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ABSTRACT

This report, the third and final part of a three-part study of Soviet space programs, provides a comprehensive survey of the Soviet space science programs and the Soviet military space programs, including its long history of anti-satellite activity. Chapter 1 is an overview of the unmanned space programs (1957-83). Chapter 2 reports on significant activities in Soviet unmanned flight programs (1981-83), including space science activities, space applications, and military missions. Chapter 3 provides detailed information on Soviet unmanned scientific programs, considering the early years, suborbital programs, earth orbital development and science, the Soviet lunar program, and other areas. Chapter 4 provides additional information on applications of space activities to the Soviet economy, examining meteorological satellites, and space manufacturing. Chapter 6 discusses Soviet military space activities, documenting their uses of space systems for military purposes. (JN)

99th Congress
1st Session

COMMITTEE PRINT

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Part 3

SOVIET SPACE PROGRAMS: 1976-80

(WITH SUPPLEMENTARY DATA THROUGH 1983)

UNMANNED SPACE ACTIVITIES

PREPARED AT THE REQUEST OF

Hon. JOHN C. DANFORTH, *Chairman*

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

Part 3

MAY 1985

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LETTER OF TRANSMITTAL

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC, May 15, 1985.

DEAR COLLEAGUE: I am pleased to transmit for your information and use a report on the Soviet unmanned space program. This is the third and final part of a comprehensive report on all aspects of the Soviet space program.

This report updates the Soviet space activities of 1981–83 and follows two previous reports on Soviet launch vehicles and facilities and Soviet manned space programs.

This third part, just as the first two parts of the study, should contribute significantly to the discussion of issues over which this Committee has jurisdiction.

JOHN C. DANFORTH, *Chairman.*

ERRATA SHEET

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LETTER OF SUBMITTAL

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

Hon. JOHN C. DANFORTH,
Chairman, Senate Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, DC.

DEAR MR. CHAIRMAN: Transmitted herewith is the third of a three part study, entitled "Soviet Space Programs: 1976-80." Prepared at the request of the Subcommittee on Science, Technology, and Space, the report presents a comprehensive and detailed overview of the Soviet space program.

This third and final part of the study reviews the Soviet unmanned space programs during the period of 1957-83. Specifically, this part provides a comprehensive survey of the Soviet space science programs and the Soviet military space programs, including its long history of anti-satellite activity.

Part 1 of this study contains detailed information on supporting vehicles and launch facilities, political goals and purposes, international cooperation in space, and the future outlook for Soviet space programs. Part 2 of this study reviews Soviet manned space activities and supporting life sciences research.

With the completion of the final part of this study, it is appropriate and timely to commend the Congressional Research Service for such a scholarly and thoughtful effort in each of the three parts of this study. These three volumes will serve as one of the truly authoritative sources for information on the Soviet space programs, and the Committee and other Members of Congress are fortunate to have this study as a reference.

Sincerely,

SLADE GORTON,
Chairman, Subcommittee on Science, Technology, and Space.

CONGRESSIONAL RESEARCH SERVICE,
THE LIBRARY OF CONGRESS,
Washington, DC, January 29, 1985.

Hon. SLADE GORTON,
Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, DC.

DEAR MR. CHAIRMAN: We are happy to transmit to you herewith the third and final part of our review of Soviet space activities for the period 1976-80. As you know, Dr. Charles S. Sheldon II, who spearheaded the preparation of earlier editions of this report and was to have been primarily responsible for this edition as well, passed away in 1981. As a result, this report has taken longer to prepare than we had planned, and we have, therefore, included a supplementary chapter which highlights significant Soviet space activities from 1981 to 1983. Information in this report is current as of December 31, 1983.

This volume has been written by Marcia S. Smith, Specialist in Aerospace and Telecommunications Systems; Geoffrey E. Perry, M.B.E., head of the Kettering Group of amateur satellite observers in England; and Patricia E. Humphlett, Analyst in Aviation and Space. Ms. Smith was responsible for overall coordination of the report, and for writing the sections concerning space science, as well as the Executive summary and the overview. Ms. Humphlett contributed to the chapter on space science programs. Mr. Perry was responsible for the two chapters on space applications and military space activities, and contributed to the overview section. Before his illness, Dr. Sheldon had prepared many of the tables which appear in this volume.

As requested, this part of the report is being sent to you in camera ready copy to accelerate the publication process. Ms. Shirley Williams and Mr. Terrence Lisbeth of the Production Support Unit of the Science Policy Research Division have been responsible for preparing the copy, and Ms. Sandra Burr, Ms. Kaseem Hall, and Ms. Karina Bush have all contributed to preparation of the manuscript. Mr. John Ragsdale of CRS' Automated Information Systems Office and Mr. Lloyd Beasley of your committee's staff have been particularly helpful in this process.

It should be emphasized that this report is based exclusively upon unclassified sources, including Soviet announcements and independent analyses made by Western observers of the Soviet space program and reported in the United States and abroad.

Special thanks are extended to Mr. David R. Woods, an engineer with IBM Federal Systems Division in Owego, NY, who has provided many of the illustrations for this volume. All the illustrations are based on unclassified materials appearing in scientific journals or actual models shown at the Paris Air Show and other technical displays, and various Soviet documentary films. These illustrations are copyrighted and may not be used elsewhere without his permission.

Part 1 of this review, dealing with launch vehicles and sites, political goals and purposes of the Soviet program, the Soviet attitude toward international cooperation in space, Soviet organization for conducting its space activities, and the resource burden of the space program on the Soviet economy, was published in December 1982 by your committee. Part 2, covering the Soviet manned space program and the space life sciences, was published in October 1984 by your committee as well. We hope that these comprehensive reviews of Soviet space activities, which CRS has prepared since 1961, continue to be useful in your deliberation on priorities for the U.S. space program.

Sincerely,

GILBERT GUDE, *Director.*

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Executive Summary

Since 1976 when the last edition of this study was published, the Soviet Union has continued its unmanned space programs for Earth orbital science, planetary exploration, space applications, and national security, but there have been few great strides. Rather, it has been a period of steady evolution of the satellites used for these purposes.

Of the various types of space activities addressed in this study, the most controversial have certainly become those which support national security goals, with a growing worldwide debate over the "militarization of space." In some minds, this is a debate over whether or not there should be weapons in space; in others, it concerns whether there should be any military uses of space, aggressive or nonaggressive. In general, however, it is the issue of space weapons which has received the most attention.

The Soviet Union has been testing an antisatellite [ASAT] device since 1968, and in 1977, the United States declared the Soviet system operational. In response, the U.S. initiated development of its own ASAT, and called on the Soviet Union to negotiate over limiting such weapons. Three rounds of talks were held from 1978 to 1979, but they were not resumed following the Soviet incursion into Afghanistan in December 1979.

During the next several years, the expanding budgets for U.S. military space activities and the continuing development of the U.S. ASAT prompted concern in the United States and abroad over what was viewed as the increasing military involvement in space, particularly for weapons purposes. Then, in March 1983, President Reagan began a chain of events which ignited the debate not only about ASAT's, which attack satellites, but the prospects for a space-based ballistic missile defense [BMD] system for attacking ICBM's and SLBM's enroute to their targets.

In a nationally televised address on March 23, 1983, President Reagan called on the scientific community which had developed nuclear weapons to now develop a system to render those weapons "impotent and obsolete." His advisers indicated that one possibility would be to base directed energy weapons (lasers or particle beams) in space to intercept nuclear missiles during boost phase. Thus, the President's idea became known as "Star Wars," conjuring up images of Luke Skywalker and Darth Vader, even though the President himself had said nothing about where such a ballistic missile defense system would be based. Also, the President initiated only a research program (formally called the Strategic Defense Initiative) and did not make a decision to develop, test or deploy a

BMD system. Nevertheless, the ensuing debate focused on the technological and cost implications of deploying a space-based BMD system, and interest naturally grew in what the Soviets were doing in the area of military space operations in general, and space weapons in particular.

The United States and Soviet Union use space for essentially the same military functions, and have done so since the beginning of the space program. Both have military communications, reconnaissance, navigation, meteorological, and geodesy and mapping satellites, and both have or have had space weapons. Although space weapons have become a topic of widespread interest only in the past 2 or 3 years, they have been part of the space program since at least 1959 when the United States launched a missile from an aircraft to intercept a U.S. satellite. Although that program was cancelled, the United States did have an operational ASAT system using ground-launched missiles from 1964 to 1975.

The Soviet Union may have had an ASAT capability as early as 1962 using the Galosh antiballistic missile system deployed around Moscow, because during that year Nikita Khrushchev announced that they had a missile that could "hit a fly in outer space." In any case, they began orbital testing of their current ASAT system in 1968, and 20 tests of the system had been made by the end of 1983. It is this system which the United States declared operational in 1977.

Thus, it is not fair to claim that either side is single-handedly responsible for "militarizing" space, whether that term is used generically to refer to any military activity in space (such as communications), or just to weapons systems. This does not make the debate over the militarization of space any less important, but should place the issue in a broader perspective.

It is not within the purview of this report to enter into the debate concerning space-based BMD, other than to say that it can safely be assumed that the Soviet Union is aware of the advantages (and disadvantages) of developing such a system, and is performing some amount of research in these technology areas. From the unclassified literature, there is no evidence that they have consolidated research activities into an equivalent of the SDI Program, however.

The Soviets have shown interest in negotiating a treaty to ban weapons from space, as has the United States. The initial negotiations over ASAT's resulted from a U.S. initiative. Two years after they ended, the Soviets introduced a draft treaty at the United Nations which would have banned the stationing of weapons in outer space (and therefore would not have affected either the operational Soviet ASAT System or the U.S. ASAT system in development). In August 1983, 5 months after President Reagan's "Star Wars" address, the Soviets introduced another draft treaty to ban the use of force in space, which would include ASAT's and space-based BMD, and instituted a unilateral ASAT testing moratorium (without admitting that they already had an ASAT system).

At the end of 1983, no negotiations were in progress between the two countries or at a multilateral level, and the debate over space weapons continued at a high pitch.

Although space weapons have occupied the public mind in recent years, the other unmanned activities, space science and space applications, should not be overlooked. In the Soviet program, space science activities continued at a modest pace, and in space applications, significant progress was made in communications and navigation satellites.

Only one more Soviet lunar probe was launched—Luna 24 which returned a third sample from the surface of the Moon. Like the United States, the Soviet Union seems to have temporarily lost interest in sending spacecraft to Earth's only natural satellite. No more attempts were made to send spacecraft to Mars, although the Soviets have indicated that they may do so in 1988. No Soviet attempts were made to send spacecraft to Mercury, Jupiter, or Saturn, planets to which U.S. probes have been sent already. Since 1976, only Venus has been visited by Soviet probes, and a total of eight were launched. The results from the Venus probes have been very good, but the limited scale of the Soviet planetary effort remains quite evident.

The unmanned Soviet Earth Orbital Science Program also continued on a modest scale, although the launch of two observatory class satellites in 1983 (Astron and Prognoz 9) may signify an increased interest in such missions. Few observatory class scientific payloads have been launched in the Soviet program, although the United States has had several major series of these satellites.

The scarcity of unmanned Earth Orbital Space Science Programs is somewhat mitigated by the research which can be performed on the Salyut space stations (see part 2 of this study), but it would appear that the lack of an organization like NASA to support space science in the Soviet Union has relegated it to a comparatively minor role in the overall program.

The most notable gains in the area of unmanned space applications in the Soviet program has been in utilization of geostationary orbit for communications satellites, initiation of the GLONASS navigation satellite system, and the use of a side-looking radar for ocean monitoring, although it should be noted that two other space applications areas, remote sensing and space manufacturing, have achieved substantial results in the manned program (see part 2 of this study).

Although the Soviet Union was the first country to have a domestic communication satellite system, the highly elliptical "Molniya" orbit used for these satellites was of limited utility for international communications, which are better served by satellites in geostationary orbit [GEO] where they maintain the same position relative to a given ground station. The first Soviet geostationary satellite was not launched until 1974, 11 years after the first such U.S. satellite, but by the end of 1983, the Soviets had three different systems in place (Ekran, Raduga, and Gorizont) and at least three more planned (Volna, Loutch, and Gals). Clearly they have found GEO satellites a valuable adjunct to their Molniya system.

The GLONASS navigation satellite system can provide three-dimensional data (altitude, latitude, and longitude) like the U.S. NAVSTAR Global Positioning System. Although the United States had its first NAVSTAR launch in 1978, only seven were in orbit by the end of 1983, all in the developmental (rather than operational) series. By contrast, the Soviets launch the GLONASS satellites three at a time, and accomplished three such launches between 1982 and 1983, for a total of nine satellites in orbit. In this case, the Soviets appear to have progressed further than the United States, even though they started much later. Neither system was operational by the end of 1983.

The launch of Kosmos 1500 in 1983 signalled an expanded interest in performing ocean surveys from space. The spacecraft, with its side-looking radar, was used to help extricate Soviet ships from arctic ice, and continues to be used for ocean surveys with wide dissemination of the data through inexpensive ground stations.

The most notable lack of progress in the Soviet unmanned space applications program was the absence of a geostationary meteorological satellite. It had been promised in 1979 as part of an international weather program, but still had not been launched by the end of 1983.

Thus, it can be said that progress was made in all the areas covered in this volume, but the Soviets still have some distance to go in their space science and space applications programs to catch up with the United States.

Chapter 1

Overview of Unmanned Space Programs: 1957-83

The largest component of the Soviet space program, and the U.S. space program as well, is unmanned space activities. These activities include those related to science, applications (such as communications and remote sensing), and national security. The most well known of the Soviet unmanned probes is, of course, Sputnik 1, which ushered in the space age on October 4, 1957.

Although there have been many projects with specific names such as Meteor, Molniya, Venera, Mars, and Luna, the largest number of unmanned launches in the Soviet program have been given the generic designation, Kosmos. By the end of 1983, there had been 1,591 Kosmos spacecraft. The word simply means "space" in Russian, and satellites launched with this name include scientific probes and engineering tests, but the largest single category applies to military missions. Spacecraft which fail once they reach orbit are often designated Kosmos, too, despite whatever their original mission might have been.

This report is part 3 of the most recent of a series of 5-year reports prepared for the Senate Commerce, Science, and Transportation Committee [1] by the Congressional Research Service, and provides information on unmanned scientific, applications, and military space programs. Volume I discusses launch vehicles, launch and tracking sites, international cooperation, organization for Soviet space activities, and how much the Soviets spend on their space activities. Volume II addresses manned space activities, including the space life sciences.

Chapters 3, 4, and 5 of this part of the report provide comprehensive details on space science, space applications, and military space programs, respectively. Chapter 2 has been provided to highlight activities from 1981 to 1983, the time during which the report was written. This chapter serves as an overview of the unmanned programs of both the Soviet Union and the United States. Readers interested in more detail on the Soviet flights will find information in the remaining chapters of this volume. Detailed information on U.S. space science and space applications activities is contained in U.S. Civilian Space Programs, volume I and volume II, prepared by the Congressional Research Service for, and published by, the

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[1] Until 1976, the Aeronautical and Space Sciences Committee.

House Committee on Science and Technology in 1981 and 1983, respectively.[2]

SPACE SCIENCE

The launch of Sputnik 1 on October 4, 1957, is remembered for its historic role as the world's first artificial satellite, but it should not be forgotten that it was also the first satellite for space science. In fact, it was the scientists who urged both the United States and the Soviet Union to launch satellites to assist in their investigation of atmospheric phenomena during the International Geophysical Year (July 1, 1957 to December 31, 1958).

Both Sputnik and the first U.S. satellite, Explorer 1, were launched during the IGY. The United States had not planned that Explorer 1, built by the Army's Jet Propulsion Laboratory, would be the first U.S. satellite, however. Rather, President Eisenhower had established the Vanguard Program to develop a civilian satellite and launch vehicle to demonstrate the U.S. commitment to the peaceful uses of space. The Vanguard Program did not receive very high priority until the launch of Sputnik, however, after which an accelerated schedule resulted in an embarrassing failure when the first launch was attempted on December 6, 1957. Despite his opposition to using a military rocket to carry the first U.S. satellite into orbit, President Eisenhower was forced by events to permit the Army to use its Jupiter C rocket to place Explorer 1 in orbit on January 31, 1958.[3]

Eisenhower continued to insist that the United States have a strictly civilian space program, which ultimately led to the creation of the National Aeronautics and Space Administration [NASA]. U.S. military space programs remained under the jurisdiction of the Department of Defense. In the Soviet Union, no such distinction was made. The entire Soviet Space Program is conducted by the Strategic Rocket Force, except for cosmonaut training which is under the jurisdiction of the Soviet Air Force. There is no Soviet equivalent of NASA; scientific input is made primarily through the Soviet Academy of Sciences.

EARTH ORBITAL SPACE SCIENCE

Sputnik 1 revealed characteristics of the ionosphere through variations in its beeping signal, and its orbital perturbations and eventual decay provided information on atmospheric density. This was the beginning of the Soviet Earth Orbital Space Science Program, which has subsequently involved satellites launched under the Kosmos and Interkosmos designations, the latter denoting flights which are conducted cooperatively with other countries. In addition, there have been a few other programs, the most significant of which are the Prognoz series and the Astron satellite. The Kosmos and Interkosmos spacecraft are similar to the satellites in the U.S. Explorer series and generally are single purpose satellites optimized for a specific mission. Prognoz and Astron are observato-

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[2] A report on U.S. military space activities is now in preparation by CRS and should be available as a CRS report in the spring of 1985.

[3] It was Jan. 31 local time; Feb. 1, Greenwich mean time.

ry class satellites with multiple scientific objectives, in the same category as the U.S. Orbiting Astronomical Observatories, Orbiting Solar Observatories, and High Energy Astronomy Observatories. The United States has done much more with its Earth Orbital Space Science Program than the Soviet Union, although the launch of Prognoz 9 for radio astronomy and Astron for x ray and ultraviolet astronomy in 1983 may signal an increased Soviet interest in such activities.

EXPLORING THE MOON AND PLANETS

Although the Soviets were not successful in sending people to the Moon (see volume 2 of this report for a discussion of the "Moon Race"), they did have an active program of unmanned lunar probes from 1959 to 1976. The United States launched unmanned lunar probes from 1958 until 1968, followed by the manned Apollo landings from 1968 to 1972.

The first attempts to send probes to the Moon were made by the United States and met with mixed success. Satellites in the Pioneer series between 1958 and 1960 were meant to either orbit or fly by the Moon, and only one of the nine probes launched accomplished a fly-by mission. The Ranger Program which followed, from 1961 to 1965, was intended to return television pictures of the Moon before the spacecraft made a hard impact on the Moon's surface. The first six Rangers failed (the first two were vehicle tests), although the last three were successful.

During this period, the Soviets launched Luna probes with a variety of missions, including flybys, hard landings, and soft landings. Of the eight Lunas launched from 1959 to 1965, two are considered complete successes in the West. One of these, Luna 3, returned the first pictures of the far side of the Moon in 1959.

From 1966 to 1968, the United States launched two series of lunar probes, Surveyor and Lunar Orbiter. The Surveyor Program, which was much more successful than Pioneer and Ranger, involved probes which could make soft landings on the lunar surface to provide data to be used for the manned Apollo Program. The completely successful Lunar Orbiter Program involved spacecraft which made detailed maps of the lunar surface to provide data on landing sites for the Apollo crews. The Soviets, meanwhile, continued the Luna series, and succeeded in attempts at soft landings and orbiters.

In 1969, attention in the United States turned to the manned Apollo Program, and six crews landed on the Moon through the end of 1972. No further U.S. lunar probes, manned or unmanned, have been launched since that time.

For their part, the Soviets continued the Luna Program, launching orbiters and soft landers. Two different types of landers were developed, one for automated sample return, and the other which deposited roving vehicles called Lunokhods for long-term studies of the lunar surface. Three samples were successfully returned (in 1970, 1972 and 1976), bringing back a total of approximately 330 grams of lunar material (compared with 380 kilograms returned by the six U.S. Apollo crews). The two Lunokhods were launched in

1970 and 1973 respectively. No Soviet lunar flights have taken place since the last successful sample return in 1976.

In the field of planetary exploration, the Soviets have never attempted to send unmanned spacecraft as close to the Sun as Mercury, or as far from it as Jupiter and Saturn. By contrast, U.S. probes have visited Mercury, Venus, Mars, Jupiter, and Saturn, and one is now en route to Uranus. One of the probes which visited Jupiter (Pioneer 10) became the first manmade object to leave the solar system in 1983.

The Soviets have focussed on Mars and Venus. With Mars, they have had little success, but the results of the Soviets Venera probes has been extremely good.

