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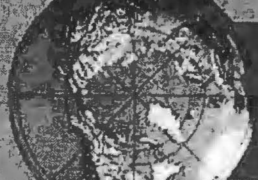

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Soviet defense spending provides security at a high cost. For an analysis see article on Soviet Budget beginning page 4. (U)

FOREWORD

MISSION: The mission of the monthly *Defense Intelligence Digest* is to provide all components of the Department of Defense and other United States agencies with timely intelligence of wide professional interest on significant developments and trends in the military capabilities and vulnerabilities of foreign nations. Emphasis is placed primarily on nations and forces within the Communist World.

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Joseph F. Carroll

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Director

SOVIETS PROGRESSING TOWARD REAL-TIME

Soviet photograph of the track of Sputnik II (above); base of 2.6-meter reflecting telescope at Crimean Astrophysical Observatory (below left); external view of telescope's protective enclosure (below right). ~~(S)~~

THE Soviets have developed the capability for optically tracking space vehicles in a "near real-time" frame. Described in a paper presented at the Cospar Conference of May 1968, the new technique reportedly permits the measurement of a spacecraft's orbital parameters, the comparison of these with the desired parameters, and the transmission of corrective instructions to the orbiting vehicle—all within the time it takes for the spacecraft to make one pass over Soviet territory. The new system reportedly is based at the Crimean Astrophysical Observatory on the Black Sea, and the Soviets claim to have used it effectively in tracking Luna's 11, 12, and 13, as well as one of the Molniya-I series of space probes.

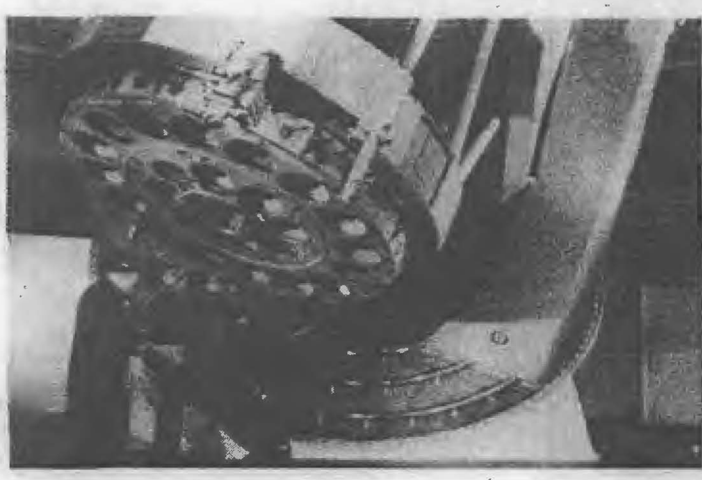
Impact and advantages

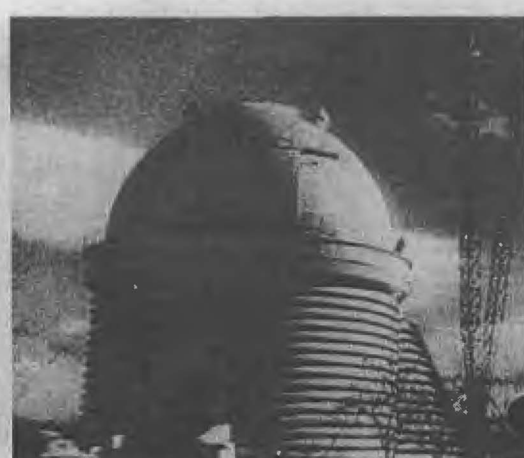
The military and scientific impact of this achievement is considerable when compared to previous space tracking systems. Optical tracking has long been the "ideal" method of following space probes because of its advantages over radar tracking techniques:

- Optical tracking is more accurate than radar, in part, because light waves are higher in frequency than microwaves.
- Radar tracking is limited to the near-earth "regime" (between 2,000 and 5,000 nautical miles in altitude); space probes above this altitude are beyond the effective range of radars, but not beyond the range of optical detection.

Heretofore, numerous technical obstacles have rendered optical tracking impractical. Chief among these have been the length of time required by conventional optical techniques, which employed photography in a microcomparison procedure and often required several months to complete. (Diagram of the conventional system is shown on page 16.)

