfer to the moon, with arrival along a direction nearly perpendicular to the lunar axis and the rays of the sun (Figure 8). We soon saw that this choice of trajectory offered excellent conditions for either a lunar orbiter or a landing mission. For an orbiter over the lunar poles, the arrival conditions thus selected would provide continuous sunlight for the spacecraft in orbit, assuring a ready source of power and a reference point for stabilization. The orbiter would continuously pass over the "terminator," or edge of the lighted part of the moon, where the shadows are best for photography, while the moon's slow turning on its axis in its course around the earth would continuously bring new areas into view for mapping.

For a landing, the vertical arrival path would be such as to set the spacecraft down close to the dawn terminator, again providing good shadows for imaging the surface and also assuring a maximum period, roughly two weeks, of sunlight after landing. Here once more we noted a characteristic common to many of the Soviet space systems: the designers select trajectories very cleverly to take advan-

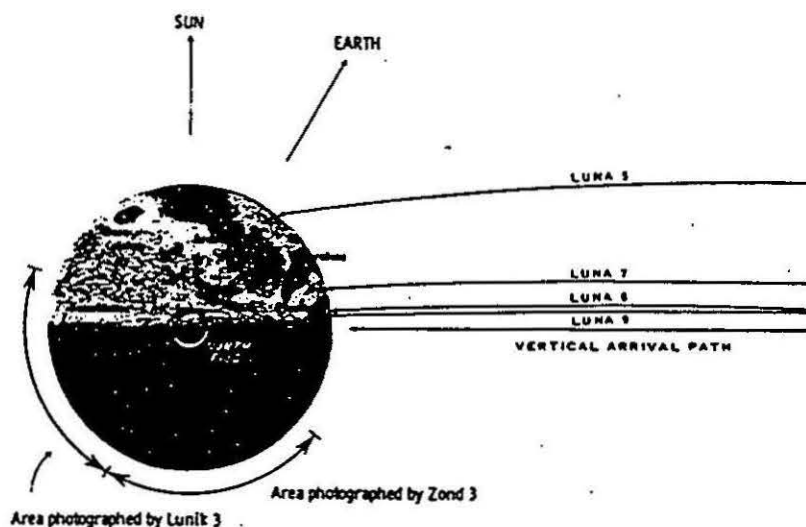


FIGURE 8. Arrival Geometry for Soviet Lunar Probes.

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tage of simplifying geometrical arrangements and then do not tolerate much deviation from the optimum.

The 4 January celestial conditions were repeated on 3 February 1963, and right on schedule another lunar probe was launched. This one failed even to achieve earth orbit. Then for the first time we saw possible evidence of reaction to failure: the Soviets skipped the March opportunity. But on 2 April they came on again, and this time the probe was ejected toward the moon. They named it Luna 4. At first, the bulletins on its progress sounded optimistic, though no description of its mission goal was given. When it was about half way to its target, the reporting took on a neutral tone; we took this, without any confirmatory data, to mean that a mid-course maneuver had been unsuccessful. On 5 April 1963, Luna 4 passed within a few thousand miles of the moon's sunlit side and sailed on out into space.

In addition to the Jodrell Bank reporting, NSA had improvised a collection capability that enabled us to record several hours of telemetry data while the probe was en route and during the fly-by. Our station was a Naval Research Laboratory experimental site in Maryland with a 150-foot antenna of the same kind planned for Asmara. Because of its western longitude this station could see only the latter part of each day's communications period when the Crimea passed under the probe. But Luna 4 was very late in arriving at the moon, the transfer taking 88 hours instead of the planned 80, so the NRL site got a good look at the fly-by. The telemetry data were complicated and full of variety: the spacecraft kept switching from one transmission mode to another as though its masters were calling upon it to execute some series of actions. But we never figured out what the data meant, and the Soviets gave us no help with a bland statement to the effect that much had been learned during the fly-by.

#### *The 1964 Effort*

When we studied the trajectories of the 1963 lunar probes, we found that they had another "optimum" characteristic: not only was each probe launched on the best day of the month for a terminator-plane arrival, but also they were all launched in winter and spring, when the moon would be well north of the equator when they arrived. This timing both assured a maximum period of viewing from the Crimea each day and caused the troublesome fourth-stage ejection to take place over the south Atlantic, in an area accessible to shipborne

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instrumentation. Firings in the summer, with the moon in south latitude on arrival, would have entailed ejection over central Africa.