The Soviets have only admitted to launching seven probes to Mars: one in 1962, two in 1971, and four in 1973. The two in 1971 were combination orbiter/landers, but did not carry biological experiments as did the U.S. orbiter/lander Viking probes in 1975-76. Of the Soviet probes, only one (Mars 5, an orbiter) can be considered a complete success by Western standards, although most returned at least some data about the planet. The primary problem seemed to be in targeting the spacecraft and in ensuring that the braking rockets functioned properly. Two of the landers (Mars 3 and Mars 6) proceeded to the surface correctly, but Mars 3 ceased transmitting 20 seconds after it reached the surface, and contact was lost with Mars 6 just before it reached the surface.

By contrast, the United States had good results from its Mariner 4, 6, and 7 fly-by probes (Mariner 3 was a failure), and Mariner 9, an orbiter, provided the first detailed mapping of the Martian surface in 1972 (Mariner 8 was lost in a launch vehicle failure). The landing of Viking 1 and 2 on the surface of Mars in 1976 provided detailed information on the two landing sites, although results from the experiments designed to determine if there is life on the planet were inconclusive. The Viking 1 lander lasted longer than any of the other Viking spacecraft, returning data until November 1983. The Viking orbiters returned exhaustive data about the Martian surface and Mars' moons, Phobos and Diemos.

At the end of 1983, plans were reportedly underway by the Soviets to launch a probe to Mars in 1988, apparently for detailed studies of Phobos, and the United States was contemplating the launch of a Mars "geoscience/climatology" orbiter in 1990 to attempt to determine what happened to the water that scientists believe once flowed on the planet's surface.

The Soviets have devoted considerable effort to detailed studies the atmosphere and surface of Venus. Between 1961 and 1983, 16 Venera spacecraft had been launched, and two were in orbit around the planet performing mapping studies using side-looking radars. The United States has devoted less effort to studying Venus, launching five probes between 1962 and 1978, one of which had five separate entry probes for atmospheric studies. The Pioneer Venus 1 orbiter, launched in 1978, continued to return data at the end of 1983, after more than 5 years of operations.

The most startling discoveries about Venus have came from images returned by Venera 9 and 10 in 1975. They were the first to return pictures from the surface of another planet, having landed on Venus a year before the U.S. Vikings reached Mars. The pictures were surprising for several reasons. For example, it had been expected that Venus was a geologically "dead" planet, and that rocks would long since have been eroded by the harsh climatic conditions on the planet's surface. Instead, Venera 9 and 10 found plenty of rocks with sharp cleavages, indicating that Venus was geologically active, a discovery supported by additional Venera and the U.S. Pioneer Venus missions. In addition, it had been thought that it would be relatively dark on the surface since the thick clouds were thought to obscure most of the sunlight, and Venera 9 and 10 carried spotlights to illuminate the landing area. Instead, it was found that the surface was as bright as Moscow on a cloudy summer day. Thus, the Venera 9 and 10 spacecraft, and their successors including Venera 13 and 14 which returned color photographs showing the surface and atmosphere to be reddish-orange (because of iron oxide in the soil, which is blown up into the clouds by winds), have significantly changed scientific theory about Venus.

The Soviets are planning two Venus-related launches in December 1984. Called VEGA, for Venus-Halley's Comet, the probes will drop off landers at Venus, as well as balloons which will float down through Venus' atmosphere for detailed studies of its constituents. The spacecraft buses, which carry imaging equipment, will then continue on to a rendezvous with Halley's Comet in 1986. The United States is not sending any spacecraft to Halley's Comet, although an existing spacecraft has been modified so that it can return data about the Giacobini-Zinner Comet for comparative studies. Originally called the International Sun-Earth Explorer 3 [ISEE], the spacecraft was placed in an orbit half way between the Earth and Sun, and was performing magnetospheric studies in connection with its sister satellites, ISEE 1 and 2, in Earth orbit. ISEE-3 has now been redesignated ICE [International Comet Explorer] and is using onboard propulsion to change its orbit so that it can intercept the comet for comparative studies. Japan and the European Space Agency (a group of 11 European countries) are sending probes to Halley's Comet, and an international agreement has been signed for sharing of the data from all these probes, plus Earth-based studies.

The United States is planning to launch the Venus Radar Mapper [VRM] mission in 1988 which will provide more detailed mapping of the planet's surface. The radars on the Soviet Venera 15 and 16 spacecraft have a resolution of 1-2 kilometers; VRM will have a much better resolution of 200-330 meters.

SPACE APPLICATIONS

The several disciplines of communications, meteorology, navigation, Earth resources, geodesy and mapping, and space manufacturing are all examples of what may be termed space applications.

The United States and the Soviet Union both have large space applications programs, although the United States was first in the field and has remained ahead in most respects, including the number of satellites employed for particular applications, the serviceable lifetime of the satellites, and the sophistication of the equipment. Nevertheless, the Soviet Union continues to make steady progress in all applications areas and the operational lifetimes of their payloads are becoming longer.

SPACE MANUFACTURING

Space manufacturing is the only area in which the Soviet Union has surpassed the United States by virtue of the work performed by cosmonauts on the long duration Salyut space station missions. Materials processing furnaces have taken advantage of the opportunity provided by microgravity conditions and the high vacuum of space to produce commercial quantities of superpure cadmium-mercury-telluride, an important component of infrared devices, and samples of "new" materials, such as superconductors, glasses, pure metals, alloys and eutectics, semiconductors and crystals which are difficult or impossible to produce on Earth. They have also produced vaccines by electrophoretic techniques. The United States, having experimented with furnaces in Skylab and, briefly, during the Apollo-Soyuz Test Project [ASTP], has been forced to wait for the space shuttle to resume similar experiments. The focus on the U.S. materials processing in space program is currently on continuous-flow electrophoresis for vaccine production, which is being performed under a Joint Government-industry arrangement.

COMMUNICATIONS

Following experiments with both military and civil communications satellites in low Earth orbit, the United States launched the first geostationary communications satellite in 1963. The geostationary orbit is a special orbit 35,800 kilometers above the equator where a satellite can maintain a fixed position relative to any point on Earth because the orbital period of the satellite matches the sidereal period of Earth.

The Soviets did not launch their first geostationary satellite until 1974 primarily because of the greater energy required for a launch vehicle to accomplish such a task from the more northerly Soviet launch sites. In addition, geostationary satellites have a more limited utility for the Soviet Union itself, since so much of its territory is at far northern latitudes which are difficult to reach with transmissions to and from an equatorial orbit. Consequently, the Soviet Union developed a communications satellite system called Molniya, which uses what is appropriately called a Molniya orbit. This is an eccentric orbit with a very high apogee (40,000 kilometers) over the Northern Hemisphere and a low perigee (500 kilometers) over the Southern Hemisphere. Inclined at 63°, these orbits have a 12-hour period (semisynchronous), and provide a long linger time of as much as 8 hours over the Northern Hemisphere. A system of these satellites, then, can provide 24-hour coverage, and the Soviets use Molniya 1 and Molniya 3 satellites for this purpose.

While of less utility for domestic communications, geostationary satellites are nevertheless valuable for international communications, and beginning in 1974 the Soviets began launching geostationary communications satellites. Currently, they have series of Ekran, Raduga, and Gorizont satellites for various types of communications, and they have registered with the International Telecommunications Union for three more series: Loutch (or Luch), Volna, and Gals. The latter apparently will be for military communications. Experimental Loutch and Volna transponders have been flown on other Soviet communications satellites. It would appear that both semisynchronous and geostationary satellites will have major roles to play in Soviet communications plans in the near and long-term future.

In 1968, the Soviets announced that they would form the Intersputnik organization as an alternative to the Intelsat international communications satellite organization which they considered too strongly under the influence of the United States. Intersputnik began operations in 1971 relying entirely on the Molniya system, and only the Soviet Union and it allies joined the system. Even with the advent of Soviet geostationary satellites, few countries have joined Intersputnik instead of Intelsat, and at the end of 1983, there were 108 countries that had joined Intelsat, and 14 which belonged to Intersputnik. Although it has never joined Intelsat, the Soviet Union does use the Intelsat system.

METEOROLOGY

The Soviet Union still has not launched geostationary meteorological satellites, relying instead on the polar orbiting Meteor spacecraft which are somewhat similar to the U.S. NOAA satellites. They have no equivalent of the GOES system, although they had announced plans to launch a geostationary weather satellite in 1979 as part of an international meteorological effort which involved satellites launched by the United States, the European Space Agency, and Japan. By the end of 1983, the Soviet satellite, called GOMS [Geostationary Orbit Meterological Satellite], still had not been launched.

Two generations of Meteor satellites have been used since 1969 to provide cloud-cover imagery. The Sun-synchronous retrograde orbits used by the U.S. NOAA weather satellites was not adopted until 1977 by the Soviet Union, and satellites in these orbits are designated as Meteor-Priroda (Nature) and primarily perform Earth resources roles.

EARTH RESOURCES

The United States was first in the Earth remote sensing field, launching the first dedicated remote sensing satellite, Landsat 1 (then called ERTS 1), in 1972. Since then, four more Landsats have been launched. They carry multispectral scanners for gathering data which can be used for a variety of purposes including assessing crop yields, performing mineral surveys, and studying geological features.

The Soviet approach to remote sensing is somewhat different, relying on film cameras rather than scanners. Much of their remote sensing work is performed on the Salyut space stations (in orbits which are inclined at 51.6°), augmented by several 2-week Kosmos flights per year inclined at 82.3°, all of which use film. There have been a few Meteor-Priroda satellites, as mentioned above, which are in Sun-synchronous orbits and use scanners, and Kosmos 1484, launched in 1983 into a Sun-synchronous orbit, may be a closer

Soviet equivalent to the U.S. Landsat satellites, but few details have been released.

NAVIGATION

The United States developed a navigation satellite system called Transit which provides two-dimensional data (latitude and longitude). Satellites launched in this series are called Transit or Nova, the latter being an improved Transit satellite. Although it is technically a Navy program, more than 90 percent of the users are in the civilian sector. The Soviet Union has a similar system The satellites in this series are given Kosmos designations, and according to analysis by the Kettering Group, there is a constellation of six satellites at 30° plane spacings which apparently serves the military sector, and a constellation of four satellites at 45° plane spacings (called Tsikada) which apparently serves the civilian sector.

The United States decided that it would be useful to have a navigation satellite system which provided three-dimensional data (altitude as well as longitude and latitude), so began development of the NAVSTAR Global Positioning System, which will also provide much greater accuracy than the Transit system. When operational, the system will use 18 satellites in 6 orbital planes. NAVSTAR is expected to be fully operational in 1988, although seven satellites in the developmental series have already been successfully launched. Similarly, the Soviet Union decided to develop a three-dimensional system, called GLONASS. The Soviets launch their satellites three at a time. By the end of 1983, there had been three such launches, for a total of nine GLONASS satellites in the experimental series. The first two sets went into the same plane, but the third entered a plane separated by 120° from the first and may signal a move toward an operational status, although the satellites are not equally spaced around each orbital plane.

THE KOSPAS/SARSAT SEARCH AND RESCUE SATELLITE SYSTEM

The KOSPAS/SARSAT Search and Rescue Satellite Program is an international effort which involves satellites launched by the Soviet Union and the United States, and control centers and ground stations in those countries plus Canada, France, Norway, and Britain for receiving messages from aircraft and ships in distress. The SARSAT equipment is launched on U.S. NOAA weather satellites and was developed jointly by the United States, Canada, and France; the KOSPAS equipment was developed by the Soviets and is launched on Kosmos satellites using the Tsikada navigation satellite design. Finland, Bulgaria, and Sweden also participate in the program.

The first Soviet KOSPAS satellite was launched in June 1982 as part of the demonstration phase of the program, and the first rescue took place in September of that year. The second KOSPAS satellite was launched in March 1983; the first Sarsat equipped

NOAA satellite was also launched that month. By the end of 1983, more than 60 lives had been saved by the system.[4]

GEODESY AND MAPPING

The United States has flown many geodetic flights in order to correlate maps of different parts of the world and for determining the true shape of the geoid from analysis of small perturbations of the orbits. Data from the NASA geodetic missions (such as PAGEOS and LAGEOS) have been published, but not those from DOD missions.

The Soviet Union claims to be interested in geodesy and mapping, but has identified few flights for these purposes. Kosmos satellites in near-circular orbits are presumed to have such roles, along with several others which are subsets of the reconnaissance satellite program.

MILITARY SPACE MISSIONS

The distinction between civilian and military space missions is, at best, nebulous. As noted earlier, the Soviet Union has no civilian space agency comparable to NASA, and uses the Kosmos label for all launches other than a few named applications satellite and scientific programs, interplanetary and lunar flights, and programs related to manned spacecraft.

RECONNAISSANCE

Approximately half of all Kosmos launches have accounted for payloads which disappear from orbit while their orbital parameters indicate that they would not decay from orbit naturally. These recoverable payloads are thought to perform photographic reconnaissance missions, and their flight durations have progressed through four generations from an initial 3 days to more than 7 weeks. The Soviet Union currently obtains almost continuous coverage from one or more "third-generation" satellites whose flight times last for 2 weeks, and "fourth-generation" satellites with lifetimes of either 4 or 6 weeks. This approach to reconnaissance demands a launch rate of approximately 30 satellites per year, in contrast to the U.S. reliance on fewer satellites with much longer lifetimes to provide equivalent coverage. Fourth-generation Kosmos reconnaissance satellites may employ both film return and digital image transmission techniques.

A different type of observation satellite, which uses a nuclear reactor powered side-looking radar capable of penetrating cloud cover and darkness, is used for ocean surveillance. These radar ocean reconnaissance satellites [RORSAT's], are designed so that the nuclear reactor portion separates from the instrument section after the end of the mission, and is boosted into a higher orbit from which it would not naturally decay until the radiation no longer presents a severe health hazard.

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[4] An agreement between the Sarsat members and the Soviet Union for the operational phase of the program was signed in October 1984, at which time there were three operational KOSPAS satellites in orbit The NOAA satellite which carried the Sarsat transponder had ceased operating by that time, although another launch was expected in November 1984.

On two occasions, however, malfunctions have occurred and the entire satellite has reentered. In January 1978, Kosmos 954 reentered over Canada, spreading radioactive debris over the northern region of that country. When the RORSAT Program resumed 2 years later, a design modification had been made to separate the fuel core, from the reactor vessel following the end of the mission lifetime, normally after the transfer to a higher orbit. In this way, if another malfunction occurred, the most radioactive part of the satellite, the core, would be exposed directly to the heat of reentry increasing the likelihood that it would disintegrate completely before reaching the ground.

The value of this modification was proven in 1982 when Kosmos 1402 suffered a malfunction and the reactor section did not move to the higher orbit. The core did separate from the reactor vessel, however, which was still attached to the instrument section. The less radioactive reactor vessel/instrument section reentered over the Indian Ocean in January 1983. The core disintegrated high over the South Atlantic Ocean the next month. No increase in radioactivity was detected in either area. By the end of 1983, no further satellites had been launched in this series.[5] The United States has no equivalent to the Soviet RORSAT's.

A second class of ocean surveillance satellites use electronic techniques for passive intelligence gathering and are referred to as EORSAT's [electronic ocean reconnaissance satellites]. Both the United States and Soviet Union have these types of satellites. In addition, both countries have other electronic intelligence [ELINT] satellites, sometimes referred to as Ferrets, which focus on geographical areas other than the oceans.

For early warning of ICBM and SLBM launches, the United States uses a system of three geostationary satellites referred to as the Defense Support Program [DSP]. The Soviet Union employs a different approach using nine satellites in highly elliptical Molniya orbits. The Soviet satellites transmit on frequencies close to those used by U.S. interplanetary probes and, despite their presumed military role, the Soviet Union has on request discontinued transmissions at times when NASA is trying to receive critical data from the probes during planetary encounters.

MILITARY COMMUNICATIONS

In the Soviet Union, there are several satellites which seem to be used for military communications, including Molniya 1s, possibly transponders on geostationary satellites, and two sets of satellites at 74° inclination which are often referred to in the West as "store-dump" satellites. One set is launched eight at a time by a single rocket and it is thought that a constellation of 24 of these form the operational segment of a real-time tactical communication system within a given theater of operations. The second set involves satellites which are launched one at a time into orbits with plane spacings of 120°, and these are thought to perform communications intelligence [COMINT] functions.

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[5] RORSAT launches resumed in June 1984.

The United States relies primarily on several series of geostationary communications satellites. These include the FLTSATCOM [Fleet Satellite Communication] system, the DSCS [Defense Satellite Communications System] series, and transponders leased from commercial satellites for maritime communications (MARISAT and LEASAT). In addition, the U.S. has the Satellite Data System series which are placed in Molniya orbits and provide communications with U.S. bases at far northern latitudes, and which may also provide a link with certain U.S. reconnaissance satellites.[6]

SPACE WEAPONS

Although public interest in space weapons has only been evident for a short period of time, the first test of a system for destroying orbiting satellites occurred as early as 1959. This was the U.S. Bold Orion Program in which an air-launched missile scored a deliberate near-miss on the U.S. Explorer 6 satellite. The program was subsequently terminated, and the SAINT Program was initiated, an acronym which is alternatively described as having stood for SAtellite INspecTor, SAtellite INTerceptor, or SAtellite Inspection and NegaTion. The program was cancelled in 1962 before any flight tests occurred.

In 1962, Soviet Premier Nikita Khrushchev stated in an interview with American newspaper editors that the Soviet Union had a system that could "hit a fly in outer space." It is possible that he was referring to the Soviet Galosh ABM system which was then being emplaced around Moscow, and remains there today. Following cancellation of the SAINT Program, the United States developed an antisatellite [ASAT] system using nuclear-tipped Thor missiles based on Johnston Island in the Pacific, which President Johnson declared operational in 1964. The system was dismantled in 1975 and although tests were flown during the 1960s, none apparently carried a nuclear warhead.

Beginning in 1968, The Soviets began testing a coorbital ASAT system using a nonnuclear explosive. Target satellites are launched out of Plesetsk (originally from Tyuratum), followed by the launch of an interceptor from Tyuratam. Attempts have been made to intercept the target in either one or two orbits; only two of the four single orbit tests have been successful. Two types of targeting sensors have been used, radar and an optical sensor. Only the tests using the radar have been successful. Thus, of the twenty tests conducted between 1968 and 1982 (the last time a Soviet ASAT was made), only nine have been successful. The Soviet ASAT has reached altitudes as high as 2,300 kilometers, although the highest altitude at which an interception was attempted was approximately 1,000 kilometers. This indicates that the ASAT might be able to reach U.S. weather, reconnaissance, and Transit navigation satellites (although not the NAVSTAR system which is in a much higher orbit), as well as the space shuttle. As currently configured, it cannot reach U.S. communications and early warning satellites at geostationary orbit, although it is possible that in the future it

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[6] Aviation Week and Space Technology, Jan 2, 1984, p 13.

could be launched on a more capable launch vehicle to reach such altitudes.

It should be noted that there is a class of Kosmos satellites which use orbits with similar characteristics to the Soviet ASAT target, and launches of these satellites are often mistaken by some Western analysts as target launches. Instead, they are probably for radar calibration in which fragments are released to simulate multiple independently targeted reentry vehicles [MIRV's]. Suggestions that these satellites are used to monitor the results of ASAT tests are not supported by analysis of orbital data or their regular appearance at times unrelated to ASAT tests. The radar calibration flights can be identified by their orbital period, which is approximately 94 minutes, as opposed to an ASAT target, which has a period of approximately 96 minutes.

In 1977, the United States declared the Soviet ASAT operational, and embarked on development of a new ASAT system of its own. This system is based on an F-15 aircraft and uses no explosive device. It would destroy a target satellite by direct impact, but had not been tested by the end of 1983.[7] Because it is based on an aircraft, the system is more flexible than the Soviet ASAT system in that the ASAT device can be taken (within limits imposed by the range of the F-15) to where the satellite is located, instead of waiting for the satellite to be in a correct orbital position before launch can take place. Although information on the U.S. ASAT is classified, it is thought that the U.S. ASAT suffers from altitude limitations like the Soviet ASAT, but it also could be placed on a more capable launch vehicle (such as a Minuteman) to reach higher altitudes. If its altitude limitations, as the system is currently configured, are similar to those of the Soviet system, the U.S. ASAT could attack Soviet reconnaissance, weather, and navigation satellites (although not the GLONASS system), and the Salyut space station and associated spacecraft. In addition, if altitude alone was the limitation, Soviet communications and early warning satellites which use Molniya orbits would be vulnerable at perigee, although the perigees occur far out over the ocean and the satellites have high velocities when they reach perigee, so it is questionable as to whether the U.S. ASAT could destroy them or not.