The Soviet technique (shown on page 16) has minimized this time factor considerably by employing a television—instead of film—camera. The TV camera is attached to the





OPTICAL TRACKING

prime focus of a 2.6-meter reflecting telescope. The camera's monitor screen is equipped with cross-hairs, thus permitting the image of the spacecraft to be held in the center of the screen. This procedure eliminates film processing and the need to measure film and plates for distortion; such effects reportedly can be ignored, since all measured images are placed at the center of the TV screen. Time signals are obtained from a printing chronograph, a device that records the exact time when the position measurement is made, and enables the exact orbit to be calculated and permits predictions as to the spacecraft's future position.

Another obstacle to efficient optical tracking involved the control of telescope movements in following a spacecraft's orbit. This factor is particularly acute for low magnitude targets, which require high-gain telescopes with consequent narrow fields of view. The Soviets have reportedly solved this problem. Soviet telescopes, moving at an angular velocity of 1 to 10 arc-seconds ($\frac{1}{3600}$ of a degree) per second of time, reportedly have achieved an accuracy of 0.2 arc-seconds in right ascension and two arc-seconds in declination for their data reading from control panel dials.

Mechanisms formerly used in photographically tracking Soviet satellites are the NAFA 3s/25 camera (right) and a film measuring device (below) used to reference spacecraft positions with star backgrounds. (S)

Problem of coordinates

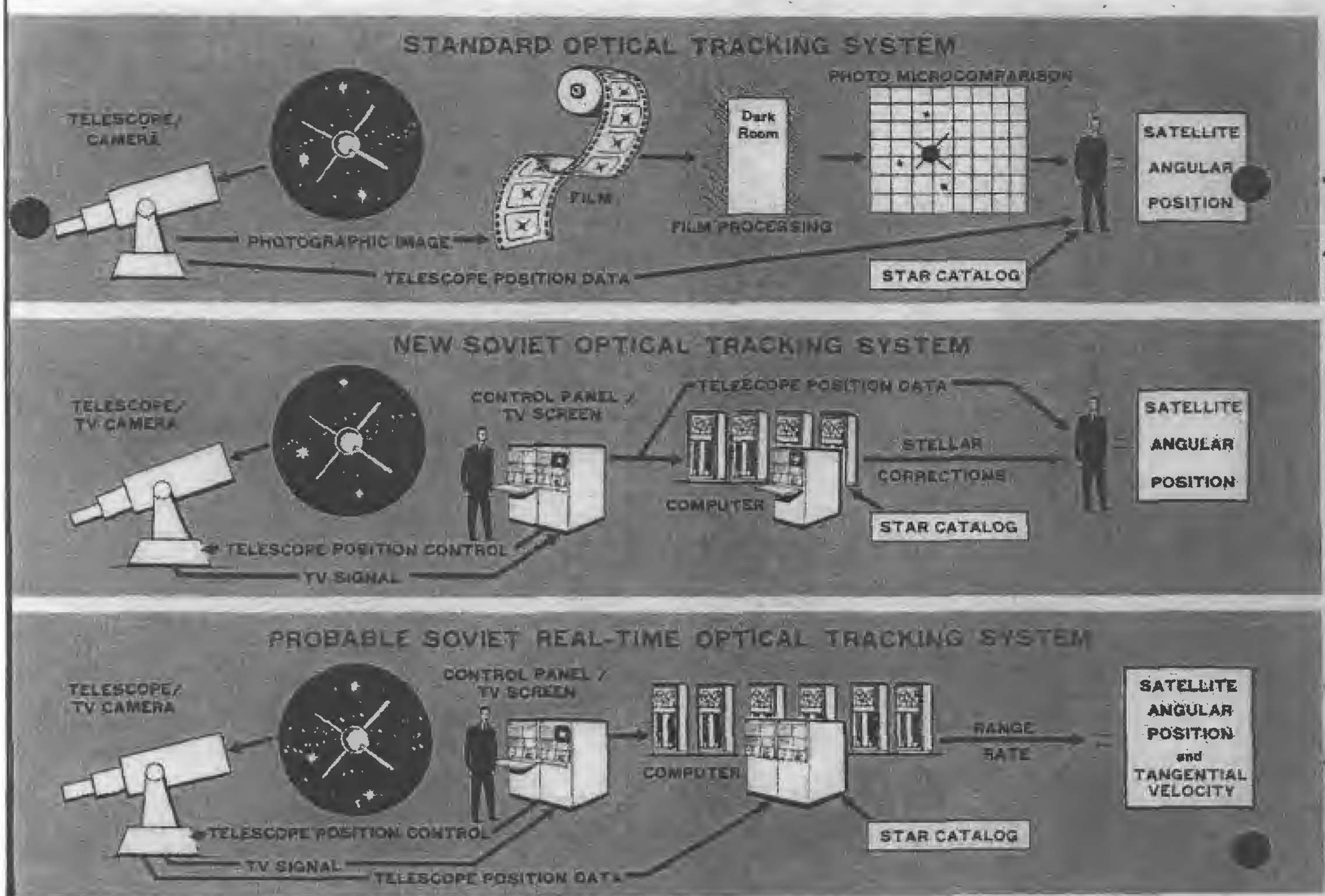
If a body traveling through space is to be tracked, it must be referenced to some coordinate system. In optical tracking, stars relatively proximate to the image of the spacecraft are used as references. However, problems are encountered in transferring and interpolating the topocentric coordinates (those linked to the position of the telescope on the earth's surface) with standard solar coordinates (those associated with the star catalogue). In solar coordinates the direction of the north pole is normally used as one coordinate axis; the other coordinate axis is usually based on a specific equinox. The gravitational attraction of the moon and the sun on the earth's equatorial bulge, however, causes this coordinate system to rotate and thus requires a specific time to be selected to completely fix the directions of the axes. (Astronomers have arbitrarily selected equinox 1950 for most tracking applications.)