Taking these considerations as constraints, we predicted no further lunar attempts until the winter of 1963-64; and there were none. Indeed, the lunar effort may have suffered a schedule slippage, because when the favorable period came there still were no launch attempts until near its end, when there was a Venus opportunity at the same time. The Soviet deep-space performance in the spring of 1964 went as follows: 21 March, lunar probe failure; 27 March, Venus probe failure, called "Cosmos 27"; 2 April, Venus probe, Zond 1; 20 April, lunar probe failure.

To anyone who has seen the strenuous efforts made in the United States to avoid such schedule conflicts on the launching range, this casual mixing of four major shots in a one-month period is a source of wonderment. Either the Soviet lunar and planetary programs are largely independent, staffed by separate organizations sharing launch vehicles and facilities but able to "play through" each other without strain, or else the spacecraft development organization is very large and versatile. A third possibility, of course, is that this phenomenal deep-space launch rate was achieved by cutting corners, with its bad failure record the result.

Zond 1 repeated its predecessors' performance: it got part way to its destination and then failed. Soviet information policy on this flight took another twist: it was described merely as a "deep space probe" despite immediate announcements of its real mission in the Western press.

As the Mars launch opportunity in November 1964 approached we confidently predicted two shots, but only one was launched. It was labeled Zond 2. In our anticipatory calculations we had noticed that ejection was going to take place over Turkey just after sunset, affording ideal conditions for visual observation. We notified U.S. personnel there, and when Zond 2 went overhead a number of people were watching for it. The weather was perfect, and the jet from the fourth-stage engine, illuminated by sunlight, was seen from widely separated points on the ground. An enterprising attaché in Ankara cabled a prompt and detailed report of his observations and also produced some remarkable photographs on which we were able to fix the approximate position of the probe with reference to visible stars. Bulletins on Zond 2's progress were issued for several months, until 5 May 1965, and then a Soviet scientist visiting the United States admitted that it had failed.

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Zond 1 and Zond 2 provided good exercise for our growing deep-space intercept capability. The Asmara station was not ready yet; Jodrell Bank continued to be the only source of information after the probes left the vicinity of earth. But other essential parts of the collection net were beginning to function. By tracking the vehicle right after ejection from parking orbit, speeding the results to the United States, and rapidly calculating the trajectory with the aid of large computers, we were beginning to be able with only a slight time lag to tell the deep-space sites where to look for the probe. Not the least of our achievements in this period was the successful integration of sensors and facilities belonging to three or four of the several U.S. agencies collecting intelligence.

Not only were we able to track signals from the spacecraft; we also began to intercept the command signals going up to it from the Soviet ground station in the Crimea—in the frequency region mentioned by the Soviet visitors to Jodrell Bank in 1961. But we still were not able to maintain enough coverage to confirm the execution of mid-course maneuvers and other en-route activities described by the Soviets, and we could not ascertain the exact intended mission (fly-by? impact? soft lander?) of either flight. In contrast to their open description of the planetary instruments on Mars 1, the Soviets gave us no help on Zond 1 and Zond 2. Perhaps the success of the U.S. Mariner flights to Venus (Aug.-Dec. 62) and Mars (Nov. 64-July 65) was an embarrassment to them.

#### *All-Out Push in 1965*

In accordance with the trajectory constraints described above, the Soviets launched lunar probes on 12 March and 10 April 1965. The first achieved parking orbit but failed to eject and was labeled "Cosmos 60"; the second did not go into orbit. The first Asmara antenna was now in operation, having been trucked in pieces into the Ethiopian mountains and assembled near the city on the high central plateau. In the absence of Soviet targets we exercised it and the NRL station against the U.S. lunar probes Ranger 8 and 9 with fairly good results.