The F-15 ASAT system is expected to be operational in 1987, although the program has encountered stiff opposition from the U.S. Congress, and the development schedule is quite uncertain.[8]

The Soviet Union developed another system which is often categorized as a space weapon, although it was essentially a long range ICBM which would have approached the United States from the south instead of the north. Called FOBS [Fractional Orbital Bombardment System], tests were made between 1967 and 1971. The satellites were recalled after completing slightly less than one orbit, and their ground tracks were primarily over oceans and deserts, far from the United States. It is not thought that they carried nuclear warheads during these tests. No flights have been

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[7] The first test of the U.S. ASAT was conducted in January 1984 against a point in space and was successful.

[8] For a discussion of the U.S. ASAT program and congressional debate over its development, see CRS Issue Brief 81123, "Star Wars": Antisatellites and Space-Based BMD, by Marcia S. Smith.

made since 1971, and it is not known for certain whether the program was abandoned or placed on a standby operational status, although the SALT II agreement (which has never been ratified) included among its agreed provisions the dimantlement of 18 "fractional orbital missile" launchers at Tyuratam, which may have been a reference to this system.

In a March 23, 1983 national address, President Reagan called for research and development on a system to render nuclear weapons "impotent and obsolete" by developing a ballistic missile defense system. Although the President never mentioned space, the proposal immediately became known as the "Star Wars" proposal since his advisers stated that components of such a system might be based in space in order to attack ballistic missiles during their boost phase, prior to the deployment of MIRV's.

Reagan's address evoked considerable controversy over the technical feasibility, economic costs, and political wisdom of deploying a BMD system. The United States and Soviet Union signed a treaty in 1972 (the Antiballistic Missile, or ABM, Treaty) allowing each side to have one fixed land-based ABM site, and prohibiting the development, testing, and deployment or air-based, space-based, and mobile land-based ABM systems, although new systems based on "other physical principles" were subject to further negotiations and possible amendments to the treaty. The program proposed by the President, formally called the Strategic Defense Initiative [SDI], does not violate the treaty as long as it remains in the research phase. Among the research programs included in the SDI are directed energy weapons, which include lasers and particle beams.[9]

The Reagan speech, coupled with the imminent testing of the U.S. ASAT system, prompted widespread debate over the "militarization of space" which was continuing with vigor at the end of 1983. For their part, the Soviets introduced a revised draft treaty at the United Nations in 1983 (the first one had been profferred in 1981) calling for a ban on the use of force in space, which would affect both ASAT and space-based BMD systems. In addition, Soviet President Andropov announced a unilateral moratorium on testing ASAT's, promising that the Soviet Union would not be the first to place an ASAT device in space (avoiding admission that it already has such a system). No Soviet ASAT tests have taken place since June 1982.

Whether or not the Soviets are contemplating a "Star Wars" system of their own is difficult to determine from unclassified sources. The Soviets characteristically place considerable emphasis on homeland defense, including air defense and civil defense. These types of activities are "strategic defense," so in that sense they already have a "strategic defense initiative." It has been reported in the Western press that they are developing space-based weapons, although they could be for ASAT rather than BMD purposes, and Pentagon witnesses have stated for many years that the Soviets spend three to five times as much as the United States on directed energy research, although this could be for ground-based rather than space-based applications. No useful conclusions can be drawn

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[9] For a discussion of the Strategic Defense Initiative and congressional reaction to it, see CRS Issue Brief 81123, "Star Wars" Antisatellites and Space-Based BMD, by Marcia S. Smith.

from the open literature regarding the existence of a Soviet SDI Program.

CONCLUSION

As can be seen, the United States has done more than the Soviet Union in both Earth orbital and planetary space science, although the Soviets have achieved spectacular results from their probes to Venus.

In the field of space applications and military space missions, both countries utilize spacecraft for essentially the same purposes, but since the Soviet spacecraft generally have shorter lifetimes, they must be replaced more frequently, resulting in a significantly higher launch rate for the Soviet Union. For example, in 1983, the Soviets launched 27 photographic reconnaissance satellites alone (37 if the Kosmos satellites identified as having Earth resources missions are included), compared with two launched by the United States. The only military space system the Soviets have for which there is no U.S. counterpart is the nuclear-reactor powered radar ocean reconnaissance satellites.

In both countries, it is extremely difficult to differentiate between military and civilian space missions, since the data received from or transmitted via the satellite can serve both sectors. This is particularly true for communications and navigation satellites. Thus, it cannot be said with any certainty that one program is oriented more towards military goals than the other, since both have used space to support the military sector since the earliest days of the space program, and continue to do so.

Chapter 2

Significant Activities in Soviet Unmanned Flight Programs: 1981-83

The main chapters of this text provide information on Soviet unmanned flight programs (space science, space applications, and military space activities) for the period 1976-80 in conformance with the pattern of 5-year studies which CRS has prepared for the Senate since the early 1960's. Since this edition of the 5-year update has taken additional time to complete following the 1981 death of Dr. Charles S. Sheldon II, who had spearheaded preparation of the earlier reports and was to have written this version, the authors decided to prepare the following supplementary chapter to bring the volume up to date through December 31, 1983.

SPACE SCIENCE

Space science was fairly active in both 1981 and 1983, but there were no space science missions launched in 1982. No spacecraft were sent either to Mars or the Moon, although four were sent to Venus. There were two observatory class satellite launches, and three smaller satellites.

This section does not discuss several satellites which are sometimes classified as science: the launches of amateur radio satellites (Radio 3-8, launched on a single booster in 1981; Iskra 1 launched with the Meteor-Priroda satellite in 1981; and Iskra 2 and 3, deployed from Salyut 7 in 1982); ocean resources flights, which are discussed under applications; and the Kosmos 1514 biosatellite mission which is discussed in Part 2 (Manned Space Programs and the Space Life Sciences) of this report. Table 1 summarizes unmanned Soviet space science flights from 1981 to 1983.

TABLE 1.—SOVIET UNMANNED SPACE SCIENCE MISSIONS, 1981-83 [1]

Name	Launch date	Apogee (km)	Perigee (km)	Inclination (deg)	Period (min)	Purpose/comments
Interkosmos 21	Feb 6, 1981	520	475	74.0	94.5	Primarily ocean resources.
Interkosmos 22 (Bulgaria 1300)	Aug 7, 1981	906	825	81.2	101.9	Primarily Bulgarian experiments to celebrate the country's 1300th anniversary.
Aureole 3 (Arcad 3)	Sept 21, 1981	1.920	380	82.6	108.2	Cooperative with France; ionospheric and magnetospheric studies.

TABLE 1.—SOVIET UNMANNED SPACE SCIENCE MISSIONS, 1981–83 [1]—Continued

Name	Launch date	Apogee (km)	Perigee (km)	Inclination (deg)	Period (min)	Purpose/comments
Venera 13	Oct. 30, 1981	([2])	([2])	([2])	([2])	Landed on Venus Mar. 1, 1982; returned color photographs, performed soil analysis.
Venera 14	Nov. 4, 1981	([2])	([2])	([2])	([2])	Landed on Venus Mar. 5, 1982; similar to Venera 13.
Astron	Mar. 23, 1983	200,000	2,000	51.5	5,880.0	X ray and ultraviolet astronomy.
Venera 15	June. 2, 1983	([2])	([2])	([2])	([2])	Entered orbit around Venus Oct. 10, 1983. Radar mapping.
Venera 16	June 7, 1983	([2])	([2])	([2])	([2])	Entered orbit around Venus Oct. 14, 1983. Similar to Venera 15.
Prognoz 9	July 1, 1983	720,000	380	65.5	[3] 38,448.0	Radio astronomy.

[1] Does not include launches or deployments of amateur radio satellites, which sometimes are classified as science rather than communications; the Kosmos 1514 mission, which is described in pt. 2 (Manned Spaceflight and the Space Life Sciences) of this report; or ocean resources missions (discussed in ch. 4).

[2] Planetary trajectory.

[3] 26.7 days

PLANETARY MISSIONS

VENERA 13 AND 14

Venera 13 was launched on October 30, 1981, and was followed 5 days later, November 4, by the launch of Venera 14. Both were launched with the D-1-e booster into Earth orbit, and then sent into a planetary trajectory using an orbital platform.

Enroute to the planet, both spacecraft conducted studies of gamma-ray bursts, and more than 20 bursts were registered using equipment developed by France and the Soviet Union, including more than 10 associated with solar flares. An Austrian magnetometer was used to study the interplanetary magnetic field as well.

The Venera 13 lander arrived at Venus on March 1, 1982, and proceeded to the surface, landing at 7°30′ south latitude, 303° longitude, on the plains east of the Phoebus area. Scientific data were returned for 127 minutes, four times longer than planned.[1] Venera 14 landed on March 5 at 13°15′ south latitude, 310°9′ longitude, and transmitted data for 57 minutes. The landing sites were chosen based on radar images from the U.S. Pioneer-Venus probe,[2] and were assumed by Soviet and American scientists to be centers of volcanic activity on Venus. The buses did not enter orbit around Venus, but continued on a fly-by trajectory and entered heliocentric orbit. Experiments on the bus continued to operate after the landers had separated, and by June 1982 a total of 89 cosmic-gamma bursts and more than 300 solar flares had been recorded.[3] The experiments were expected to continue operating to the end of 1983.[4]

The landers were different from previous Soviet Venera spacecraft in that they could transmit color, rather than black and

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[1] Tass, 0740 GMT, Mar. 2, 1982.

[2] Aviation Week and Space Technology, Nov. 9, 1981, p. 23.

[3] Kosmicheskiye Isseldovaniya, vol 21, No. 3, May–June 1983, pp. 480–488.

[4] Vienna, Volksstimme, July 19, 1983, p. 3.

white, pictures and were equipped with soil sampling equipment.[5] The eight panoramic views sent back to Earth by Venera 13 showed the Venusian surface to be covered with sharp rocks, partially covered with fine dust, and sand. Large grey boulders were also observed. The Venera 14 spacecraft landed in a plain area, covered with sandstone. Initially, the Soviets stated that the surface was brown, but later concluded that it was yellowish orange, with some green. The Venusian sky reflects the colors of the surface, and is primarily orange.

Soil analysis was accomplished using a drill to obtain a sample which was then sucked inside the spacecraft by a vacuum cleaner-type device. Analysis was accomplished using an x ray fluorescent spectrometer contained in a special chamber which maintained a pressure of 50 mm Hg (1/2000th of that outside) and a temperature of 30° C (compared to 457° C outside).

Analysis showed that at the Venera 13 site, the rock was leucitic basalt with a high potassium and magnesium content, which is rare on Earth, but found in the Mediterranean volcanic area. At the Venera 14 site, the rock corresponded to oceanic tholeitic basalts which are widespread on Earth. Scientists concluded from the absence of secondary changes in the soil that it was relatively young.

The mechanical strength of the rocks was measured using a spring-powered rod, and it was found to be in the range 2.6–10 daN/square centimeter at the Venera 13 site, and 65–250 daN/square centimeter for the Venera 14 location (although the Soviets stated that there was a partial equipment failure on Venera 14).[6]

The spacecraft also studied seismic activity using unilaxial seismometers which could measure only the vertical component of ground displacement. Venera 13 recorded no seismic events, while two were recorded with Venera 14, but Soviet scientists felt that they could not preclude the possibility that they resulted from instrument effects or wind, so stated only that the data were inadequate to draw unambiguous conclusions about seismic activity at the sites.[7]

The two landers also analyzed the Venusian atmosphere on their way to the surface using a mass spectrometer, gas chromatograph, optical spectrophotometer, a hydrometer, a nephelometer, and an x ray fluorescent spectrometer. Data showed the most ultraviolet radiation is absorbed at an altitude of 60 km, and Venus' clouds are mostly sulfur. Soviet scientists also detected xenon and a new isotope of neon in the atmosphere.

VENERA 15 AND 16

In 1983, the Soviets launched another pair of Venus spacecraft, but these were significantly different from previous Venus probes—both are orbiters which carry side-looking radars for mapping the surface of the planet.

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[5] There have been hints that the Venera 11 and 12 imaging systems would have sent back color photographs if they had worked

[6] Kosmicheskiye Issledovaniya, vol 21, No. 3, May-June 1983, pp. 323-330.

[7] Ibid., pp. 355-360

Venera 15 was launched on June 2, 1983, and Venera 16 on June 6 by D-1-e launch vehicles. As with previous Venera spacecraft, studies of cosmic rays and charged particles were made enroute to the planet. Venera 15 entered Venusian orbit on October 10, 1983, followed by Venera 16 on October 14. Orbital periods are approximately 24 hours, and the orbits are highly inclined at 87°,[8] providing coverage of the polar regions of the planet. Apogees are on the order of 65,000 km, and perigees about 1,000 km.[9] The side-looking radars point 10° off nadir,[10] and although their resolution is only 1-2 kilometers at best,[11] about the same as is achievable using Earth-based radars, the probes do provide data on regions of the planet not seen from Earth.

The spacecraft are based on the same design used since Venera 9, but the radar is positioned in place of the landing probe. More fuel was required to put each spacecraft into polar orbit around Venus, so the fuel tanks were lengthened by more than 1 meter, and the solar panel array size was almost doubled to provide power for the radar. The radar, called Polyus-V, has an antenna 6 meters long and 1.4 meters across, and the cone of the launch vehicle had to be lengthened to accommodate the radar in its folded state. Improvements in both the spacecraft transmitter and the receiving antennas on Earth are said to have increased the capacity of the Venus-Earth link 30 times, with a transmission rate of 100,000 units of information per second.[12] The radar was designed by the Moscow Power Engineering Institute. Initial data reception is made at the Long-Range Space-Communications Center, and then transmitted to the Institute of Radio Engineering and Electronics of the Soviet Academy of Sciences for processing and analysis. A special high speed processor was developed for these missions, and processing of one image takes 8 hours.[13]

The first radar images were received from Venera 15 on October 16, and from Venera 16 on October 20, although orbital adjustments were made to each throughout their first month in orbit.

An onboard radio altimeter can measure the height of the area with an accuracy of up to 50 meters.[14] The radar has a 20-minute scanning period and views through three slits simultaneously, with an area about 150 kilometers wide viewed through each slit;[15] one slit faces directly ahead, and the others slightly to the left and right.[16] Each image displays an area of 1 million square kilometers.[17]

An infrared spectrometer-interferometer is also carried on each spacecraft for obtaining atmospheric temperature profiles. The in-

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[8] Paiz, B.J. Summary of Venera 15/16. Pasadena, CA, Vista Laboratory, 1984, p. 4.

[9] Ibid.

[10] Sotsialisticheskaya industriya, Oct. 21, 1983, p. 3.

[11] Moscow Domestic Television Service, 1800 GMT, Oct. 19, 1983.

[12] Izvestiya, Oct. 21, 1983, p. 3.

[13] Pravda, Nov. 17, 1983, p. 3. Another report in Pravda on Feb. 26, 1984, stated that it takes 12 hours to sift through the output of the two Veneras each day, with another 4 hours required for collating the radar data with the altimeter data.

[14] Izvestiya, Oct. 21, 1983, p. 3.

[15] Trud, Oct. 20, 1983, p. 4.

[16] Izvestiya, Oct. 21, 1983, p. 3.

[17] Moscow Domestic Television Service, 1800 GMT, Oct. 19, 1983.

strument was developed by the East German Academy of Sciences.[18]

Images from Venera 15 showed the region of the north pole of Venus to be similar to Tibet and the Himalayas. Photographs published in Aviation Week and Space Technology showed large volcanic features, rolling terrain and band-link structures that could be canyons or ridges.[19] The Soviets plan to produce four maps of Venus based on the Venera 15 and 16 data.

EARTH ORBITAL SCIENCE

INTERKOSMOS 21

On February 6, 1981, the Soviet Union launched Interkosmos 21 carrying scientific equipment designed by Hungary, East Germany, Romania, Czechoslovakia, and the Soviet Union. The satellite was placed in an orbit 520 by 475 km, with a period of 94.5 minutes and an inclination of 74°.

The satellite was designed to study the ocean and land masses while working in concert with land and sea based data collection stations (located in Berlin, Budapest, Moscow, the area around Moscow, Baku, Sebastopol, Vladivostok, and the Indian Ocean). Among the scientific areas of investigation were: studying the potential of using satellites to locate areas of high marine bioproductivity and pollution; studying the boundaries between land and water, water and ice, and snow cover; defining the optical thickness of the atmosphere in different spectral ranges; and obtaining data on thermodynamic temperatures of the ocean's surface. Equipment included the SGDD (experimental automatic system for gathering and disseminating scientific data); a multichannel spectrometer for measuring the absolute value of the brightness of ascending radiation flows in the spectral range 415–274 nm; a bipolar radiometer designed for measuring the atmospheric thermal intensity at 2.5 cm; and a three-component magnetometer for measuring the Earth's magnetic field.[20]

INTERKOSMOS 22/BULGARIA 1300

To celebrate the 1300th anniversary of the founding of Bulgaria, the Soviet Union launched the 22d Interkosmos mission, called Interkosmos-Bulgaria 1300. The satellite was launched on August 7, 1981, into a 906 by 825 km orbit, inclined at 81.2° with a period of 102 minutes.

The main purpose of the satellite was ionospheric and magnetospheric studies, and it worked in concert with the Meteor-Priroda satellite which had been launched by the Soviets on July 10, 1981 (see chapter 4). In addition to Soviet experiments related to Earth resources sensing, the Meteor-Priroda spacecraft carried several Bulgarian-made experiments to provide data for use with those from Interkosmos-Bulgaria 1300, including: a multichannel spectrometer operating in the visible and near infrared wavelengths; a

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[18] Izvestiya. Oct 22. 1983. p 3

[19] Soviet Venus Probe Reveals Volcanoes. Aviation Week and Space Technology, Nov. 28, 1983. p 23

[20] COSPAR Information Bulletin. No 91. August 1981. pp. 67–68.

single channel microwave radiometer; and a computer system for recording and preliminary processing of the data.

The Interkosmos-Bulgaria satellite itself had four groups of instrumentation, and of the 15 instruments carried, 12 were built in Bulgaria.[21] One group included seven systems and instruments for studying electrons and ions in near-Earth space (measuring their concentration and temperature, and distribution according to energy and ion mass). A second group included a system for determining permanent and varying electric fields, and a highly sensitive magnetometer. The third group contained an electro-photometer for determining weak emissions of light in the upper atmosphere and a device for detecting and recording ultraviolet radiation.[22] Finally, there was an angular laser reflector for geodetic studies using ground-based lasers at 14 locations around the world.

Preliminary results from the program were published in the September–October 1983 issue of Kosmicheskiye Issledovaniya. Among the findings cited were the detection of small scale disturbances in the velocity of the ionospheric plasma at altitudes of about 900 km, where velocity was measured in excess of 4.5 kilometers per second; a marked longitudinal correlation between streams of charged particles and the maxima recorded in the area of the Brazilian anomaly (detected through earlier studies from the Salyut 6 space station); and the conclusion that large scale longitudinal currents can exist at any level of geomagnetic activity, and have a two-layer configuration in the morning and evening sectors.

AUREOLE 3 (ARCAD 3)

The joint Soviet/French space mission Aureole 3 (Oreol 3 or Arcad 3) was launched on September 21, 1981, into an orbit 1,920 by 390 km inclined at 82.6° with a period of 108.2 minutes. The spacecraft carried a total of 200 kg of scientific instruments, half Soviet and half French. This mission continued the program of satellites begun with Aureole 1 (Arcad 1) in 1971, and discussions which led to the Aureole 3 launch began in 1974.