Under the new Soviet tracking system, several stars of known coordinates, also appearing on the television screen, are used as references to correct the space probes' orbital coordinates to the standard system of equinox 1950.

Errors in angular position measurement of the reference stars, derived from aberration, precession, and refraction factors, must also be considered:

- Aberration errors stem from the apparent change in the angular position of a star owing to the earth's movement around the sun and the finite velocity of light arriving from the star. The magnitude of the required correction—from the apparent angular position to the actual angular position—depends on the star's actual angular position and the magnitude and direction of earth's motion in respect to that angular position. From an earthbound vantage point this correction factor varies from the spacecraft to the stars and from star to star.
- Precession errors stem from the motion of the earth's rotational axis about a fixed direction in space. This motion causes the angular position of a star to change over a period of time with respect to a fixed point on the earth's surface.
- Refraction errors refer to the bending of light rays as they pass through the atmosphere, which changes the apparent angular position of a star from where it would appear if the earth had no atmosphere. The amount of refraction depends upon the angle at which light from the star enters the earth's atmosphere. Thus, for an earthbound observer, the correction factor needed increases as the star's angle from the local vertical increases.

The Soviets have found that the calculation of the position of a spacecraft—in reference to proximate stars—can be simplified and still remain accurate by assuming that the required correction term varies linearly over short distances. For star positions that are close together—with a spacecraft in between—the position correction needed for the spacecraft would have a magnitude varying from that of the reference stars in proportion to its separation from the reference stars. This process is called interpolation. The Soviets discovered through observation tests that the correction term is actually constant (within the desired accuracy) for all objects within a field of view of two-degrees-by-two-degrees. Hence interpolation is unnecessary and a mean stellar correction factor can be



Soviet cinetheodolite, used in measuring trajectory angles of moving objects, reportedly was employed in tracking early space probes. ~~[S]~~

used through a computer in correcting the spacecraft's position, as read from the control panel dials.

More advances likely

With their current tracking system the Soviets can obtain "near-real-time" tracking data. However, several modifications in this system could result in significantly faster data response ("true real-time" optical tracking) using essentially the same hardware. A modified "true real-time" tracking system (shown on page 16) would operate as follows:

- A technician at the control panel would maneuver the telescope so that the space probe image is held on the cross-hairs of the TV screen.
- Telescope positions would be fed directly from the scope mount to a highspeed electronic computer.
- The relative displacements for the reference stars from the cross-hairs on the screen could be electronically sensed and also fed to the computer.
- The computer would transfer stellar positions from a standardized star catalog to determine the necessary correction to convert spacecraft position to a standard coordinate system.
- The speed of the computer in both data sampling and calculation would allow the determination of apparent tangential velocites (the angular velocity that a spacecraft has in crossing a field of view) by differentiation of the position data (which cannot be accurately and quickly accomplished by the present system).
- The spacecraft position data could be combined from several observing stations to determine orbits and ranges, using standard methods of triangulation.
- The actual construction and deployment of this type of "true real-time" optical tracking system is clearly within Soviet technological capabilities, and is a likely development for the future. [END]