On 9 May, about at the end of the proper season, Luna 5 was successfully launched. Three and a half days later, after Tass announcements that a mid-course maneuver had been made and that the spacecraft carried, "for the first time, elements of a system" for soft landing, it smashed into the southeastern portion of the moon's Sea of Clouds (Figure 9). The Soviets almost admitted the failure:

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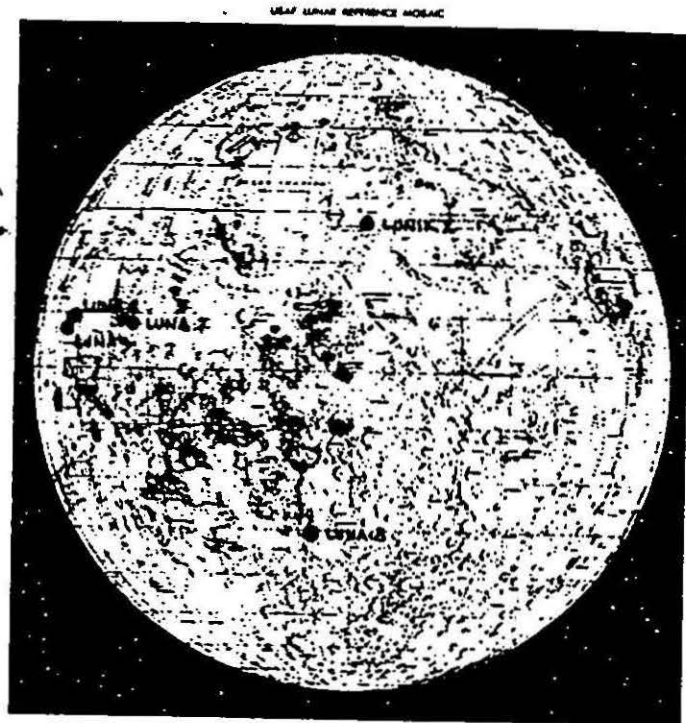
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FIGURE 9. Impact Locations of Soviet Lunar Probes.

they said that much had been learned, but the system needed further "elaboration."

Luna 5 gave the Asmara station its first real chance to perform. The station intercepted both of the two spacecraft signals several times during the mission, and both Asmara and Jodrell Bank were listening during the final approach to the moon. The telemetry data were like those from Luna 4, with minor changes, and their meaning remained obscure. The Doppler frequency shift of the signal was measured, rather imperfectly on this first attempt, and gave no evidence of any retrorocket deceleration.

On the basis of previous performance this would have been the end of the lunar effort until the following winter. During the summer months the moon would be far south on the arrival dates, making tracking difficult and placing the critical ejection operation out of range of ship coverage. But this time the Soviets decided to ignore

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the constraints. In what had evidently been planned months before as an all-out effort to gain a lunar landing success ahead of the United States, they kept right on firing away after the end of the favorable season.

On 8 June they launched Luna 6, which failed at mid-course. According to Tass, the engine powering the mid-course maneuver failed to shut off, causing a lunar miss of 100,000 miles. Using the knowledge of the trajectory obtained from our tracking system, we were able to show that such a large miss would require a speed change of thousands of feet per second, and this was possible only if the spacecraft used at mid-course the propellant supply carried for the main retromaneuver at the moon.

On 18 July 1965 Zond 3 was launched. Almost certainly this was the second of the anticipated 1964 Mars pair, of which only one got off during the November opportunity. By holding this shot and launching it later as a test, the Soviets showed increased prudence relative to their previous prodigal expenditure of planetary vehicles. But Zond 3 was not just a deep-space test. By a clever choice of launch time, its trajectory carried it past the sunlit side of the moon and it photographed most of the far-side area left unexplored by Lunik 3 (Figure 10). Tass said that the pictures would be played back from greater and greater distances as a communication test. We did not intercept any of these transmissions because we did not have a good fix on the trajectory so as to tell our deep-space antennas where to look. This flight demonstrated the crucial importance of early and accurate tracking after ejection.