The spacecraft was based on the three-axis stabilized AUOS (automatic universal stations) design used for other Soviet scientific probes. In addition to 100 kg of experiments which were provided by the French, some of the satellite's service equipment (the infrared horizon sensor, an onboard computer, and a 136 megahertz telemetry system for transmitting data from the French experiments directly to France) was also built in France, a first for the Soviet space program. The onboard microcomputer, provided by the French, was used to collect data from all the instruments on the spacecraft and perform preliminary processing before transmission of the data to Earth.[23]

Experiments were related to studies of charged particles, particularly electrons, ions, and thermal plasmas; studies of magnetic and electrical fields at very low frequencies and magnetic field fluctuations; and a photometric analysis of the aurora borealis.[24]

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[21] Pravda, Sept 2, 1983, p 3

[22] Serafimov, Kirill Joint Research. Izvestiya, Aug. 12, 1981, p. 5

[23] Tass, 0650 GMT Apr 3, 1982

[24] Langereux, Pierre. Franco-Soviet Arcad-3 Magnetosphere Experiments. Air & Cosmos, July 18, 1981, pp. 53-54

ASTRON

On March 23, 1983, the Soviet Union launched an observatory-class astronomical satellite into orbit. Called Astron, it was placed in a highly elliptical orbit with an apogee of 200,000 km and a perigee of 2,000 km, with a period of 98 hours and an inclination of 51.5°. The spacecraft is based on the design for the Venera probes,[25] but in this case it carries instruments for X-ray and ultraviolet studies of the universe. The orbit was selected so that orbital perturbations that affect spacecraft in low Earth orbits would be reduced to enable the telescope to operate more efficiently.[26] In addition, with a high apogee, measurements can be made outside the high energy radiation belts (Van Allen belts) which encircle Earth.[27]

The ultraviolet telescope, called Spika, was developed at the Crimean Astrophysical Observatory with the participation of French scientists. It weighs 400 kg, is 4.2 meters long, and has a double reflecting telescope based on Ritchey-Chretien optics (the main mirror has a diameter of 80 cm, the secondary mirror, 26 cm), with a focal length of 8 meters for the entire system.[28] The area of the collecting surface was described as being one-third greater than that of the U.S. Copernicus space telescope.[29]

The spacecraft also carries a Roentgen telescope designed to study sources of X-ray radiation in the 2-25 kiloelectronvolt range. Called SKR-02, the telescope has a collecting area of 0.2 square meters, and 10 spectral channels.[30]

The chief object of study is the Taurus constellation which includes two dispersed stellar concentrations and a crablike nebula with a pulsar. Other celestial objects have also been studied, including the star Kappa in the constellation Cancer which Soviet scientists discovered had one hundred times as much lead as Earth's Sun.[31] By September 1983, radiation had been recorded from 50 stars and 15 galaxies,[32] and observations were continuing at the end of 1983.

Reference has also been made to the fact that Astron can aid in the search for extraterrestrial intelligence. V.G. Kurt, chief of ultraviolet and X-ray astronomy at the Institute of Space Studies, stated in an interview with Trud that the telescope could intercept signals from "hitherto unknown worlds. Who knows, these could be calls from extraterrestrial civilizations, with whom our acquaintance will begin with the information that we receive from 'Astron' "[33]

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[25] Izvestiya, Apr 1983, p 2

[26] Pravda, Mar 24, 1983, p. 6

[27] Zemlya i Vselannaya, July-August 1983, p. 2

[28] TASS, 1929 GMT, Mar 23, 1983 Pravda Ukrainy, Apr. 9, 1983, p. 4.; Zemlya i Vselannaya, July August 1983, p 2

[29] Pravda, Apr 9, 1983, p 3 Copernicus (OAO-2) was launched in 1972 and operated until 1981

[30] Zemlya i Vselannaya, July-August 1983, p 3

[31] Sotsialisticheskaya industriya, Aug 5, 1983, p 4

[32] Sotsialisticheskaya industriya, Sept 6, 1983, pp 7-8

[33] Trud, Mar 24, 1983, p 4.

PROGNOZ 9

The ninth Prognoz satellite was launched on July 1, 1983, into a highly elliptical orbit with an apogee of 720,000 km, well past the orbit of the Moon. The satellite has a perigee of 380 km, a period of 26.7 days, and is inclined at 65.8°. Equipment from the Soviet Union, Czechoslovakia, and France is aboard the spacecraft, and it is designed to study the universe at radio wavelengths, although X-ray and gamma ray studies are also being conducted.

Prognoz 9 is dedicated to gathering information on the structure and evolution of the universe. The radio telescope onboard the satellite has two antennas which operate at 8 mm. One is a horn antenna oriented along the satellite's axis of rotation and receives radiation from the direction away from the Sun; the other is oriented perpendicularly to the first. The satellite revolves around an axis directed toward the Sun with a period of 2 minutes. During one rotation, 72 sections of the celestial sphere can be surveyed, each with an angular dimension of 5°. Mapping of one "ring" of the celestial sphere takes 1 week, after which the satellite axis is tilted 7° and the next ring is mapped. A map of the entire sphere can thus be made in 6 months.[34] The sensitivity of the radio telescope has been described as ten-thousandths of a degree of arc.[35] Results from the satellite's observations were not available by the end of 1983.

SPACE APPLICATIONS

COMMUNICATIONS

THE MOLNIYA AND ORBITA SYSTEMS

Molniya 1 and Molniya 3 satellites continued to be launched through the end of 1983.

Table 2 lists the launches within the various groups. Figures in parentheses indicate which earlier satellite was being replaced by the new launch. It can be seen that, with two exceptions, launches have been successful. The two mission failures were given the Kosmos label: Kosmos 1305 was intended to replace Molniya 3/12 but, due to an underburn of the e-stage, entered an orbit with a period of only 264 minutes, and was replaced by Molniya 3/17 36 days later; Kosmos 1423, intended to replace Molniya 1/48, exploded when the e-stage was fired in an attempt to achieve the highly elliptical orbit. It was nearly another year before Molniya 1/48 was finally replaced by Molinya 1/59. All but 5 of the 22 launches from 1981-1983 originated from Plesetsk. After an interval of 4½ years when no launches in this series came from Tyuratam, it was used for the launch of Kosmos 1423, and Molniyas 1/52, 1/55, 1/57, and 1/58, and these are denoted by a T in table 2.

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[34] Pravda, Oct 10, 1983, p 7

[35] Leninskoye Znamyua, Oct 18, 1983, p 3

TABLE 2.—REPLACEMENT SEQUENCE OF MOLNIYA SATELLITES, 1981-83

Group	A		B		C		D	(A)
	1/45	1/41	1/39	1/44	1/46	1/42	1/47	1/48
	3/13		3/10		3/11		3/12	
1981				3/14(10)				
			1/49(41)					
					3/15(11)			
			3/16(14)					
						1/50(42)		
							K.1305(12)	
							3/17(12)	
			1/51(39)					
	1/52(45)T							
1982							1/53(47)	
					3/18(15)			
				1/54(44)				
					1/55(46)T			
	3/19(13)							
								K.1423(48)T
							3/20(17)	
	1/57(52)T							
		1/58(49)T						
		3/21(new)						
1983								1/59(48 & K.1423)
			3/22(16)					

Notes

1 Figures above the line at the head of the table indicate the operational status as of Dec. 31, 1980.
2 Figures in parentheses indicate which earlier satellite was being replaced by the new launch.
3 Figures preceeded by K indicate the Kosmos designation of a failed mission.
4 T indicates a Tyuratam launch. All other launches were from Plesetsk.
5 Groups A, B, C, and D are separated by 90° in right ascension of the ascending node.
6 Molniya 3/21 is deliberately displaced (see text).

The established pattern was maintained of having pairs of Molniya 1 and 3 satellites in groups A through D, with orbital planes separated by 90° and then four additional Molniya 1's placed midway between these pairs. However, Molniya 3/21 was placed between groups A and B, but only 40° out of plane with the group A satellites. Thus it did not form an intergroup pair with Molniya 1/58. To date it is the only Molniya 3 not to have been placed in one of the four main groups. The 40° plane-spacing is reminiscent of the Kosmos early warning satellites and might signify the initiation of the expansion of the Molniya 3 system into a constellation of nine at 40° plane-spacing. On the other hand, Molniya 3/22, placed in group C, 140° out of plane with Molniya 3/21, does not lend support to such a hypothesis and Molniya 3/21 may prove to be an "on orbit spare" or it could have performed a fill-in role for the gap created by the Kosmos 1423 explosion. Its ground trace was partially stabilized after 6 days but not finalized until the 22d day of the mission. Johnson suggests that it was placed in the "empty" Molniya 1/48 position,[36] but this takes no account of the initial 40° offset, rather than the desired 45° midway spacing.

The Soviets experienced some difficulty in stabilizing the ground tracks of several of these satellites. Two opportunities were missed before the ground track of Molniya 1/49 was stabilized. The ground track of Molniya 3/19 was not stabilized at the first opportunity and was finally nudged into the correct position by a series of

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[36] Johnson, N L. The Soviet Year in Space: 1983. Teledyne Brown Engineering, 1984, p. 18.

burns at 2- or 3-day intervals some 3 weeks later. The Molniya 1/59 ground track was not stabilized until the 17th day of the mission, its very low initial period of 702 minutes and Plesetsk launch causing the ground track to drift the "wrong" way. It has been reported that Molniya 3/19 carried a new SHF transponder and that, in the future, Molniya satellites may carry the Volna transponders for maritime and other mobile users.[37]

According to Valeriy Dudkin, head of the television department of the Ministry of Communications, the construction of receiving stations of the Orbita type for purely television purposes has been virtually stopped. Since the stations of the Ekran and Moskva systems cost less than the Orbita stations and are more widely spread they ensure reception of the first channel of Central Television while the Orbita stations in these zones are used for telecasting a second channel. All in all, one Molniya 3 and five satellites in geosynchronous orbits—Ekran, Raduga, and Gorizont—are used for television broadcasting in the Soviet Union.[38]

THE SYNCHRONOUS COMMUNICATIONS SATELLITES

The use of communications satellites in geosynchronous orbits has increased steadily over the past 3 years. The six launches in 1982 and again in 1983 set and maintained a new annual launch record.

Kosmos 1366 was described in the launch announcement as being a new experimental communications satellite to test superhigh frequency, SHF, equipment.

With the exceptions of Ekran 8 and Ekran 10, which were given Statsionar-T designations, Statsionar locations have not been specified in TASS launch announcements since the end of 1981.

One cannot be certain that the placing of a new satellite close to another already in geosynchronous orbit is an indication of the failure, or imminent failure, of the earlier payload. The use of "on-orbit spares" to ensure continuity of service is a common practice in the satellite communications industry. A more definite pointer to the end of the useful life of such a satellite is its removal from the geosynchronous orbit to prevent the increasing overcrowding of that unique orbit.

During 1981, Raduga 3 and Raduga 4 were maneuvered into eccentric orbits.

On March 27, 1983, it was reported that Indian Television has started broadcasting its program via the Soviet satellite Statsionar 6 [sic] instead of Intelsat 5.[39] The change was effected 2 days earlier following the leasing of a transponder on the Soviet satellite for a period of 10 months after the Intelsat authorities expressed an inability to continue to provide the facility. The arrangement was obviously made to ensure the continuation of the service to areas remote from ground-based television transmitters until the arrival of the dedicated Indian communications satellite, Insat 1B, which was launched from Challenger on the STS-8 mission on August 31.

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[37] Johnson, Nicholas L. The Soviet Year in Space, 1982. Teledyne Brown Engineering, 1983, p. 11

[38] Dudkin, Valeriy. Soviet Weekly (London), Feb. 12, 1983, p. 8

[39] Delhi Domestic Service in English, 0240 GMT, Mar. 27, 1983.

On the following day, a Tass dispatch from New Delhi made political capital out of the situation and accused the United States of "depriving other countries of space means of communication" and attempting to "hold the Indian scientists, who controlled Insat 1A, responsible for the cessation of its work." The Press Asia Association, which was cited as the source of the allegations, was said to have claimed that Insat 1A, "for which a large sum of money was paid, had a whole number of defects." The dispatch ended by reporting representatives of Indian Television as saying that the quality of the signals transmitted by the Soviet satellite was "to their full satisfaction." [40]

The satellite in the Statsionar 6 location, above the Equator at 90° E, at that time was Gorizont 6 which was joined, or replaced, by Gorizont 8 later in the year.

Table 3 lists the geosynchronous launches for 1981 through 1983 together with Statsionar locations, where announced.

TABLE 3.—SOVIET GEOSYNCHRONOUS LAUNCHES, 1981-83

1981		
Ekran 7	Raduga 8 (S 2)	
	Raduga 9 (S 2)	
	Raduga 10 (S 3)	
1982		
Ekran 8 (S T)	Raduga 11	Gorizont 5
Ekran 9		Gorizont 6
1983		
Ekran 10 (S T)	Raduga 12	Gorizont 7
Ekran 11	Raduga 13	Gorizont 8

INTERNATIONAL LINKS

Intersputnik

At the 12th session of Intersputnik in Tashken, in October 1983, the Bulgarian chairman of the Intersputnik Council stressed that the cooperation and international contacts of the organization were continually expanding. He went on to say that, in the next few years, it was planned to build new ground stations in Yemen, Syria, Kampuchea, Nicaragua, Grenada, and other countries. Zubarev, Deputy Minister of Communications of the U.S.S.R., was elected as the new chairman of the council.[41] Later events in Grenada may well have caused a revision of part of these plans.

Inmarsat

Inmarsat operations commenced on February 1982, when the Operations Control Center at its London headquarters assumed the network coordination functions previously performed in Washington, DC by Comsat General Corp. Maintenance and control of space-based hardware remain the responsibility of the respective spacecraft owners.

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[40] Tass in English, 1347 GMT, Mar 28, 1983

[41] Moscow Home Service, 1600 GMT, Oct 19, 1983.

The first transmissions of information to merchant ships was successfully carried out in Vladivostok in 1982.[42] The dedicated CES (Coast-Earth Station) near the Black Sea port of Odessa commenced operation on December 30, 1983.[43] It was said to be able to simultaneously receive and transmit information from all ships sailing in the Indian and Atlantic Oceans.

Although the second such station, at Nakhodka in the far eastern U.S.S.R. had been expected to become operational before the end of 1982, the report stated that it was "still being built." [44]

To date, no Soviet satellite has been added to the system although overtures have been made to have satellites launched by the D-1 Proton-class booster.

In 1983, Yuri Atserov, president of Morsviasputnik, assumed the 1-year appointment of chairman of the Inmarsat Council, having formerly served as vice chairman.[45]

KOSPAS-SARSAT

Kospas equipment was installed on the Kosmos 1383 and Kosmos 1447 navigation satellites which took identity numbers 11 and 13 respectively in the civil Navsat system and which therefore operate in orbital planes separated by 90°.

During the first few weeks of its operation, Kosmos 1383 was involved in rescue operations on at least six occasions, quickly validating the search and rescue principle. On September 10, 1982, it was instrumental in locating a light aircraft that had crashed in British Columbia on the previous day.[46]

The United States installed its first Sarsat equipment onboard NOAA 8, launched on March 28, 1983. By the close of 1983 these three satellites had been instrumental in saving 63 lives in accidents.[47]

The system has been troubled by more than its fair share of false alarms. In 1983, it was instrumental in locating a radio distress beacon that had been stolen from the Shell Leman Echo gas platform in the North Sea between May 13 and 19. For some reason or other it began transmitting on June 15 and was received and located by the Kospas-Sarsat system. After a major land and sea search it was discovered on top of a wardrobe in a spare bedroom of a house near Glasgow, Scotland. As a result of legal action, the occupier of the house was convicted, at Ipswich Crown Court, of stealing the beacon, fined 500 pounds and ordered to pay costs and compensation totaling 1,599 pounds.[48]

TRACKING AND DATA RELAY SYSTEM

Details of an Eastern Satellite Data Relay Network [ESDRN] lodged with the International Frequency Registration Board in

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[42] Moscow in English for North America, 2200 GMT, Aug. 26, 1982.
[43] Tass in English, 1205 GMT, Dec. 30, 1983.
[44] Idem.
[45] Soviet Weekly (London), July 30, 1983.
[46] Aerospace Daily, vol. 117, Sept. 17, 1982, pp. 94-95.
[47] Wilkinson, J. High Life (Headway, London), February 1984, p. 77.
[48] Daily Telegraph (London), Mar. 6 and 9, 1984.

1981[49] show that the Soviets intend to operate a system employing frequencies of 10.82, 11.32, 13.7, and 13.52 GHz for downlink and 14.62 and 15.05 GHz for uplink (similar to the American TDRSS) for communicating with Salyut stations and other spacecraft operating in low Earth orbit. The date for the commencement of operation was given as "no sooner than December 1985." Figure 1, prepared by Sven Grahn, is an interpretation of the IFRB information.

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[49] Special Section No. SPA-AA/343/1484 annexed to IFRB Circular No. 1484, Sept. 1, 1981.

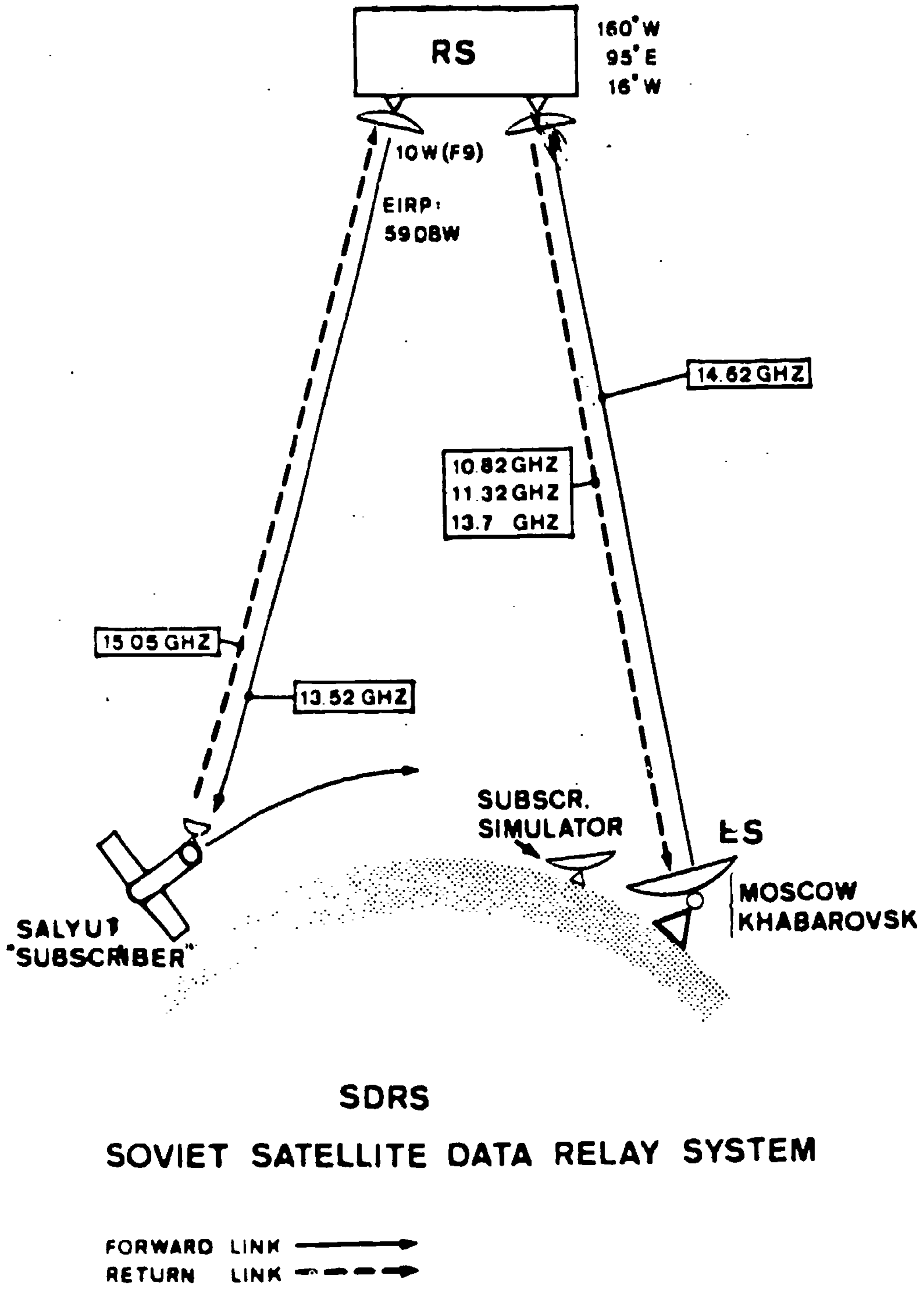

FIGURE 1.—The proposed Satellite Data Relay Network as interpreted by Sven Grahn, based on information lodged with the International Frequency Registration Board.

It may well be that the experimental SHF Kosmos 1366 is a development flight related to this proposed system and that the mysterious Kosmos 1426 and Kosmos 1516 satellites, from which the Kettering Group failed to detect transmissions, were operating with Kosmos 1366 in a TDRSS-type mode. Kosmos 1426 flew in an orbit very similar to that of a Salyut space station and, indeed, came very close to a rendezvous with Salyut 7 at the beginning of 1983 and would have been well suited to simulating a Salyut mission. During the flight of Kosmos 1516 at the end of 1983, Kosmos 1366 was stationed at 80° from where it could have relayed data from Kosmos 1516 while it was over America.

METEOROLOGY

In the period 1981 through 1983 the Soviet Union has continually maintained two or three Meteor-2 satellites in operation at any one time. Automatic picture transmissions [APT] in the 137 MHz band are not continuous, being switched off when the satellite is over that part of the Earth's surface which is in shadow. Periodically, when this applies to the whole of the Soviet Union, the transmissions are turned off completely until the orbit precesses to a more favorable position. The turning off and resumption of work is routinely reported in the FANAS messages.