Device used in measuring and computing satellite coordinates. [U]

Launchings reached a new high with 80 attempts—9 more than in the previous year—of which 74 were considered successful

SUMMA

SOVIET SPA

In 1968, as in 1967, the Soviet Union set a world record for the number of space launchings attempted. Nearly half the attempts directly supported military programs. Among the remainder, some may have supported military interests less directly. Four lunar-related launchings signaled the escalation of the Soviet Lunar program to a new level—following relative inactivity in 1967—by addition of a new booster system, the SL-12, for circumlunar flights.

Excepting the manned space flight in October, perhaps the most significant overall achievements have been the unmanned Zond 5 and Zond 6, both of which circumnavigated the moon and were recovered on earth; Zond 5, after a ballistic re-entry of the earth's atmosphere and splashdown in the Indian Ocean; and Zond 6, after a skip re-entry and soft landing in the Soviet Union. Satellite launchings included missions in photoreconnaissance, communications, meteorology, and navigation.

The missions of two launches have not yet been determined. Both originated from Tyuratam. The first, a failure, occurred on 15 June; the second, designated Cosmos 236, was launched on 27 August.

There were no interplanetary missions launched during the period. Emphasis remained centered on translunar and lunar orbiter flights with further implications of man-related missions—a Soviet potential brought out also by some of the near-earth experimentation.

Overall, the number and kinds of missions undertaken during the year served to accentuate the apparently high priority accorded the space program among the various Soviet military and national objectives.

Photoreconnaissance

Of 25 photoreconnaissance satellites launched successfully—7 more than in 1967—14 carried high-resolution camera systems that have a [redacted]

50X1 and 3, E.O.13526

All photoreconnaissance satellites were placed into orbit by the SL-4 space launch system, consisting of the SS-6 booster plus the Venik upper stage. The SL-4 can inject 12,000 to 15,000 pounds into a 100-nm earth orbit. The launchings were distributed almost equally between the Plesetsk and the Tyuratam Missile and Space Test Complexes.

The Soviets extended the inclinational planes of their photoreconnaissance satellites from an upper limit of 72 degrees to 81 degrees, thereby providing virtually worldwide photographic coverage.

Four satellites surpassed the previous Soviet practice for time in orbit—10 days—established by Cosmos 16 during the period 28 April to 8 May 1963. One of the four remained aloft 11 days, and three stayed up 12 days. The average duration of a Soviet reconnaissance mission had been eight days; the longer lifetime implies that the management or allotment of on-board consumables was improved. In any case, it is a natural extension of a proven system to provide a higher quality return.

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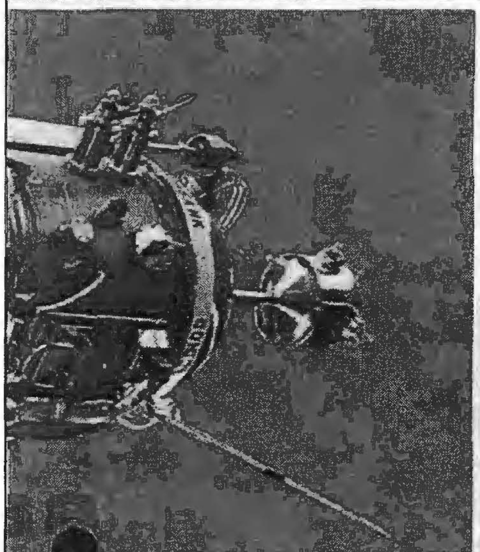


CE EFFORT

The Soviets have begun to demonstrate more flexibility in this program, with variations in further launch time to vary target illumination conditions and variations in orbit period to control target coverage.

Cosmos 231, launched from Tyuratam on 10 July, was the first Soviet reconnaissance mission to be sent up and recovered during the hours of darkness, and apparently was used to observe the French nuclear test range in the South Pacific.

SS-X-6 test missions

On 20 and 27 May the Soviets launched the SS-X-6 on a ballistic trajectory from Tyuratam; the reentry vehicle was directed by a propulsion system to an impact area 7,400-nm downrange, near Christmas Island in the Pacific Ocean. This was a new phase in testing, since previous efforts had been concerned with returning a payload from a low-earth orbit.