The Zond 3 photos showed that the Soviets were continuing to develop and use the concept for photo transmission pioneered by Lunik 3 and tested on a larger scale in the earth satellites, Cosmos 4, 7, 9, and 13.<sup>5</sup> The concept is basically different from the slow-scan television technique used by the U.S. Ranger moon probes. The Soviet method consists of taking a photo, processing the exposed film on board the spacecraft, and then scanning the resulting transparency with a flying spot generated by a cathode ray tube. A photomultiplier detects the intensity modulation of the spot by the picture shading, and the resulting signal modulates the telemetry transmitter. Since the scan speed can be varied over a wide range, the method permits slowing down the information readout rate to compensate for the narrow bandwidth of the communication link, severely limited in

<sup>5</sup> See Henry G. Plaster, "Snooping on Space Pictures," in *Studies VIII* 4, p. 31 ff.

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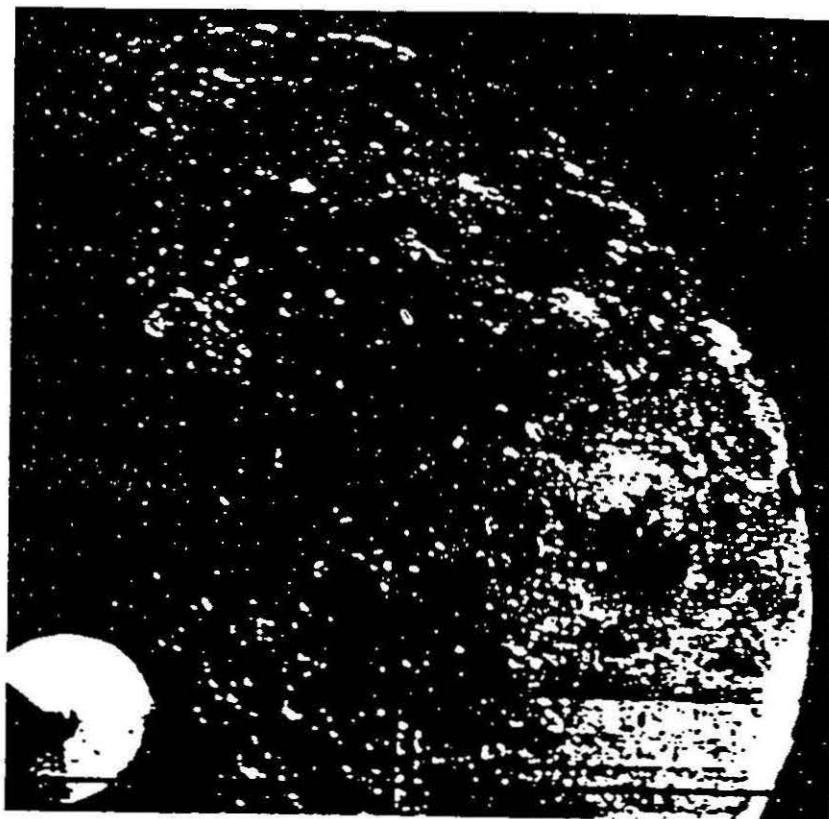
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FIGURE 10. Zond 3 Photo of Western Part of Moon's Far Side.

deep space probes. Such a system is very well suited to lunar mapping from an orbiter, and a system using the same principles is being developed for the U.S. lunar orbiter program, scheduled to begin flight tests in 1966.<sup>6</sup>

On 4 October 1965, anniversary of Sputnik 1 and Lunik 3, the Soviets launched Luna 7, again overriding their own trajectory and tracking constraints. Apparently their tracking was adequate, however, because the mid-course maneuver was successful for the first time, and the spacecraft impacted nearly vertically in the Ocean of

<sup>6</sup>The Murray-Davies article cited in footnote 1 contains a discussion of the potential of the Zond 3 photo system at planetary distances and a comparison with the somewhat different system, based on magnetic-tape storage, used by the U.S. Mariner 4 to obtain pictures of Mars.

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Storms (Figure 9). The performance of our collection systems was also improved: many hours of en-route telemetry were recorded, and we were able to confirm that there was no deceleration of the spacecraft during its descent. Despite the final failure, Soviet announcements were optimistic and anticipatory of further attempts at a soft landing.

On 12, 16 and 23 November 1965 the Tyuratam rapid fire experts launched another trio of Venus probes. Two of them were ejected successfully and named Venus 2 and Venus 3. The third disintegrated in earth orbit and was labelled "Cosmos 96." Three and one-half months later, after numerous progress bulletins, Tass announced that Venus 3 had delivered a capsule to the surface of Venus and Venus 2 had made a close fly-by, but that neither probe had returned data during the planetary encounter.