Meteor-2 8, launched on March 25, 1982, signalled a departure from the standard 850 km circular orbit at 81.2° inclination used for Meteor-2 1 through 7. Launched by what is presumed to be the new F-2 vehicle, it flew at 950 km with an 82.5° inclination. The hypothesis that this marked the transition for all future Meteor-2 launches suffered a severe blow when the ninth Meteor-2 launched on December 14, 1982, exhibited the former orbital parameters, as did Meteor-2 10, launched on October 28, 1983. Meteor-2 9 had a short operational life. No transmissions from it were received by the Kettering Group after mid-1983 and FANS messages for it were no longer transmitted. At the end of 1983, the 7th, 8th, and 10th Meteor-2's were all operational.

Meteor 31, placed into a Sun-synchronous ~~orbit~~ from Tyuratam on July 10, 1981, transmitted APT at four lines per second and carried the small Iskra (Spark) satellite pickaback. Johnson speculated that it could be a replacement for Meteor 30 [60] but that was not the case. Both Meteor 30 and Meteor 31 were still transmitting at the end of 1983 and Meteor 30 transmissions were received more frequently by the Kettering Group than those from Meteor 31. Transmission frequencies of these satellites have gradually shifted over recent months from the initial 137.15 MHz to a current 137.10 MHz although FANAS messages for Meteor 30 still give the former frequency. No FANAS messages for Meteor 31 have been received since March 4, 1983, so it may no longer be regarded as fully operational.[51]

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[50] Johnson, N L. The Soviet Year in Space: 1981. Teledyne Brown Engineering, p. 18.

[51] The first FANAS for Meteor 31 was received by the Kettering Group on Feb. 24, 1984.

NAVIGATION

Kosmos satellites for navigation continued to be launched at varying intervals. Five were launched during 1981, eight in 1982 and seven in 1983. Of these, one only in 1981 and two in each of the other years were replacements for satellites in the civil system with a constellation of four satellites at 45° orbital plane spacing, confirming an impression of generally increased longevity and the possibility of a lower order of priority and/or precision for these by comparison with the constellation of six at 30° plane spacing believed to have a military role. Tables 4 and 5 give details of these satellites and those they have replaced by identity number within each category.

TABLE 4.—MILITARY NAVIGATION SATELLITES

	Identity No.—					
	1	2	3	4	5	6
1981	K 1104	K 1225	K.1150	K.1153	K.1181	K.1141
	K 1244					
						[1] K.1275
					K.1295	
						K.1308
1982			K 1333			
	K 1344					
				K.1349		
		[2] K 1380				
		K.1386				
						K.1417
1983			K.1328			
	K 1448					
				K.1459		
					K.1464	
						K.1513

[1] Kosmos 1275 disintegrated after 50 days in orbit
[2] Kosmos 1380 decayed after only 9 days in orbit

TABLE 5.—CIVIL NAVIGATION SATELLITES

	Identity No			
	11	12	13	14
1981	K 1168	K 926	K 1226	K 1092
		[1] K 1304		
1982				K 1339
	[2] K 1383			
1983			[2] K 1447	
		K 1506		

[1] Wandered off station due to lower orbital period
[2] Kosmos 1383 and Kosmos 1447 also carried Kospas search and rescue equipment

Kosmos 1275 fragmented after 50 days in orbit—a unique occurrence for a navigation satellite. It is difficult to account for the fragmentation in view of the fact that models of Kosmos 381, Kosmos 1000 and Kospas displayed in public at the Paris Air Show no sign of a propulsion or an orbit correction system which might have been the cause. Johnson pinpoints the time of fragmentation as 2351 GMT on July 24, 1981, and does not exclude the possibility of the fragmentation being due to a collision with another object.[52]

Kosmos 1304 apparently suffered from an underburn of the final stage and entered an orbit with a period of 104 minutes rather than the intended 105 minutes. As a result of the differing rates of precession of the ascending node, the plane spacing of the civil system steadily degraded until Kosmos 1304 was replaced as No. 12 in 1983 by Kosmos 1506. This restored the 45° plane spacing. The delay in replacing Kosmos 1304, which was electronically satisfactory, is a further indication of the lower priority attached to the civil system.

Another, far more serious, final stage underburn resulted in Kosmos 1380 being placed in a 93.1-minute orbit with a 140 km perigee from which it decayed naturally after 9 days. It was quickly replaced by Kosmos 1386 as a replacement for the aged Kosmos 1225.

Between these two launches came Kosmos 1383, the first satellite to carry Kospa: search and rescue equipment. It was joined in 1983 by Kosmos 1447, also with Kospa: equipment, and the American NOAA 8 satellite which carried Sarsat equipment.

Kosmos 1506 ceased operating around December 14, 1983, and the civil system was temporarily reduced to only three satellites. However, by February 15, 1984, it was once again operational.

Following its replacement by Kosmos 1428, Kosmos 1333 took on identity No. 7 and has retained this even following the replacement of Kosmos 1428 early in 1984. Identity No. 8 has not been reallocated to any replaced satellite since Kosmos 1181, which ceased operating in mid-1983.[53] It may be that the practice of reallocating identities is being discontinued.

The first of the GLONASS test vehicles appeared as a surprising triple D-1-e launch at 51.6° with a plane change to 64.8°. Kosmos 1413, 1414, and 1415 were not spaced at 120° around the orbit as with the American GPS Navstar test satellites, but drifted slowly apart from a common injection point. However, Kosmos 1414 did appear to make a small inorbit maneuver suggesting some propulsion capability

The second launch in the series, on August 10, 1983, placed Kosmos 1490, 1491, and 1492 into the same orbital plane as the first three satellites, but the third launch, on December 29, 1983, put Kosmos 1519, 1520, and 1521 into a plane separated by 120° from the first six. In all cases the final orbits fell short of the completely semisynchronous 717.7 minutes and this is now felt to have been intentional rather than a systematic failure to achieve a desired set of orbital parameters. Any inorbit maneuvers have been small and it can be presumed that the system is still in the development and testing stages.

EARTH AND OCEAN RESOURCES

Interkosmos 21, launched by a C-vehicle from Plesetsk into a 94.5-minute orbit with a 74° inclination, on February 6, 1981, car-

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[52] Johnson, op cit., pp 16-17

[53] Daly, P University of Leeds Private communication.

ried instrumentation produced by Czechoslovakia, the German Democratic Republic, Hungary, Romania, and the Soviet Union. The announced mission was the conduct of oceanographic and remote sensing experiments.

The 31st Meteor, in a Sun-synchronous orbit like its predecessor, carried some 600 kg of remote sensing equipment. High-resolution, electronically scanned and medium-resolution, mechanically scanned instruments transmitted on the standard 465 MHz downlink but a special 1 GHz downlink was added for the wider range "Fragment" eight-channel, multispectral system. Greater detail will be found in chapter 4 of this study.

Aside from the recoverable Kosmos missions described in chapter 5, there were no specifically dedicated Earth resources missions launched during 1982.

Kosmos 1484, launched on July 24, 1983, in the Sun-synchronous orbit characteristic of the Meteor-Priroda satellites, was announced as having an Earth resources mission. This announcement, coupled with the interception of its transmissions in Sweden, dispel any suspicion of it being a failure in the Meteor-Priroda series.

Kosmos 1500, placed into a 97.8-minute, 82.5° inclination orbit, was announced as performing a similar mission to the earlier Kosmos 1076 to investigate sea, ice, and wind conditions. It was immediately effective in providing imagery which enabled the freeing of Soviet merchant ships trapped by a sudden freeze in the ice in the eastern sector of the Arctic Ocean.[54] Although it was reported that the orbit would be "corrected to monitor the ice situation in the western sector of the Arctic," [55] implying some propulsion capability, no such maneuver was detected.

It was subsequently announced that Kosmos 1500 was equipped with side-looking radar which had been installed for the first time on an oceanographic satellite.[56] The equipment, which had been developed by Ukrainian scientists, was said to "ensure high-quality photography at any time of the day and in any weather," a statement having implications for the consideration of military imaging systems discussed in chapter 5.

GEODESY AND MAPPING

Table 39 classifies spacecraft whose orbits have periods greater than those of similar navigation satellites as possible geodetic missions. That table also includes the F-2 launched Kosmos 1045 at 82.5° with an orbital period of 120 minutes because its orbital elements were closer to those of the geodetic class of payload than any other and, for that reason, perhaps Kosmos 1312 and Kosmos 1410, launched in 1981 and 1982 respectively, together with Kosmos 1510 launched in 1983 with the unusual 73.6° inclination, all with periods close to 116 min, should also be considered as possible candidates for such a mission.

All flights of recoverable satellites in the special subset presumed to carry out mapping missions were launched by the F-2 vehicle into orbits with 82.3° inclination and transmitted simple f.s.k.

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[54] Moscow World Service in English, 2200 GMT, Nov 10, 1983

[55] Ibid

[56] Tass in English, 1136 GMT, Jan 23, 1984

beacons on 19.994 MHz. These were Kosmos 1239 and Kosmos 1309 in 1981 and Kosmos 1332 and 1398 in 1982. TL recovery beacons were received by the Kettering Group from the last three of these missions. For consistency, details of these satellites are given in table 6 d. There were no flights in this category during 1983.

TABLE 6.—MILITARY PHOTOGRAPHIC RECOVERABLE MISSIONS

a High resolution, maneuverable, A-2 launched. Simple f.s.k. transmissions on 19.989 MHz.

	Tyuratam			Plesetsk
	64.9°	70.0°	70.3°/70.4°	72.8°/72.9°
1981	1329(14)F		1268(14)F	1262(14)
			1279(14)F	1265(12)F
			1313(14)F	1297(12)
			1316(14)F	
1982			1368(13)F	1334(14)
			1416(14)F	1342(14)
			1419(14)F	1343(14)F
			1421(14)	1396(14)F
				1411(14)
				1422(14)
1983		1446(14)	1438(11)	1469(10)
				1509(14)

Notes

1 Kosmos launches subdivided by launch site and inclination The Kosmos number is followed by the flight duration in days in parentheses.
2 The letter F indicates that a TF recovery beacon was observed by the Kettering Group.

b Medium resolution (?) A-2 launched, maneuvering to a higher, near circular orbit toward the end of the first day in orbit. Simple f.s.k. transmissions on 19.989 MHz

	Tyuratam		Plesetsk	(F-2 launched)
	70.0°	70.3°/70.4°	72.8°/72.9°	82.3°
1981		1259(14)F	1237(14)	1283(14)F ER
		1264(14)F	1245(14)	1284(14)F ER
		1272(14)	1281(14)F	
		1277(14)	1307(14)F	
1982	1425(14)	1352(14)	1338(14)	1385(14) P
		1372(14)F	1404(14)F	
		1381(13)F		
		1403(14)F		
1983	1482(14) ER	1460(14)F	1444(14)	1472(14)F ER
			1449(15)	
			1467(12)	
			1485(14)F	
			1493(14)	
			1497(14)	
			1499(14)	
			1505(14)	
			1512(14)	

Notes

1 Kosmos launches subdivided by launch site and inclination The Kosmos number is followed by the flight duration in days in parentheses
2 The letter F indicates that a TF recovery beacon was observed by the Kettering Group
3 Flights announced as performing Earth resources missions are indicated by the letters ER, or P if announced as reporting to the Priroda (Nature) Center
4 A subset of the F-2 launched flights also maneuvers to a higher, near circular orbit toward the end of the first day and are shown in the final column for convenience

c Fourth generation with solar panels High resolution, A-2 launched. No shortwave telemetry discovered.

	Tyuratam		Plesetsk
	64.9°	70.3°	67.2°
1981	1240(28)	1330(31)	1248(30)
	1246(23)		1274(30)
	1270(30)		1296(31)
	1282(30)		1318(31)
	1298(42)		
1982	1370(44)	1386(27)	1350(31)
	1377(44)	1347(50)	1384(30)
	1399(43)		1407(31)
	1424(43)		
1983	1466(41)	1439(16)	1442(45)
	1489(44)	1457(43)	1454(30)
	1504(53)		1471(30)
	1516(44)		1511(44)

Notes

1 Kosmos launches subdivided by launch site and inclination The Kosmos number is followed by the flight duration in days in parentheses.

2 Although no VHF transmissions were intercepted from Kosmos 1516, its orbital parameters and flight duration suggest that it belongs in this category

d. Possible F-2 launches. Simple f.s.k. transmissions on 19.989 MHz. Plesetsk launches at 82.3°.

	High resolution	Medium resolution (?)	Medium and geodesy
1981	1273(13) P	1283(14)F ER	1239(12)
	1276(13)K ER	1284(14)F ER	1309(13)L
	1280(14) P		
	1301(14)F ER		
	1314(13)K P		
1982	1353(13)K P	1385(14) ER	1332(13)L
	1369(14)F ER		1398(10)L
	1376(14)F P		
	1387(13) P		
	1401(14) ER		
	1406(13) P		
1983	1440(14) ER	1472(14)F ER	
	1451(14)		
	1458(13) P		
	1462(14) P		
	1468(14)F P		
	1483(14)F ER		
	1487(14)F P		
	1495(13)K ER		
	1498(14) ER		

Notes:

1 The Kosmos number is followed by the flight duration in days in parentheses

2 The medium resolution (?) flights have also been included in table 6(b).

3 The mapping and geodesy flights of 1981 and 1982 transmitted on 19 594 MHz.

4 The letters F, K, and L indicate that a TF, TK, or TL recovery beacon was observed by the Kettering Group.

5 Flights announced as performing Earth resources missions are indicated by the letters ER, or P if announced as reporting to the Priroda (Nature) Center

MILITARY MISSIONS

RECOVERABLE PHOTOGRAPHIC RECONNAISSANCE FLIGHTS

As can be seen from figure 58, recoverable payloads continue to account for nearly 50 percent of all Kosmos launches.

Details of these launches are given in table 6 a through d. Several trends can be readily identified, the most significant possibly being the increased employment of the fourth generation long-duration missions which provide almost continuous coverage all year. It has been reported that the Soviet Union has an advanced imagery reconnaissance spacecraft using digital image transmission rather than film-return capsules and this might refer to this class of payload.[57] This is discussed more fully in chapter 5.

Four of the high-resolution, maneuverable, A-2 launched missions were flown in 1983. Many more of the high-perigee missions were flown including four at the F-2 inclination of 82.3°. All of these were designated as Earth resources missions as was Kosmos 1482 from Tyuratam at 70.0°. In fact, the F-2 launches at 82.3° produced the second largest number of satellites at a given inclination during 1983; 10 compared with 11 at 72.9°.

No particular targets were immediately obvious for the 1981 flights, but the Falklands conflict gave rise to speculation that Kosmos launches during April and May of 1982 were all Falklands related.[58] In the case of the photographic recoverable satellites this was certainly not so. Part of the cause for the misunderstanding was a failure to identify different types of missions when in possession of the announced initial orbital parameters only. Thus Kosmos 1347, Kosmos 1352, and Kosmos 1368, all with inclinations of 70.4°, appeared at first sight to be identical missions.[59] However, lack of short-wave telemetry, even before the 50-day duration became apparent, revealed Kosmos 1347 to be a fourth generation spacecraft. Kosmos 1352 raised its perigee towards the end of the first day in orbit and falls within the "medium resolution (?)" category and only Kosmos 1368 was the older close-look high resolution spacecraft.

Johnson pointed out that poor weather in the South Atlantic made photographic observations improbable and that the Argentines, who were purportedly in receipt of Soviet intelligence, held the islands until the last days of the conflict. Furthermore, no perigees were located in the southern hemisphere and no steps were taken to provide stabilized ground-tracks over the islands.[60]

However, Johnson did draw attention to possible coverage of the Israeli incursion into Lebanon on June 6, the flare up of hostilities on the Iranian-Iraqi front in November, and passes over the landing sites of STS-1 at Edwards AFB, CA, and STS-3 at White Sands, NM, although in the latter cases it is difficult to visualize the value of imagery obtained before the landing.[61]

Pairs of mapping and geodesy missions were flown only in 1981 and 1982 and were at 82.3° as reported earlier.

RADAR OCEAN RECONNAISSANCE (RORSAT'S)

Kosmos 1249, launched on March 5, 1981, was placed into an orbital plane at the usual separation from the EORSAT pair, Kosmos 1167 and Kosmos 1220. It formed with Kosmos 1266, launched on April 21, the first pair of nuclear-powered satellites since Kosmos

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[57] Aviation Week and Space Technology. Nov. 2, 1981, p. 48.
[58] Halloran, R New York Times, May 3, 1982.
[59] Aviation Week and Space Technology, May 31, 1982, p. 20.
[60] Johnson, N.L. The Soviet Year in Space: 1982. Teledyne Brown Engineering, p. 8.
[61] Ibid., pp. 8-9

952 and Kosmos 954 in 1977. However, it would appear that Kosmos 1266 quickly malfunctioned for its nuclear reactor was raised to the high "safe" orbit after only a few days. It was noticed that, as with Kosmos 1176 in 1980, two pieces appeared in the high orbit whereas, prior to the Kosmos 954 accident in 1978, only one piece had been observed.[62] The operational phase of Kosmos 1249 terminated on June 19. Later in the year, Kosmos 1299 flew a mission of 2 weeks before that, too, was terminated. Johnson pointed out that Kosmos 1299 flew at the same time as large-scale naval maneuvers by both NATO and the Warsaw Pact countries.[63]

There were four launches in this series during 1982. Kosmos 1365 was launched on May 14, well after the British Task Force had reached the Falkland Islands. Possibly its imminent launch was taken into consideration for potential coverage of the area surrounding the Islands when the EORSAT, Kosmos 1355, was launched on April 29, into a plane bearing little relation to previous EORSAT missions because Kosmos 1365 and Kosmos 1355 displayed the usual plane relationship. Kosmos 1372 was coplanar with Kosmos 1365 but some 38.5 minutes behind it producing a form of triple interlacing of the ground tracks of each satellite. They operated as a pair for a record 71 days.

Kosmos 1402 replaced Kosmos 1372 and, for a time operated as a pair with Kosmos 1365. Kosmos 1365 was eventually replaced by Kosmos 1412, only 25.5 minutes behind Kosmos 1402 producing simple interlacing of ground tracks. Kosmos 1365 operated for a record 136 days before being separated into its individual components and having its reactor raised to the "safe" orbit. Kosmos 1412 ceased its operational phase after 40 days on November 10. Kosmos 1402 continued in orbit until December 28 when it split into three components, all of which remained in low Earth orbit. The world's media became aware of the situation on January 5, 1983, and, mindful of the Kosmos 954 incident, gave the story maximum publicity. One piece, cataloged by NORAD as "B" decayed rapidly leaving pieces "A" and "C" in decaying orbits. Initially the Soviets denied that there was any problem in response to questions from the Western press at the press conference in Moscow held in honor of the record breaking Salyut 7 cosmonauts. However, on the following day, it was admitted that the satellite was out of control, but they emphasized that all precautions had been taken to ensure that no parts reached the Earth's surface.[64] Later still, on January 15, in a 10-minute television transmission, Oleg M. Belotserkovskiy, the director of the Moscow Physico-Technical Institute, disclosed that the two remaining parts were the main section of the satellite and fuel core of the reactor.[65]

It was immediately clear that the reactor core was the more dense piece "C" which was decaying at a slower rate than "A" and that the two pieces observed in the "safe" orbit since the resumption of the program in 1980 were indeed the reactor and the separated fuel core.

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[62] R A E Table of Earth Satellites 1981 82, Jan 1, 1983, p 641
[63] Johnson, N L. The Soviet Year in Space 1981 Teledyne Brown Engineering, 1982, p 23.
[64] Pravda, Moscow Jan 8, 1983 2d ed , p 2
[65] Schemann, S New York Times, Jan 16, 1983, p. 13

The main part decayed over the Indian Ocean on January 23, at 2210 GMT and the fuel core over the South Atlantic, east of Brazil, at 1056 GMT on February 7. By the end of 1983, there had been no further missions of this type.

ELECTRONIC INTELLIGENCE

EORSATS WITH THE F-1-S

For the first time, in 1981 the Soviet Union had at least one EORSAT operational throughout one whole calendar year. Kosmos 1167 and Kosmos 1220 were still operating as a pair at the start of 1981. Kosmos 1220 ceased operation shortly after the launch of Kosmos 1260 in March 1981 and Kosmos 1260, which had replaced Kosmos 1167 within hours of that satellite ceasing to be operational, operated alone between June 19 and the launch of Kosmos 1286 on August 4. This immediate replacement was duplicated in September when Kosmos 1306 replaced Kosmos 1260 within a day. On this occasion, however, it took a week for the new satellite to be maneuvered into the desired orbit. By the beginning of November precise station keeping was no longer being maintained.