The combination of the SS-X-6 warhead deceleration capability and the suborbital, low-apogee trajectory used in the May tests raises the possibility of a depressed-trajectory ICBM role for the system. In effect, the warhead could strike a target while appearing to overfly it, except for the last three minutes.

Scientific

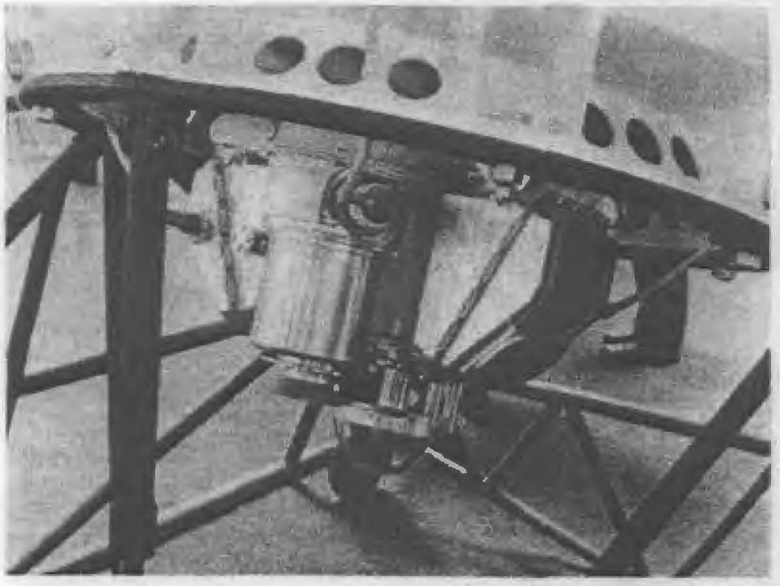
The Soviets launched 18 scientific satellites—4 more than in 1967. The scientific satellite Proton 4—described by the Soviets as a space station weighing about 37,500 pounds including 27,562 pounds of scientific and cosmic ray equipment—was launched from Tyuratam on 16 November. In an unusual comment, Tass annnounced that the overall vehicular weight did not include the last stage of the booster.

In addition, eight scientific satellites were sent up from Plesetsk and nine from Kapustin Yar; one of the latter failed to achieve orbit. The satellites, weighing in the region of 400 to 800 pounds, were sent into orbit by the SL-7. The system consists of the SS-4 and an upper stage. The satellites perform near-earth scientific missions, emphasizing radiation measurements including data collection for studies in meteorology, biology, and solar plasma.

On 9 June the Soviets announced that Cosmos 215, launched from Kapustin Yar on 18 April, was an astronomical observatory carrying small reflecting telescopes with mirrors of 70-mm (2.75-in) diameters. The telescopes were designed to study the radiation of "hot" or "young" stars that emit a greater amount of visible light than do ordinary stars. The observations ranged from invisible ultraviolet rays with a wavelength of 1,225 angstroms* through the visible part of the spectrum—between 4,000 and 7,700 angstroms. About 150 communications sessions were held with the spacecraft for the relay of data to earth receiving stations.

The launching of Cosmos 242 (a probable solar-radiation sensing satellite) from Plesetsk on 20 September coincided with the total eclipse of the sun visible in the USSR on 22 September.

*Lightwave units of length equal to one ten-millionth of a millimeter.



Solar sensor array ensures panel orientation in Molniya system. ~~(S)~~

Communications

The Soviets had three active Molniya–1-type satellites in orbit at the beginning of 1968. These relay-communications craft provide high effective radiated power—about 1200 watts—for relay among the Molniya ground stations and between the Orbital ground stations. A minimum of three active Molniya satellites are required to maintain round-the-clock communication between Moscow and remote sections of the USSR, including the Soviet Far East.

Four additional Molniya–1-type satellites were placed into orbit. Molniya–1/8, launched from Tyuratam on 21 April, may have been intended to replace Molniya–1/4, apparently inactive since January 1968. Molniya–1/9, Molniya–1/10, and Cosmos 260 were launched from Tyuratam successively on 5 July, 5 October, and 16 December. The Soviet designation of the 16 December launch as Cosmos 260—instead of the expected Molniya–1/11—may be construed as indicative of the satellite's failure to perform its intended Molniya–1-type mission.

Meteorological

Two weather satellites—Cosmos 206 and Cosmos 266—were launched into near-circular orbits on an 81-degree inclination to the equator. Cosmos 226 was launched approximately 115 degrees out of phase of Cosmos 206, so that the combination provides full coverage of temperate latitudes daily.