As in the previous planetary flights, our collection system was unable to provide any deep-space data to confirm or contradict these Soviet assertions. The near-earth part of the system, however, was improving. These Venus probes were launched into parking orbits inclined  $52^\circ$  to the equator, rather than the  $65^\circ$  used for all previous probes, and the change afforded improved post-ejection visibility to both the Soviet and the U.S. sensors. On Venus 2, when the change came as a surprise, our coverage was incomplete. But four days later our whole network of stations tracked Venus 3 during its departure.

On 3 December 1965 Luna 8 ejected from a  $52^\circ$  parking orbit. It had a successful flight up to the point of its terminal retromaneuver, when, according to Soviet statements validated by our intercepted data, its attitude stabilization system failed. Our data did show deceleration during the last few seconds of the flight, but the spacecraft was probably still going thousands of feet per second when it crashed. Soviet announcements after this failure implied that the soft landing was very close to realization, and the next flight proved them right.

#### *The Payoff*

On 31 January 1966, after more than three years and following eleven in-flight failures, began the mission that was to return the USSR to its early position of leadership in the lunar race. Launch, orbit, and ejection were normal. Our sensors functioned well and soon showed that Luna 9 had an excellent trajectory. Asmara acquired the telemetry signal while the spacecraft was still over the Soviet Union on its first pass after ejection.

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On 1 February the mid-course maneuver was executed, and we recorded telemetry throughout this phase. The Doppler shift showed clearly when the engine fired to place the spacecraft on a lunar-impact trajectory. On 2 February the spacecraft cruised quietly toward the moon, holding only short periods of communication with earth. On 3 February, about an hour before landing, it was oriented for the retrorocket maneuver. Asmara, Jodrell Bank, the Royal Radar Establishment, and NRL were listening. At 1844:09.5 GMT the retrorocket ignited and our Doppler count showed a rapid slowing down. At 1844:54.5 the main retro shut off, leaving the spacecraft descending slowly toward the lunar surface. At 1845:05 the signal went off the air. The next four minutes must have been tense ones in the USSR; they certainly were at the U.S. sites. Then, at 1849:45 GMT, 3 February 1966, came the long-awaited message from the surface of the moon.

The signals from the landed capsule included telemetry modes previously heard en route and also a new mode that was immediately recognized as a photofacsimile transmission similar to those used for wirephoto service on earth. On both sides of the Atlantic facsimile machines were hastily modified to accept the signal format, and poor pictures were quickly produced. Newspaper publication of some of the pictures obtained at Jodrell Bank brought on an amusing episode: the Soviets, processing the pictures at their own pace, were scooped and complained about it.

Later processing of the recorded signals by special photo-reproducing equipment brought out much more detail and showed that the facsimile system had yielded excellent imagery of the lunar surface.<sup>7</sup> Additional pictures were transmitted on the nights of 4, 5, and 6 February. In addition to showing the changing angle of sunlight, these pictures revealed that the capsule moved from its initial inclined orientation to one with more tilt, as if the ground supporting it were giving way slightly. The pictures were, of course, of enormous scientific interest, and papers describing the Jodrell Bank results were promptly published.<sup>8</sup>

<sup>7</sup> S/O/RUGM/R-22-66 (Secret).

<sup>8</sup> See "Observations of the Russian Moon Probe Luna 9," by J. C. Davies and others, and "The Moon from Luna 9," by G. Fielder and others, *Nature*, Vol. 209 No. 5026, 26 Feb. 66.

More recently these results and Soviet releases have been analyzed in an "Appreciation of the Luna 9 Pictures," by Eugene M. Shoemaker and others, *Astronautics & Aeronautics*, Vol. 4 No. 5 (May 66), p. 40 ff.

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Luna 9

The use of the photofacsimile principle was another example of a minimum-complexity design choice. The Soviets could have used their camera with on-board film development and flying-spot read-out, as developed for other missions, if the weight and ruggedness requirements for landing could have been met. But they saw that there was no need to do this. The illumination changes so slowly on the lunar surface that the scene is essentially stationary. This means that the surroundings can be scanned slowly, point by point, by a device such as a small nodding mirror, and the brightness data for each point measured by a simple photodiode and sent to earth in real time over a narrow-band link. Thus no on-board storage via film, slow-scan vidicon, or tape is required. A system virtually identical in concept to Luna 9's was developed and tested in 1962-63 for the U.S. Ranger project, but it was never flown.