The first EORSAT of 1982, Kosmos 1337, malfunctioned within a week during February and, with the end of a restored operational phase of Kosmos 1286 in mid-March, the outbreak of the Falklands conflict in April found the Soviet Union without any operational ocean surveillance satellites of any type.

As mentioned in the previous section, the positioning of Kosmos 1355 might well have been determined by a desire for joint operation with the two RORSAT's which were to follow. When Kosmos 1405 was launched early in September, the Soviet Union, for the first time, had two of each type of ocean surveillance satellite operational simultaneously.

Two further EORSATS were orbited during 1983, Kosmos 1461 and Kosmos 1507. The former satellite ceased operation on January 30, 1984, when its orbital period was increased in a two-burn maneuver from 93.3 to 99.3 minutes.

ELINT WITH THE C-1 AND A-1

Following the decay of 28 C-1 launched ELINT satellites in 1980 and 1981 under the influence of increased drag due to high solar activity, there were no similar launches in 1981 and one only, Kosmos 1345, in 1982. Initial speculation that Kosmos 1345 might be the first of a new series being established to monitor minor military communications traffic is no longer justified.

Three of the heavier, A-1 launched satellites, Kosmos 1242, 1271 and 1315 were launched during 1981 to replace Kosmos 1063, 1077 and 1154 respectively. The 1982 launches of Kosmos 1340, 1346 and 1356 to supposedly replace Kosmos 1206, 1222 and 1184 respectively created confusion in analytical minds by being in planes somewhat removed from those of the satellites they were thought to be replacing. The fourth launch of 1982, Kosmos 1400, although near to Kosmos 1315, increased the confusion by being placed 65° away from Kosmos 1346. The launches of Kosmos 1437 and 1441 in 1983 did nothing to resolve the situation and what was once a precisely maintained constellation has now degraded to something approaching random access.

POSSIBLE ELINT WITH THE F-2

Other possible candidates for ELINT missions are those Kosmos satellites, also having 97.6 minute periods but launched by the presumed F-2 into 82.5° inclinations. No mission was specified for Kosmos 1025, the first in the subset, but both Kosmos 1076 and 1151 were described as oceanographic research laboratories (see chapter 4, section V.D.). This description was not given to the next six launches in the series but Kosmos 1500, launched on September 28, 1983, was announced as "continuing the testing of new types of information measuring equipment and methods of remote explorations of the world ocean. . . ." (see above). No mission was announced for Kosmos 1515, launched on December 15, 1983, nor for Kosmos 1536 launched early in 1984.

The absence of an announced mission coupled with the orbital plane spacings of the 1981 and 1982 launches in the series led to speculation that these satellites were taking over the heavy ELINT role of the "non-Meteors". Kosmos 1300 and 1328, launched in 1981, were spaced 45° apart and Kosmos 1378, the first of the 1982 launches, was placed 90° away from Kosmos 1328 leaving a gap between them to be filled by another satellite to complete a four-at-45° constellation. However, Kosmos 1408, was placed in almost the same plane as Kosmos 1378 and might be considered to be its replacement. Grahn discovered that Kosmos 1378 transmitted on the same frequency as Kosmos 1151 and that might be an indication that it had an oceanographic role.

The four 1983 launches did not fill the vacant space. It has already been noted that Kosmos 1500 was announced as oceanographic in character and was actually reported as having used side-looking radar to assist in the rescue of shipping trapped in the ice. No clear pattern of plane spacings emerged until the launch of Kosmos 1536 and, even then, an element of ambiguity remained. Kosmos 1536 could be seen to fill the vacant gap between Kosmos 1328 and Kosmos 1408. On the other hand it would be reasonable to ask why it had taken so long and also whether those earlier satellites were still operational. Moreover, Kosmos 1536 is spaced 60° away from Kosmos 1515, the last of the 1983 launches, and that was 60° away from Kosmos 1445, the first of the 1983 launches. If Kosmos 1445, 1515, and 1536 do, in fact, constitute a new three-at-60° constellation, it leaves only Kosmos 1470 unaccounted for.

EARLY WARNING OF MISSILE AND SPACE LAUNCHES

[illegible] reason for the choice of an initial 80° plane spacing for the Kosmos satellites in semisynchronous orbits, differing only in partial parameters from the Molniya communication satellites in having arguments of perigee at 315° rather than at 280°, was obscure but between 1981 and the end of 1983 Kosmos launches into planes midway between these resulted in the development of a constellation of nine satellites spaced at 40° intervals.

Four of the 1981 launches—Kosmos 1247, 1261, 1278, and 1317—entered the new orbital planes and only Kosmos 1285 was a direct replacement of an earlier satellite in the system, Kosmos 1261, which had broken up within a month of its launch.

Five more launches in 1982 saw the ninth location filled by Kosmos 1367 with Kosmos 1341, 1348, 1382, and 1409 replacing Kosmos 1247, 1172, 1223, and 1217 respectively.

There were three such launches only in 1983, Kosmos 1456, 1481, and 1518 replacing Kosmos 1191, 1285, and 1341 respectively.

Neither Kosmos 1285 nor Kosmos 1481, its replacement, were ground track stabilized on reaching orbit. Nor were they speedily replaced. Whereas the orbital period of Kosmos 1285 was higher than the truly semisynchronous period, that of Kosmos 1481 was less, due to differences in launch profile. One feels that this can hardly be coincidental. A constellation of nine satellites provides some redundancy and it might be that this particular orbital plane is used to hold an in-orbit spare.

The launch on February 19, 1981, of Kosmos 1247 reverted to the method of placing the satellite at the desired location last used in 1976 for Kosmos 862. The initial orbital period of only 707 minutes produced an eastward drift of the ascending node to 49°W where, on February 23, the ground track was stabilized by raising the apogee. That this was no accident was confirmed by the simultaneous relocation of the four satellites currently operational at that date. On February 21, the apogee of Kosmos 1191 was lowered inducing an eastward drift and during the next few days the apogees of Kosmos 1172, 1217, and 1223 were also lowered. The rapid eastward drifts were arrested by raising the apogees once more when the ascending nodes reached the vicinity of 60°W in the first week of March and, as expected, complete stabilization was achieved with all ascending nodes located close to 55°W. Figure 2, originally produced for a meeting of the Gatwick Branch of the Royal Aeronautical Society on March 20, shows the manner of placing Kosmos 1247 at its desired location together with the relocation of Kosmos 1191. Plots for Kosmos 1172, 1217 and 1223 would be similar to that for Kosmos 1191 and are not shown to avoid confusion. Kosmos 1261 used the same procedure for achieving a stabilized location at 55°W as that for Kosmos 1247.

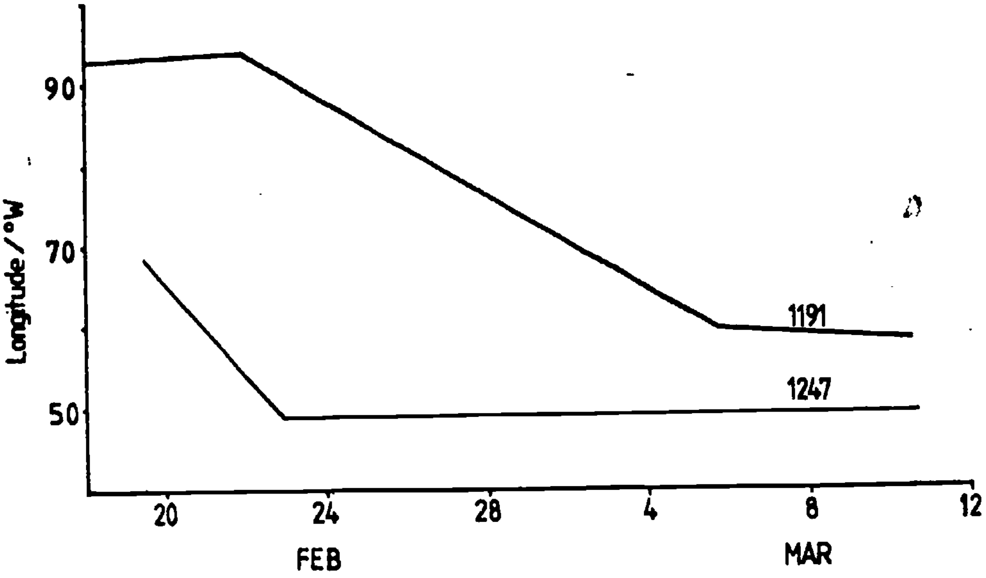

FIGURE 2.—Locations of ascending nodes of Kosmos 1191 and Kosmos 1247 during the first quarter of 1981.

MILITARY COMMUNICATIONS, COMMAND, AND CONTROL

TACTICAL AND THEATRE COMMUNICATIONS; OCTUPLE LAUNCHES

Octuple launches appear as routine replacements for satellites which have failed electronically.

In 1981, there were three such launches; Kosmos 1250–1257, Kosmos 1287–1294, and Kosmos 1320–1327. In the latter case all eight payloads were found in slightly higher orbits than usual and it may be that there was a minor malfunction in the timing of the ejection sequence. The rocket's final stage was tracked in the usual orbit.

In 1982 and 1983 there were two octuple launches respectively; Kosmos 1357–1364 and 1388–1395 in 1982 and Kosmos 1429–1436 and 1473–1480 in 1983.

COVERT STORE-DUMP MISSIONS

Nine such missions were launched in 1981 through 1983 with a further launch early in 1984. The replacement sequence is shown in table 7.

TABLE 7.—STORE-DUMP MISSIONS WITH THE C-1 LAUNCH VEHICLE

	1110	1190	1140	
1981	1269			
	1302			
1982	1331			
		1354		
			1371	
	1420			
1983				1452

TABLE 7.—STORE-DUMP MISSIONS WITH THE C–1 LAUNCH VEHICLE—Continued

	1110		1190		1140
			1486		
				1503	
1984		1538			

Notes.

1 Kosmos numbers are given in 3 main columns with 120° spacing in right ascension of ascending between columns.
2 Data above the broken line indicates the status of the constellation at the start of 1980
3 Three payloads are shown offset from the main columns by some 10° These mark the establishment of a new constellation somewhat displaced from the original

Kosmos 1269, the first of these, was replaced by Kosmos 1302 after a period of less than 3 months and Kosmos 1302 was itself replaced before either of the other two operational satellites in the constellation.

The first launch of 1983, Kosmos 1452, was not placed in precisely the same plane as Kosmos 1371 and when Kosmos 1486 proved to be an exact replacement for Kosmos 1354, doubts arose as to whether or not Kosmos 1452 was part of the series. However, Kosmos 1503, the last of the 1983 launches was also displaced from the main groups and when Kosmos 1538 was launched early in 1984, there was once more a constellation of three at 120° spacing. It remains to be seen if the old constellation is maintained simultaneously by further launches or is permitted to phase itself out.

ANTISATELLITE TESTS [ASATS]

Antisatellite tests were carried out in 1981 and 1982, but rather surprisingly, not at all in 1983. The first of the 1981 tests was monitored in some detail by Sven Grahn.

Kosmos 1241, the target satellite, was launched from Plesetsk on January 21, with orbital parameters of 65.8°, 1012–978 km, and 105 min. Basing his calculations on data from the 1980 test, Grahn deduced that the most probable time for an interception would occur early in the morning of February 2. By January 30, he had monitored Kosmos 1241 and discovered that its signals were of a pulsed radar type. On the morning of February 2, he picked up these signals again between 0345.49 and 0346.35 GMT. He immediately commenced a search for signals from the expected interceptor and discovered them at 0358.20 on a frequency well used by F-launched payloads. These were AM pulseposition modulated signals and lasted until 0402.40. Kosmos 1243 had been launched from Tyuratam at around 0225 into a 65.1°, 308–61 km, 88.2 min. orbit and these signals were received at the end of its first revolution. At the time of the launch, Kosmos 1241 was southbound near the Kamchatka peninsula. With its lower orbital period, Kosmos 1243 began overtaking Kosmos 1241 and, on reaching the Equator at the end of its first orbit, fired its maneuvering stage to produce a small plane change and establish a transfer orbit with para meters of 65.8°, 1017–297 km, and 97.9 min. By the start of the third orbit, the time difference had been reduced almost to zero and Kosmos 1243 began its climb to rendezvous with the target near apogee. Grahn picked up signals from both spacecraft simultaneously shortly after 0530 and lost them both when they fell below his eastern horizon at

0544.56. Kosmos 1243 was deorbited following this flyby, but a second interception was made by Kosmos 1258 on March 14. On that occasion there were reports that a Pentagon source had claimed that the target satellite had been successfully "knocked out," the interceptor exploding near to it in what has come to be called a "hot metal" kill as opposed to use of a directed energy beam weapon. However, no fragments were cataloged by NORAD sensors.

Following the launch of Kosmos 1375 in 1982, with similar orbital parameters to those of Kosmos 1241, it was reported that Kosmos 1243, employing a new unjammable optical guidance system, was judged to have failed in its mission but that Kosmos 1258, with the older onboard radar guidance, had probably been successful.

The June 18, 1982, test appears to have been a carbon copy of the 1981 tests, Kosmos 1379 making a pass close to Kosmos 1375 before being deorbited. NORAD data for the rocket of Kosmos 1379 shows that the orbital planes were matched and the TASS announcement gave numbers showing the Kosmos 1379 apogee at the height of Kosmos 1375's circular orbit. However, in the absence of NORAD data for the Kosmos 1379 payload, it is not possible to estimate how close it approached the target. On this occasion Grahn failed to discover radio transmissions from the target, but received signals from Kosmos 1379 at the end of its first revolution.

Apparently Kosmos 1241 had been active during March and May 1982 since Branegan reported the "familiar spread-spectrum test signals with their covert telemetry around 144.3 MHz."[66] He continued, "Tests proper began on June 6 (the launch date of Kosmos 1375) and continued until June 18 in a series of about 10 tests carried out, culminating in two (sic) tests where target telemetry ceased abruptly (a point subsequently confirmed by U.S. Secretary Haig)." The reference to two tests by the Secretary of State drew attention to a large-scale strategic weapons exercise of which the ASAT test was only one feature, occurring over a 7-hour period. The "nuclear war scenario" began with the ASAT test and was followed rapidly by the launching of two ICBMs, an SLBM from a submarine, an IRBM and two ABMs, and were said by Secretary Haig to be "integrated" and "unprecedented in their scope."[67] On the day following the statement, speaking on ABC TV's "This Week with David Brinkley," Defense Secretary Caspar Weinberger, agreeing with Secretary Haig, said that this was "just another piece of evidence to display the fact that they believe a nuclear war can be fought and won."[68]

Two Kosmos satellites, a navsat failure (Kosmos 1380) and a high-perigee photographic reconsat (Kosmos 1381), were launched on the same day as all these weapons tests. Johnson points out that both of these launches occurred between the time of launch of Kosmos 1379 and its interception of Kosmos 1375 and notes that never before had any satellite launch taken place during the conduct of an ASAT test. He speculated that both of these flights may

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[66] Branegan, J. Oscar News No. 40, Jan. 1983, p. 4.
[67] Aerospace Daily, vol. 115, June 22, 1982, p. 283.
[68] Idem.

have simulated replacement of Soviet satellites negated by Allied forces during the war scenario.[69]

KOSMOS 1267

At the end of October 1981, a report appeared in the Washington Roundup column of Aviation Week to the effect that the Soviet Union was operating in low Earth orbit an antisatellite battle station equipped with clusters of infrared-homing guided interceptors that could destroy multiple U.S. spacecraft. *"The podded miniature attack vehicles provide a new U.S.S.R. capability for sneak attacks on U.S. satellites."* (Aviation Week's emphasis)[70] In the following week's column it claimed that Defense Department officials were checking for signs that the space station would be expanded for ballistic missile defense purposes and went on to say that the Soviet Union was expected to launch additional spacecraft equipped with infrared-homing kill devices which could be applied to a new ballistic missile defense system.[71]

Additional details were provided in the same column at the end of November.

> . . . The Defense Department is concerned that future operational spacecraft like Cosmos 1267 will be launched into *geosynchronous orbit to threaten U.S. communications and missile early warning spacecraft.* . . .
>
> . . . Cosmos 1267, docked to Salyut 6, is *equipped with firing ports to eject 1-meter-long miniature vehicles guided by infrared sensors.* The possibility also exists that radar homing may be employed. Docking of this antisatellite weapon platform with Salyut 6 means the U.S.S.R. would be able to use a manned Salyut to direct antisatellite attacks against U.S. spacecraft or to protect Soviet satellites against a U.S. retaliatory attack.
>
> U.S. officials said the data on the new killer satellite system, which first appeared in an intelligence report September 17, are *now "very hard from a variety of sources and methods; harder than anything we've seen for a long time."* (Aviation Week's emphasis)[72]

Analysts without access to classified sources were mystified by these reports. Granted the ability of KH-11-type satellites to obtain imagery of orbiting satellites, which has been widely reported,[73] it seemed incredible that such precision could be obtained. Now, with the publication of drawings of Kosmos 1443 in Soviet magazines, it is possible to hazard a guess as to how the reports originated. The reader's attention is drawn to figure 2 of part 2 of this study which was based on such drawings. It will be seen that cylindrical tubes with hemispherical ends are located beneath a protective covering surrounding the main section of Kosmos 1443. One can understand that these might well be the "podded miniature attack vehicles" of

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[69] Johnson, N L. The Soviet Year in Space: 1982. Teledyne Brown Engineering, 1983.

[70] Aviation Week and Space Technology, vol. 115, No. 17, Oct. 26, 1981, p. 15.

[71] Aviation Week and Space Technology, vol. 115, No. 18, Nov. 2, 1981, p. 15.

[72] Aviation Week and Space Technology, vol. 115, No. 22, Nov. 30, 1981, p. 17.

[73] Aviation Week and Space Technology, vol. 115, No. 14, Oct. 5, 1981, p. 17.

the Aviation Week reports. However, in a labelled cutaway drawing of the Kosmos 1443-Salyut 7-Soyuz-T 9 complex these are shown as fuel tanks[74] and the cover picture of the same magazine shows them together with the associated "plumbing." The protective covering was seen to be solar cell panels.

Minor Military Missions With the C-1 Launch Vehicle

FROM PLESETSK

The three inclinations of 65.8°, 74°, and 83° continued in use for those Kosmos missions which fail to fall in readily identifiable categories and are lumped together by Western analysts as "minor military" missions.

In each of the 3 years there was a single launch of a "nontarget" at 65.8° (Kosmos 1310, 1427 and 1450). An additional launch at this inclination in 1983 placed Kosmos 1502 in a lower orbit with a period of 92.3 min. more characteristic of the Kapustin Yar payloads.

The 94.6 min period appeared once more at 74° in 1982 and 1983 with Kosmos 1335 and Kosmos 1453. Kosmos 1335 came shortly after the decay of the previous flight of this type, Kosmos 1186, but was still in orbit when Kosmos 1453 was launched.

Kosmos 1311 and its replacement, Kosmos 1501, launched in 1981 and 1983, also had the 94.5 min. period but at 83° inclination. Johnson drew attention to the point that Kosmos 1310 and 1311 and Kosmos 1501 and 1502 were pairs of consecutive launches with the same period at the different inclinations of 65.8° and 83°,[75] but this may be purely coincidental.

It was reported that Kosmos 1311's purpose was to calibrate ABM development programs at Sary Shagan but no evidence was offered to support this speculation.[76]

The highly elliptical flights with periods greater than 100 minutes at 83° were resumed in 1981. Kosmos 1238 and 1263 operated as a pair with their orbital planes 180° out of phase and might, therefore, be considered to have been travelling in approximately the same plane in opposite directions although, for that to be absolutely [illegible], the orbits would need to be perfectly polar at 90° inclination. These were followed in 1983 by Kosmos 1508. Also, in 1982, Kosmos 1463 entered the 103.5 min. elliptical orbit at 83° previously used by Kosmos 1179 in 1980. The possibility exists that scientific results from either or both of these flights may some day be published exists but, until then, they are placed in this category for convenience.

FROM KAPUSTIN YAR

There were five flights at 50.7° in the period under consideration. In 1982, Kosmos 1351, 1397 and 1418 were launched at intervals of approximately 100 days with periods of 93.5, 93.4, and 92.4 min. Johnson sees some significance in the progressive decrease in orbit-

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[74] Soviet Union, Moscow, No 2. 1984, p. 6-7.
[75] Johnson, N L. The Soviet Year in Space: 1983. Teledyne Brown Engineering, 1984, p. 36.
[76] Defense Daily, Oct. 29, 1981, p. 284.

al period and also shows that, on October 31, their orbital planes were separated by 150°.[77] However, some caution should be exercised before reading too deeply into such observations for one might just as well point out that two of the satellites were 60° apart at that time.