Navigational satellites

Five developmental navigational satellites—all launched from Plesetsk—were placed into an almost-circular orbit with a 74-degree inclination to the equator. The apogees ranged from about 290 to 650 nm. The SL–8 space launch system, comprising the SS–5 booster with a restartable upper stage, was used in each mission. Satellite transmissions—which probably contain ephemeris information—are on carrier systems close to those used by the United States, although the format is different.

The use of different altitudes suggests that the Soviet navigational program is still in the developmental stage: experiments are being conducted at various orbital altitudes in an effort to obtain the most favorable operational characteristics. The USSR apparently is pursuing the navigational satellite program aggressively, and the program is probably in a prototype flight stage that permits limited operational use and testing.

Lunar program

Two lunar orbiter missions were attempted—from Tyuratam. The first attempt, on 7 February, used the SL–6 space launch system but failed to achieve orbit. The SL–6 includes the SS–6 booster with a Venik third stage and a parking-orbit-ejection fourth stage.

On 7 April the SL–6 was again used. On that occasion it succeeded in injecting Luna–14 into a 52-degree parking orbit and then—some 80 minutes after launch—ejecting it on a trajectory to the vicinity of the moon. This was the first announced lunar probe since 1966. The operation closely resembled Luna–10, a lunar orbiter that transmitted pictures back to earth.

Man-related missions

Another lunar probe attempt, probably man-related, occurred on 22 April and used the SL–12 space-launch system, composed of a Proton launcher plus a third stage and a restartable fourth stage. The mission failed when the second stage shut down prematurely.

Nine man-related missions were launched: five Soyuz-type, three unmanned Zonds, and the 22 April failure. Four of the Soyuz-type missions were undertaken to develop rendezvous and docking techniques.

Three Zond unmanned but man-related circumlunar missions—numbered 4, 5, and 6—were placed into highly elliptical orbits by also the SL–12 launch system. The 22 April failure may very well have been of the same series.

- The Soyuz-type Cosmos 212 and 213 were launched on 14 and 15 April and, according to Tass, were successively recovered on 19 and 20 April. Cosmos 212 was the "active" and Cosmos 213 the "passive" vehicle in an automatic orbital docking maneuver performed on 15 April.
- The Soyuz-type Cosmos 238 was launched from Tyuratam on 28 August. It was brought back on 1 September after four days in flight.
- In related missions, Soyuz–2,*

*See "Soyuz–2, 3 Herald Soviet Re-entry Into Space Race," February 1969 issue, page 16.

an unmanned spacecraft, was launched from Tyuratam on 25 October, and Soyuz-3, carrying test pilot Colonel Georgiy Beregovoy, was launched from the same complex one day later. The flights lasted an overall four days. Two docking attempts, one using manual controls and the other employing an automatic system, apparently failed. However, there were conflicting Soviet statements as to whether or not docking had been planned. Both vehicles were returned safely.

The flight of Soyuz-3 was the Soviet Union's first successful manned space mission since April 1965. The safe landing of the vehicle was hailed by the Soviets as a demonstration of a new, highly accurate system consisting of a re-entry module specially designed to combine controlled aerodynamic lift or ballistic re-entry with the standard parachute and low-altitude retrorocket soft-landing system.

• Zond-4 was originally injected into a low—129-nm-altitude—parking orbit of the earth and was later injected into an orbit in a direction away from the moon with a 160,000-nm apogee, a 139-nm perigee, and a period of 7 days 1 hour 34 minutes. The mission was probably intended to simulate a mission with a duration equal to that required for circling the moon and returning to earth and may have included tests of the critical lunar system components and the re-entry vehicle. The exact results of these tests are uncertain.

• Zond-5 was injected into a circumlunar orbit after launch from Tyuratam on 14 September. Upon completion of its flight from the moon to the earth, the capsule—which carried according to the Soviets, a biomedical payload—was recovered in the Indian Ocean on 21 September. It was the first spaceship to return to earth from the vicinity of the moon. A ballistic re-entry evaluation of Zond-5 indicated a peak acceleration of 18 Gs, and accelerations in excess of 10 Gs for approximately one minute. Although these G levels are above desirable levels for manned vehicles, Zond-5 seems to have accomplished the water-recovery successfully.