According to Soviet announcements the Luna 9 capsule carried one other experiment. A radiation sensor gave data indicating that the radiation dose at the lunar surface is due mainly to cosmic rays and amounts to 30 millirads per day. Analysts have pointed out that this choice of terminology implies an interest in the biological effect of the radiation.

The published descriptions of the Luna 9 mission validated an old, small piece of intelligence obtained many months before, reminding us that it does no harm to keep loose puzzle pieces lying in our files and look at them occasionally. In a Soviet motion picture film covertly procured in mid-1964 which described the training of cosmonauts, there is a brief glimpse of a spacecraft model unlike any of those that had been publicly described. We long suspected that this might be an early version of the lunar spacecraft launched by the heavy vehicle. Now, as shown by Figure 11, we are nearly sure it was, and we have started to measure and analyze the images in the old movie to see how the design has evolved.

### *Epilogue*

One month after the historic flight of Luna 9 another lunar probe left Tyuratam on the same trajectory plan as the previous twelve shots. In a monotonous repetition of the fate suffered by so many of its predecessors, this one achieved parking orbit but failed to eject

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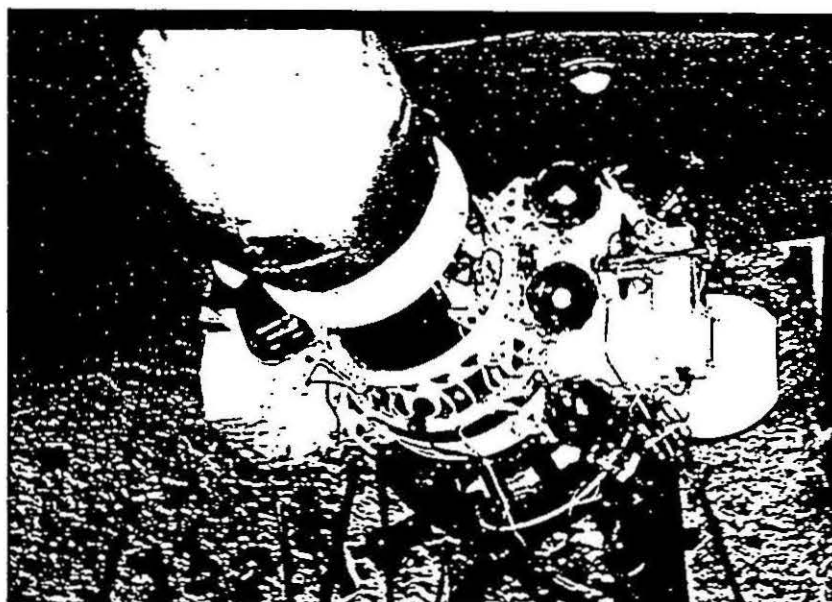
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FIGURE 11. Unidentified Spacecraft Glimpesd in 1964 Soviet Propaganda Film (at top) and Luna 9 as Displayed in Moscow, 1966 (below).

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Luna 9

and was labeled "Cosmos 111." Undaunted by this failure, the next time the moon came around (31 March 1966) the Soviets launched Luna 10. In a striking demonstration of the soundness and economy of their early program decisions, they achieved on this mission another of the great "firsts" in space exploration—the first lunar orbit—with no change in the basic trajectory and operations plan and only minor changes in the flight hardware. The near-polar orbit of Luna 10 confirms our three-year-old predictions and opens the prospect that a future spacecraft carrying cameras along the same route will provide the first complete map of the moon.

We expect Mars shots to be launched at the end of 1966 and Venus shots in mid-1967 (see Figure 3). How many more moon shots we will see between now and then depends on decisions that have probably already been made but are unknown to us. All we can do is to continue improving our collection system and exploring the data that it has already gathered, with the aim of giving the United States a maximum understanding of this extraordinary Soviet enterprise.

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