Both of the 1983 missions of Kosmos 1465 and 1494 had 93.5 min. orbital periods.

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[77] Johnson, N.L. The Soviet Year in Space: 1982. Teledyne Brown Engineering, 1983, p. 24.

Chapter 3

Soviet Unmanned Scientific Programs

EARLY YEARS

THE INTERNATIONAL GEOPHYSICAL YEAR—ORIGIN OF SPACE SCIENCE

On July 29, 1955, President Eisenhower announced that the United States would launch a satellite as part of U.S. participation in the International Geophysical Year [IGY]. A day later, authorized Soviet sources reported that the Soviets would also launch a satellite as part of the IGY, although an official announcement was not made until September 1956.[1] These actions came at the request of the scientists planning the IGY, an international scientific effort from July 1, 1957, to December 31, 1958, for global studies of scientific phenomena in the Earth's atmosphere, who hoped that observations from space would contribute to their goals.

Even though Soviet intentions to launch a satellite were therefore well known, and by June 1957 they had announced the radio frequencies which they would use, the launch of Sputnik 1 still caught the world by surprise.

THE FIRST SPUTNIKS

SPUTNIK 1

Rumors of an impending launch, perhaps in time to celebrate Tsiolkovskiy's birthday on September 17, 1957, began to circulate in Moscow. Although this did not happen, the rumors grew more positive in the first week of October, and on October 4, Sputnik 1 became Earth's first artificial satellite (see figure 3). Launched from an unspecified point, it circled the Earth every 96 minutes at an inclination of 65° to the Equator, which meant that it passed over most of the inhabited world. Using battery power, Sputnik 1 broadcast on two harmonic frequencies close to 20 and 40 megahertz, and variations in its cricket-like beeping signal revealed characteristics both of the ionosphere and of its own temperature changes. Variations in the satellite's orbit and its eventual decay also provided data on atmospheric density.

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[1] Dodd, L. Harvey, and Linda S. Ciccoritti. U.S.-Soviet Cooperation in Space. Coral Gables, FL, University of Miami Center for Advanced International Studies. 1974. pp. 4-6.

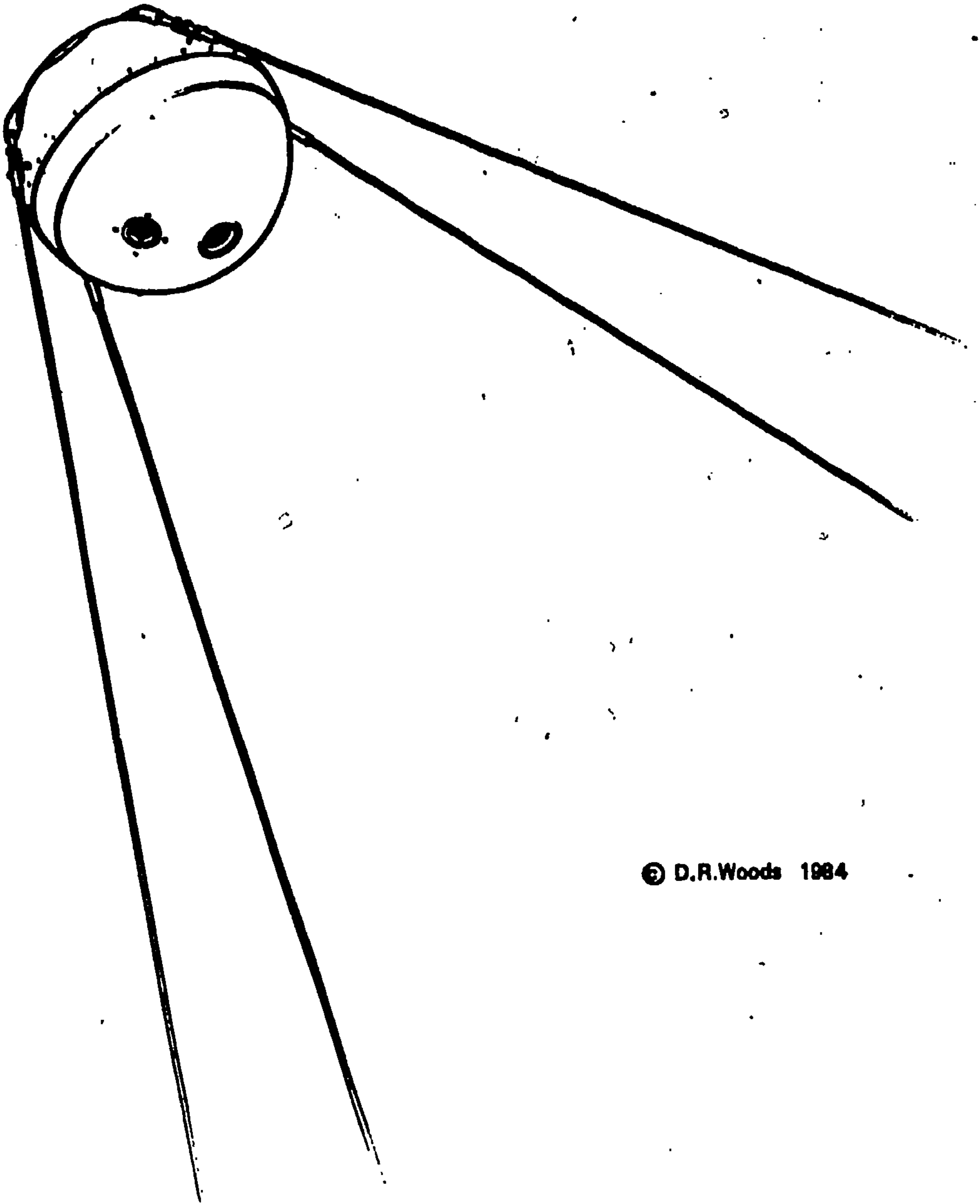
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FIGURE 3.—Sputnik-1, launched on 4 October 1957, marked the beginning of the Space Age. The 58 cm diameter sphere weighed 83.6 kg and housed chemical batteries to power a dual frequency beacon transmitter for the first 7 days of its 92-day life. There were no scientific instruments on board and hence no data returned.

It was the satellite's announced weight of 83.6 kilograms, an order of magnitude greater than the planned American satellite, that created the biggest surprise, and suggested to a number of scientists that a decimal place had been in error. Others could not accept the notion that the Soviet Union could be first in a field of advanced technology and they invented elaborate schemes for explaining Soviet trickery to simulate a satellite which they felt did not actually exist. It also became popular to believe there were constant Soviet attempts to launch satellites which failed, and that whatever had been launched was necessarily crude and only for propaganda purposes, and was certainly built by German scientists who went to the Soviet Union after World War II, or stolen from the United States. These assessments were wrong.

SPUTNIK 2

While Sputnik 1 was a shock, its simple structure, limited battery power, and lack of instrumentation (other than beacons) could be contrasted with the more elaborate, miniaturized instrumentation promised for the U.S. Vanguard. However, on November 3, 1957, the second Soviet satellite, Sputnik 2, was place in orbit and was announced as having a mass of 508.3 kilograms (see figure 4). The payload remained attached to the spent rocket casing, so the total weight placed into orbit was probably on the order of 6.5 metric tons.

Along with a respectable range of geophysical instrumentation, the spacecraft contained a life support system for the first space voyager, the dog Layka. Biomedical data were returned for a week on the effects of G load during launch, weightlessness, radiation, and temperature changes on Layka, which provided basic data for planned manned flights. Since the spacecraft was not designed to be recovered, she was injected with poison after the week of experiments. Other sensors measured certain kinds of radiation and micrometeorite impacts.

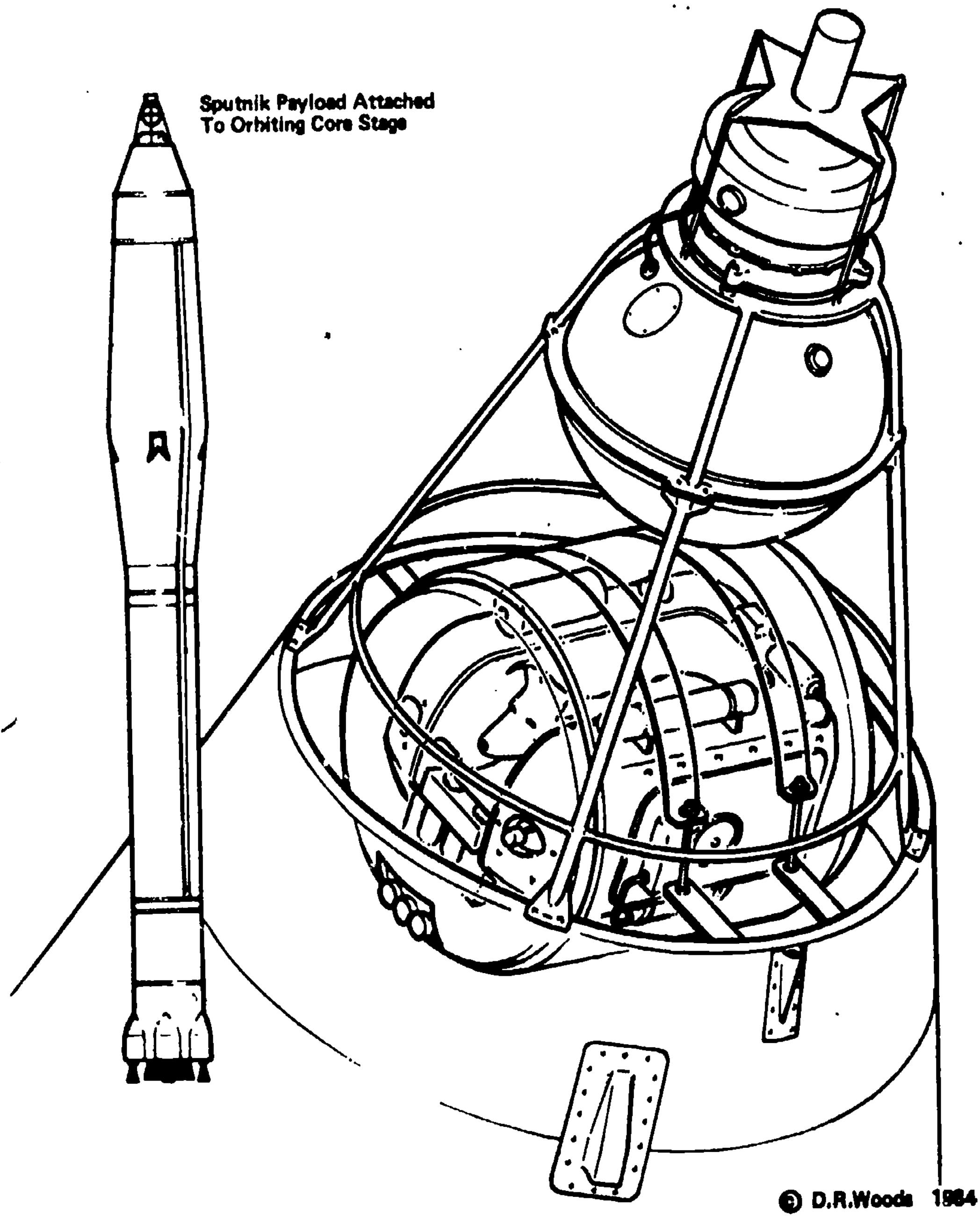

FIGURE 4.—The 0.508 metric ton Sputnik-2 payload remained attached to the A-booster final core stage, making it over 29 meters long and weighing about 7.79 metric tons. The dog Layka was housed in the cylinder with life support provisions for 7 days. Sputnik-2 was destroyed after 162 days in orbit when it reentered the Earth's atmosphere.

SPUTNIK 3

In the months which followed, the United States faced the frustrations of launch delays and launch failures, including the explosion of a vanguard test vehicle on December 6, 1957. Finally, on January 31, 1958 (local time), the American Army Explorer satellite was launched, but it weighed only 14.5 kilograms (including the payload and rocket casing). The civilian Vanguard succeeded in placing a 1.4 kilogram test vehicle and a 23 kilogram rocket casing in orbit on March 17, 1958.

On May 15, 1958, the Soviet Union launched Sputnik 3, and it was by far the most formidable challenge to the U.S. program—A 1,327 kilogram orbiting geophysical observatory of considerable sophistication (see figure 5). Unlike the two previous flights which were battery powered, this vehicle was equipped with solar cell panels, elaborate louvers for heat control, and an array of instrumentation which matched all the experiments planned for the U.S. IGY series of flights and also those planned for the immediate post-IGY period. Although this spacecraft carried heavy, off-the-shelf conventional electronic equipment such as vacuum tubes, it also contained thousands of solid state devices, and was, in effect, the early equivalent of the U.S. flights in the Orbiting Geophysical Observatory series beginning in 1964, although with a lower data rate. Sputnik 3 continued to operate until moments before its reentry 2 years after launch.

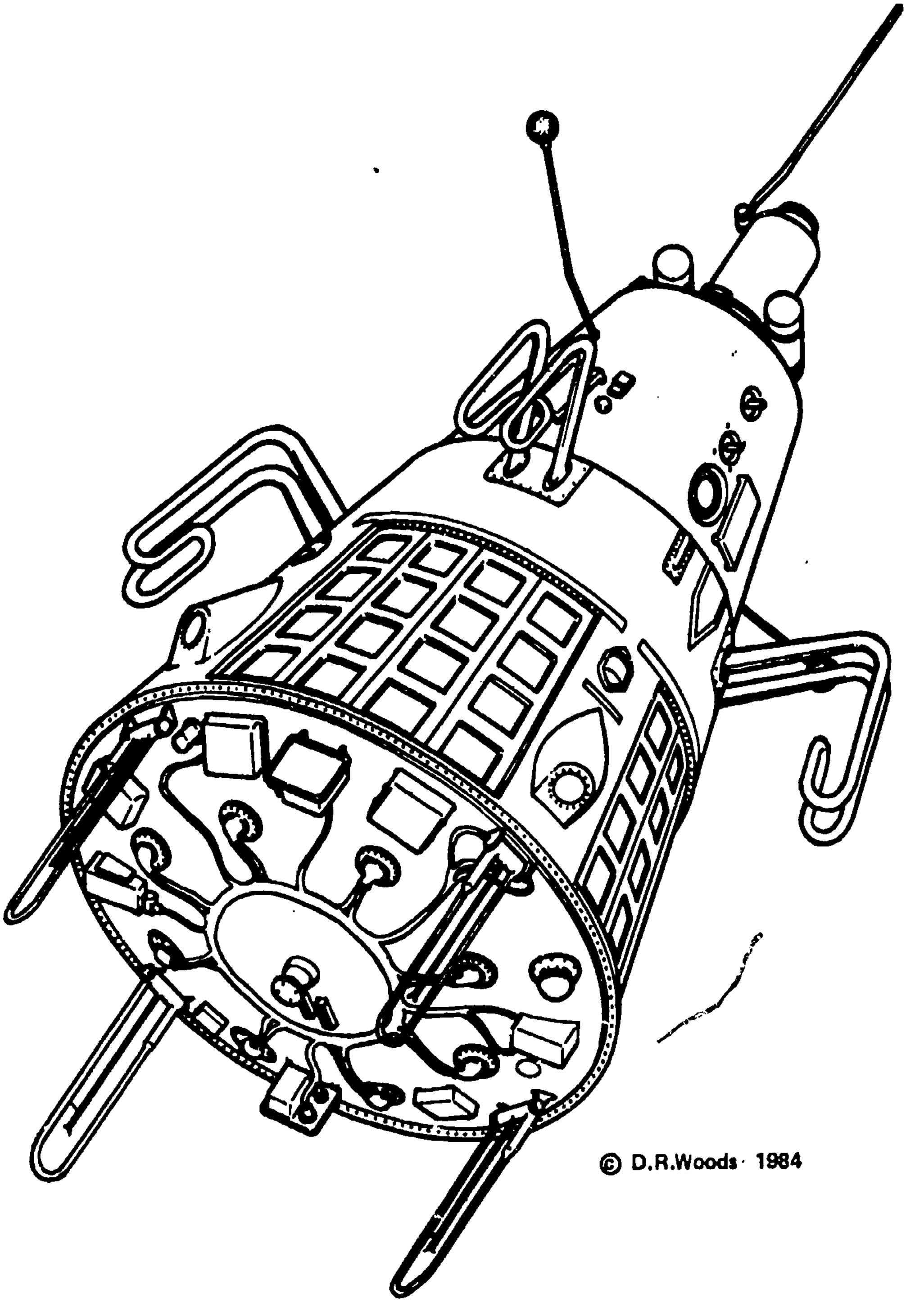

FIGURE 5.—Sputnik-3, weighing 1.327 metric tons, had solar cell arrays at its base, which powered a variety of scientific instruments during its 692 day life. It measured 1.73 m by 3.57 m.

The instruments for all three of these Sputniks were kept in sealed containers which were maintained at normal Earth surface pressures with normal atmospheric constituents. All three were launched by the same original ICBM system (although the final stage of the carrier rocket was left attached to the payload only in the case of Sputnik 2), and the entire core vehicle was placed in orbit, weighing about 6 metric tons, measuring 28 meters long, and slowly tumbling end over end. It was this rocket which was most easily identified on its passage across the night sky by observers on every continent.

SUBORBITAL PROGRAMS

THE VERTIKAL INTERNATIONAL PROGRAM

The Interkosmos organization of Soviet Bloc countries has sponsored geophysical sounding rocket flights under the name Vertikal.[2]

Vertikal 1 was launched on November 28, 1970, at Kapustin Yar, probably using the first stage of the B-1 (SS-4 Sandal), but possibly still using the SS-3 Shyster (or the Soviet designated A-3). The payload weighed 1,300 kilograms and reached an altitude of about 500 kilometers. The rocket was 23 meters long with a diameter of 1.66 meters. Instrumentation studied emissions in the x ray frequency range, the concentration of electrons and positive ions, as well as electron temperature. These instruments had been manufactured jointly by the German Democratic Republic and the Soviet Union to specifications developed by those countries, Bulgaria and Czechoslovakia.

On August 20, 1971, Vertikal 2 was launched and reached an altitude of 463 kilometers. The description of payload weight, dimensions, and participants seemed to match those of the earlier flight. The payload section separated from the single stage carrier rocket at about 90 kilometers, and was carried by momentum to the high point of the flight. Parachute recovery of the payload was accomplished.

The third flight in the series was launched on September 2, 1975, from Kapustin Yar at 0740 Moscow time, presumably with the same B-1 first stage or Soviet designated A-3 sounding rocket. Vertikal 3 reached a maximum altitude of 502 kilometers, following separation from the single stage carrier rocket at 97 kilometers altitude. The experiments continued the previous work on interactions between solar shortwave radiation and the ionosphere and upper atmosphere. The assembly of the spacecraft and launch itself were conducted by representatives of Bulgaria, Czechoslovakia, the German Democratic Republic, and Soviet Union. Two weather rockets with Bulgarian and Soviet equipment were launched at the same time, and various ground stations made simultaneous measurements.

Interestingly, during the summer of 1975, the Soviets displayed a replica of the Vertikal payload in a Moscow museum, but referred

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[2] The members of Interkosmos, in addition to the Soviet Union, are Bulgaria, Cuba, Czechoslovakia, German Democratic Republic, Hungary, Mongolia, Poland, Romania, and Vietnam

to the payload as a Prognoz. This replica (or one like it) was also shown at the Paris Air Show in the spring of the same year.

Vertikal 4 was launched on October 14, 1976, from Kapustin Yar. The geophysical rocket reached an altitude of 173 kilometers, where an astrophysical probe was released. The probe made an arc, reaching a height of 1,512 kilometers and returned to Earth with a parachute. Vertikal 4 continued the research of the previous three Vertikal flights and of Interkosmos 2, 8, 10, 12, and 14. During its 30 minute flight, Vertikal 4 took measurements at different altitudes of the concentration of neutral atoms of nitrogen and oxygen in the atmosphere. It measured solar radiation absorption to determine the concentration and temperature of molecular and atomic oxygen and molecular nitrogen. Vertikal 4 also carried a solar-guided stabilization system. The scientific equipment was developed by Bulgaria, the German Democratic Republic, Czechoslovakia, and the Soviet Union.[3]

On August 30, 1977, Vertikal 5 was launched from Kapustin Yar. The payload reached an altitude of 500 kilometers during the 10 to 15 minute flight. It carried an x ray spectrometer, a wide-band photometer, a micrometeoroid detector and a solar imaging system. Poland and Czechoslovakia contributed to the development of the scientific instruments. The mission conducted research on short-wave radiation of the solar corona and meteor particles. The payload detached from the launch vehicle at 100 kilometers and landed with the aid of a parachute.[4]

Vertikal 6 was launched on October 25, 1977, from Kapustin Yar to an altitude of 1500 kilometers. The instrument capsule was developed by Bulgaria, Hungary, the Soviet Union, and Czechoslovakia, and separated from the rocket at 173 kilometers. The flight lasted 30 minutes and collected data to improve weather and climate forecasting. Vertikal 6 continued research on the atmosphere and ionosphere and on short-wave solar radiation. A set of geophysical rockets were launched along with Vertikal 6 to take simultaneous measurements of the atmosphere and to develop measurements for rocket sounding. The geophysical rockets carried instruments developed by Bulgaria, Hungary, Romania, Poland and the Soviet Union.[5]

Vertikal 7 was launched on November 3, 1978, to an altitude of 1500 kilometers (the instrument package separated at 175 kilometers), and continued research on the ionosphere and short-wave radiation. The onboard equipment was made in the Soviet Union, Bulgaria, Romania, Hungary, and Czechoslovakia.[6]

Vertikal 8 was launched September 26, 1979, to an altitude of 505 kilometers. The probe carried equipment developed by Poland, the Soviet Union and Czechoslovakia and separated from the rocket at 100 kilometers. It continued research on shortwave radiation from the Sun. A new experiment to [illegible] a short-wave band image of the Sun was tested.[7]

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[3] Pravda. Moscow. Oct. 17. 1976. p. 3

[4] Pravda. Moscow. Aug. 31, 1977, p. 1.