• Zond-6, launched on 10 November, followed a trajectory virtually identical with that of Zond-5; the vehicle was returned to a soft earth landing after an eight-day flight. Tass announced that Zond-6 had passed around the moon at a distance of 1,502 miles and had made studies of the lunar environment. The Soviets also claimed that Zond-6 had accomplished mapping experiments essential to manned lunar landings and had taken pictures—many of the far side of the moon—that had "yielded almost a thousand times more information" than photographs taken by Zond-3. One reason for the improvement was the fact that Zond-3 transmitted its pictures through space to earth, while Zond-6 carried its photographs back, thus avoiding the limitations of a video system.

As another feature of the flight, Tass reported that the craft was able to maneuver in the atmosphere to a parachute-aided landing.

Zond-5 and Zond-6 probably helped solve major problems in interplanetary travel. These would include the technique of recovering spacecraft after interplanetary journeys. The missions indicated that the USSR could carry out a manned circumlunar flight. However, the SL-12, the largest Soviet booster tested to date, appears to be capable of placing only 10,000 to 15,000 pounds into elliptical orbits that can reach as far as the orbit of the moon. While this capability is adequate for manned circumlunar flights, it is insufficient for manned lunar landing activity. Therefore, a larger booster, using some of the equipment now being tested, probably will be employed in later missions.

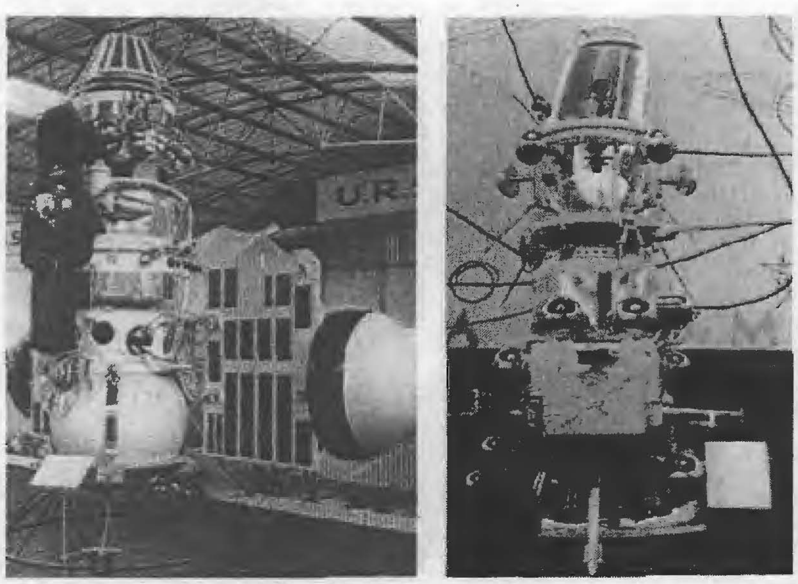
Maneuverable types

Five maneuvering satellites were launched: Cosmos 209, 217, 248, 249, and 252. Each was orbited from Tyuratam by means of the SL-11B launch system, which consists of a modified SS-9 plus a restartable upper stage. The satellites demonstrated the capability of making significant inplane orbital changes; about 2,500-ft/sec velocity change has been demonstrated:

• Cosmos 209 was launched on 22 March and may have been timed to achieve a flyby of the third-stage booster for Cosmos 208, a reconnaissance satellite.

• Cosmos 217, launched on 24 April, may have performed some orbital maneuvers.

• Cosmos 248 was launched on 19 October and performed several inplane



Earlier Soviet space equipment included Venus 3 (left) and Luna-10. ~~(S)~~

SOVIET PROGRAM FOR 1968

LAUNCH DATE	VEHICLE	LAUNCH AREA	RESOLUTION
	Photoreconnaissance		
16 January	Cosmos 199	Plesetsk	Low
6 February	Cosmos 201	Tyuratam	High
5 March	Cosmos 205	Plesetsk	Low
16 March	Cosmos 207	Plesetsk	High
21 March	Cosmos 208	Tyuratam	Low
3 April	Cosmos 210	Plesetsk	Low
18 April	Cosmos 214	Plesetsk	High
20 April	Cosmos 216	Tyuratam	Low
1 June	Cosmos 223	Plesetsk	Low
4 June	Cosmos 224	Tyuratam	High
18 June	Cosmos 227	Tyuratam	High
21 June	Cosmos 228	Tyuratam	Low
26 June	Cosmos 229	Plesetsk	High
10 July	Cosmos 231	Tyuratam	Low
16 July	Cosmos 232	Plesetsk	High
30 July	Cosmos 234	Tyuratam	High
9 August	Cosmos 235	Tyuratam	Low
27 August	Cosmos 237	Plesetsk	High
5 September	Cosmos 239	Tyuratam	High
14 September	Cosmos 240	Tyuratam	Low
16 September	Cosmos 241	Plesetsk	High
23 September	Cosmos 243	Tyuratam	Low
7 October	Cosmos 246	Plesetsk	High
11 October	Cosmos 247	Plesetsk	Low
31 October	Cosmos 251	Tyuratam	High
13 November	Cosmos 253	Plesetsk	Low
21 November	Cosmos 254	Plesetsk	High
29 November	Cosmos 255	Plesetsk	Low
10 December	Cosmos 258	Tyuratam	Low
	SS-X-6 Test Missions		
25 April	Cosmos 218	Tyuratam	
20 May	Suborbital	Tyuratam	
27 May	Suborbital	Tyuratam	
2 October	Cosmos 244	Tyuratam	
	Scientific		
20 February	Cosmos 202	Kapustin Yar	
5 March	Cosmos 204	Plesetsk	
6 March	Failure	Kapustin Yar	
9 April	Cosmos 211	Plesetsk	
18 April	Cosmos 215	Kapustin Yar	
26 April	Cosmos 219	Kapustin Yar	
24 May	Cosmos 221	Kapustin Yar	
30 May	Cosmos 222	Plesetsk	
11 June	Cosmos 225	Kapustin Yar	
5 July	Cosmos 230	Kapustin Yar	
18 July	Cosmos 233	Plesetsk	
20 September	Cosmos 242	Plesetsk	
3 October	Cosmos 245	Plesetsk	
16 November	Proton 4	Tyuratam	
3 December	Cosmos 257	Plesetsk	
14 December	Cosmos 259	Kapustin Yar	
19 December	Cosmos 261	Plesetsk	
26 December	Cosmos 262	Kapustin Yar	

LAUNCH DATE	VEHICLE	LAUNCH AREA
	Communications	
21 April	Molniya-1/8	Tyuratam
5 July	Molyniya-1/9	Tyuratam
5 October	Molniya-1/10	Tyuratam
16 December	Cosmos 260	Tyuratam
	Meteorological	
14 March	Cosmos 206	Plesetsk
12 June	Cosmos 226	Plesetsk
	Navigational	
19 January	Cosmos 200	Plesetsk
20 February	Cosmos 203	Plesetsk
7 May	Cosmos 220	Plesetsk
30 October	Cosmos 250	Plesetsk
30 November	Cosmos 256	Plesetsk
	Lunar	
7 February	Failure	Tyuratam
7 April	Luna-14	Tyuratam
	Man-Related	
2 March	Zond-4	Tyuratam
14 April	Cosmos 212	Tyuratam
15 April	Cosmos 213	Tyuratam
22 April	Failure	Tyuratam
28 August	Cosmos 238	Tyuratam
14 September	Zond-5	Tyuratam
25 October	Soyuz-2	Tyuratam
26 October	Soyuz-3	Tyuratam
10 November	Zond-6	Tyuratam
	Maneuverable	
22 March	Cosmos 209	Tyuratam
24 April	Cosmos 217	Tyuratam
19 October	Cosmos 248	Tyuratam
20 October	Cosmos 249	Tyuratam
1 November	Cosmos 252	Tyuratam
	Undetermined	
15 June	Failure	Tyuratam
27 August	Cosmos 236	Tyuratam

(S)

maneuvers before reaching a final orbit of about 275 nm.

• One day later Cosmos 249 was launched and placed in an orbit of 280/900 nm. On revolution two, Cosmos 249 passed Cosmos 248 at a distance in the order of 9 nm. Several unidentified objects were observed accompanying Cosmos 249 in its final orbit of 280/1,170 nm.

• On 1 November Cosmos 252 was orbited in a manner similar to that of Cosmos 249. Cosmos 252 on its second revolution also passed quite close to Cosmos 248 (about one nm). Later, Cosmos 252 displayed multiple objects in its orbit path; additional objects also appeared in the orbit of Cosmos 248. The appearances were traced back to about the time of close flyby. [END]