[5] Pravda. Moscow. Oct 26, 1977, p. 6

[6] Pravda. Moscow. Nov. 4, 1978. p. 2.

[7] Tass. Sept. 26. 1979, 0937 GMT.

OTHER SOUNDING ROCKETS

The record of major Soviet vertical sounding rockets made under the national, rather than international, program is incomplete, but even those that are known show they have made a significant contribution to the total program and to orbital flights which followed them. Most of the major sounding rockets have been launched from Kapustin Yar. Smaller sounding rockets and weather rockets have been launched there, as well as at Hays Island, on Soviet scientific research ships at sea, and in Antarctica.

The largest Soviet sounding rocket is called the A-3 (referred to as the SS-3 by the United States and as Shyster by NATO). It is possible that the major international cooperation flights use the Sandal or SS-4, that is, the first stage of the B-1. One mission reached an altitude much higher than the others and it is likely that it used the SS-5 Skean (the first stage of the C-1). (These probes are shown on page 120 in part 1 of this study.)

The Soviet sounding rockets which have been launched under the national program have included missions for both biological and geophysical experiments.

SOVIET BIOLOGICAL SOUNDING ROCKET FLIGHTS

In May 1957, the Russians announced they had sent a rocket to an altitude of 211 kilometers with a payload which weighed 2,196 kilograms and carried five dogs.

On August 27, 1958, a payload of 1,690 kilograms was launched to an altitude of 452 kilometers. The dogs Belyanka and Pestraya were aboard.

On July 2, 1959, the dogs Otvazhnaya and Snezhinka, accompanied by a rabbit named Marfusha, were launched to an altitude of 241 kilometers. The payload weighed about 2,000 kilograms.

On July 10, 1959, another rocket with a payload of about 2,200 kilograms was launched to an altitude of about 211 kilometers, carrying several dogs including Otvazhnaya again.

On June 15, 1960, Otvazhnaya made a fifth flight on a sounding rocket which reached an altitude of 221 kilometers. The payload weighed 2,100 kilograms, and included another dog and a rabbit.

There were similar sounding rocket flights on June 6 and June 18, 1963. The first reached an altitude of 563 kilometers.

SOVIET SOUNDING ROCKET FLIGHTS FOR GEOPHYSICAL AND PROPULSION EXPERIMENTS

On February 21, 1958, a very complex geophysical rocket with a wide range of atmospheric and solar experiments was sent to an altitude of 473 kilometers. The payload weighed 1,515 kilograms.

On September 20 and October 1, 1965, rockets were sent to an altitude of about 480 to 500 kilometers to perform a wide range of geophysical experiments including taking measurements of the ionosphere and photographs and spectrographs of the Sun in the ultraviolet and x-ray wavelengths.

A new series of flights began in 1966, quite possibly with the A-3 launch vehicle or perhaps its SS-4 Sandal successor, but adding to the usual range of geophysical experiments were some unusual propulsion experiments.

The first, called Yantar 1, was launched on October 13, 1966. In addition to making studies of electron concentrations and photo emissions in the ionosphere, it scooped up atmospheric nitrogen, after attaining speed through its rocket motor, to sustain a special ion electrical rocket with propellant. This was seen as leading toward future hypersonic aircraft. In 1969 there were more Yantar flights, but the dates and the performance have not been reported in detail. All the flights seem to have operated in the altitude range of 100 to 400 kilometers.

On October 12, 1967, a much more ambitious sounding rocket flight was made, and it seems likely that a larger launch vehicle was used, such as the first stage of the C-1. Pictures released of the payload showed an instrument container much like a small Kosmos satellite. If the larger rocket was used, it probably was launched from Tyuratam, since no pad had been used at Kapustin Yar by that year for such a large vehicle.

EARTH ORBITAL DEVELOPMENT AND SCIENCE

THE KORABL SPUTNIKS

The five Korabl Sputnik flights are discussed in chapter 3 of part 2 of this report (manned space flight). They are referenced here only as part of the chronology of the development of Soviet spacecraft.

THE FIRST MANEUVERABLE SATELLITES

On November 1, 1963, Polet 1 was placed in Earth orbit. According to Soviet Premier Khrushchev, this satellite represented the beginning of a new era in space flight where satellites could maneuver after attaining orbit. The spacecraft entered an initial orbit 592 by 339 km. After a series of maneuvers, the final orbit was 1,437 by 343 kilometers, inclined at 58° 55′. No other specifics of the flight were given, other than the importance of being able to maneuver. Since no initial information was announced, it is not possible to estimate plane change or delta V involved.

On April 12, 1964, Polet 2 was placed in Earth orbit. Again, the Soviets stressed its ability to maneuver repeatedly, but did not publish details. The final orbit was described as 500 by 310 kilometers, at an inclination of 58.06°.

The launch vehicle used for these missions was an A-m combination. Strangely, the program was never mentioned again, and one may assume that it served its purpose, and that the technology was incorporated into some other classes of vehicles as a subsystem.

THE ELEKTRON PROGRAM

On January 30, 1964, the Soviet Union launched two payloads with a single launch vehicle, the A-1, for the first time. Elektron 1, weighing 330 kilograms, was put into an eccentric orbit of 7,100 by 406 kilometers at an inclination of 61°, with a period of 169 minutes. Elektron 2, weighing 445 kilograms, was put into an even more eccentric orbit of 68,200 by 460 kilometers, also at an inclination of 61°, with a period of 1,360 minutes (see figure 6). Both were fairly complex spacecraft designed to map the radiation belts and provide synoptic readings (Western observers have noted that other experiments, such as nuclear explosion detection equipment, also might have been carried).

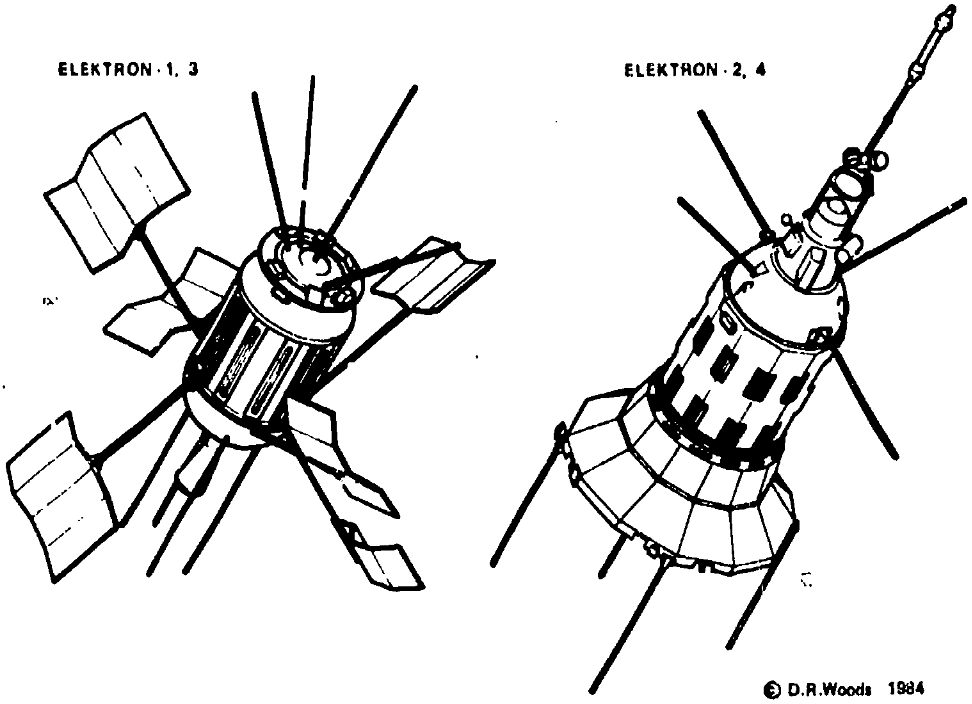

FIGURE 6.—Two sets of Elektron satellites were launched by the A-1 booster, for simultaneous studies of the Earth's radiation belts. The first Elektron was separated using a small solid propellant engine at its base, as the final stage was continuing to burn to place the second Elektron into orbit. Orbits for the first pair of Elektrons were 406 x 7100 km and 460 x 68,200 km, respectively. The orbits of the second pair were similar.

Elektron 1 was cylindrical, with six solar panels which folded out away from the craft, and it carried multiple antennas at both ends. Electron 2 was shaped like the cupola of a building, was mostly covered with solar cells, had antennas at both ends and a magnetometer boom at its pointed tip.

On July 10, 1964, Elektron 3 and Elektron 4 were put up into similar orbits in another dual launch. Elektron 3's orbit was 7,040 by 405 kilometers, 60.86° inclination, with a period of 168 minutes. Elektron 4 was in an orbit of 66,235 by 459 kilometers, inclination of 60.86°, with a period of 1,314 minutes. These flights, about 6 months after the earlier series, and launched about 12 hours later during the day, provided a second set of readings for comparison with the first flights. Weights were not announced, but presumably were similar to the earlier flights.

There have been no more flights in this series.

THE PROTON PROGRAM

After the relatively small Elektron flights, it seemed appropriate that the largest of Soviet scientific spacecraft be called Protons. Chapter 1, part 1 of this report describes the Proton or "D" class launch vehicle, about three times the capacity of the standard A class launch vehicles.

PROTON 1, 2, AND 3

On July 16, 1965, the Soviet Union launched Proton 1 into an orbit 627 by 190 kilometers at an inclination of 63.5°, with a period of 92.5 minutes. They announced that it weighed 12.2 metric tons and included a massive cosmic ray measuring experiment to provide data on cosmic rays up to an energy level of 100 trillion electron volts. The spacecraft consisted of a short cylinder about 4 meters in diameter, with four large solar cell panels or paddles which folded out from it, and a number of antennas (see figure 7). The experiment package was encased in the cylindrical section, and consisted of blocks of metal, paraffin, and plastic, often used for cosmic ray experiments. The spacecraft transmitted on many telemetry channels. Its low orbit led to its decay after 87 days.

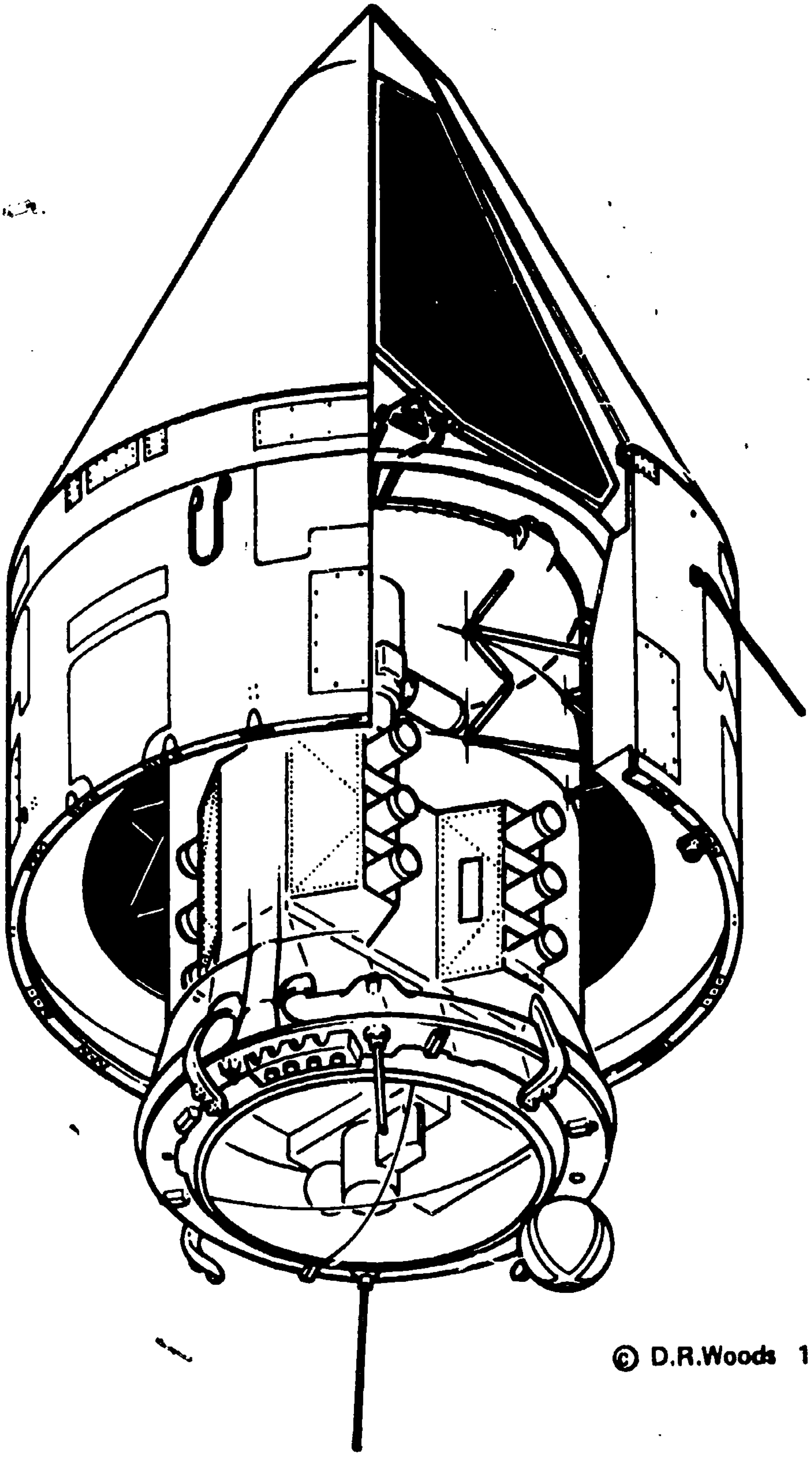

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FIGURE 7.—Proton-1, -2, and -3 were test launches of the original D-class booster. Each weighed 12.2 metric tons and carried 3.5 metric tons of high energy cosmic ray detectors in the cylindrical cores. The solar panels are shown folded under the aerodynamic shroud used during launch.

Proton 2 was launched on November 2, 1965, and lasted 92 days. It was placed into an orbit of 637 by 131 kilometers, inclined at 63.5° with a period of 92.6 minutes. Tass announced that it weighed 12.2 metric tons, and it is unclear whether or not the entire core vehicle was in orbit with the payload (the D version of the launch vehicle) or just an upper stage (the D-1 version).

The third Proton was launched on July 6, 1966, and also was announced as weighing 12.2 metric tons. Placed in an orbit of 630 by 190 kilometers, inclined at 63.5° with a period 92.5 minutes, it decayed after 72 days. The experiments carried on board continued cosmic ray studies, including solar cosmic rays (measuring their chemical composition and energy spectrum up to 100 trillion electron volts), as well as absolute intensity and energy spectrum of galactic cosmic rays, including searches for primary cosmic rays for those particles with a fractional electrical charge. Additional measurements were made in the search for quarks, the hypothetical primary particle.

It is quite possible that the primary purpose of these three flights was to test the new launch vehicle rather than obtain new science data, much like the three early flights of the U.S. Saturn I which carried the Pegasus satellites for measuring meteoroids.

PROTON 4

The final flight in the Proton program was launched on November 14, 1968, and was an improvement over the earlier missions. Placed in an orbit of 495 by 255 kilometers, inclined at 51.5°, with a period of 91.75 minutes, Proton 4 weighed 17 metric tons and decayed after 250 days (see figure 8).

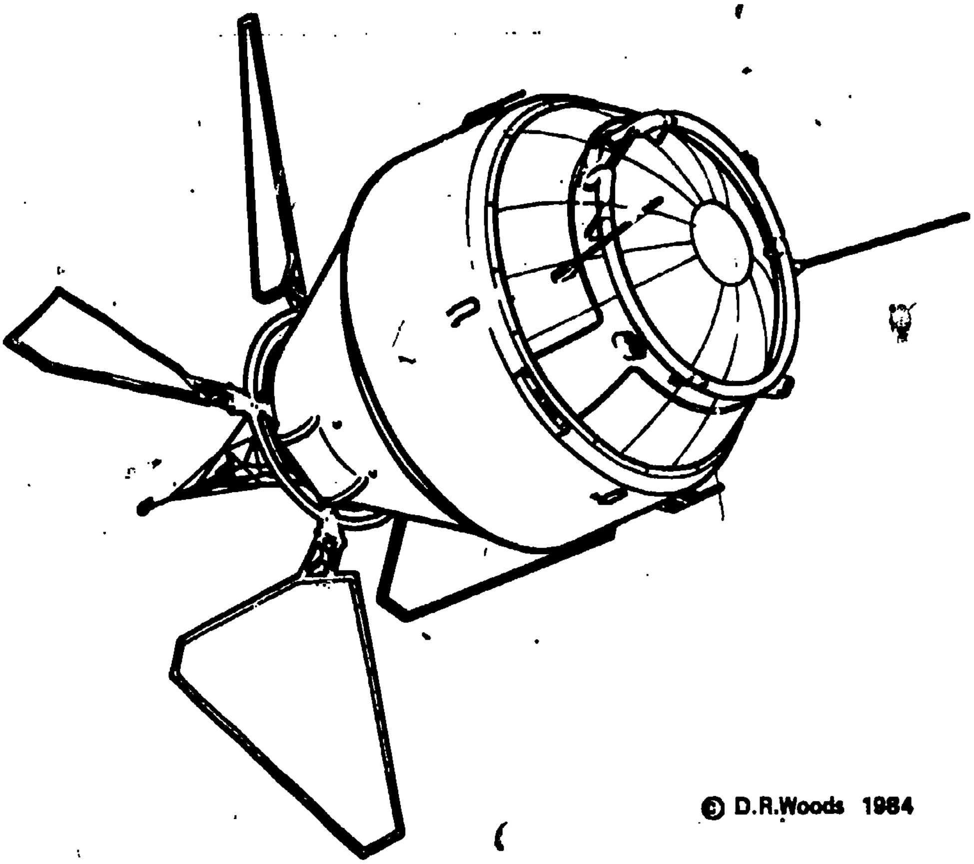

FIGURE 8.—Proton-4 weighed 17 metric tons and carried 12.5 metric tons of instrumentation payload for high energy cosmic ray studies. It measured 9.0 m x 4.5 m diameter and 10 m across its deployed solar cell panels.

Although the payload was not recoverable, there was a blunt, conical nosecone at one end. It also had a number of rod antennas and solar panels. Western observers noted that the accompanying spent rocket casing was on the order of 12 meters long, and 4 meters in diameter, the same as with the Luna 15 and Zond 4 flights, which confirmed that a D–1 launch vehicle had been used.

According to the Soviets, Proton 4 had the capacity to measure both cosmic ray energies (up to one quadrillion electron volts) and chemical composition in the range between 10 and 100 trillion electron volts. It also studied possible collisions of cosmic ray particles with the nuclei of hydrogen, carbon, and iron in the range of 1 to 10 trillion electron volts, and the dynamics of collisions of cosmic ray particles in the 10 to 100 trillion electron volt range with the nuclei of atoms. Proton 4 continued the search for primary particles with fractional electric charges, and guarks, and measured the intensity and energy spectrum of high energy electrons.

The main instrument used on Proton was an ionization calorimeter which consisted of steel bars interspersed with special plastic scintillators. When a cosmic ray primary would strike an iron nucleus, secondary particles would spread out to collide with other nuclei. The interaction of the particles were measured using a lump of carbon serving as one half of the instrument and a lump of polyethylene as the other half.

THE KOSMOS SCIENCE PROGRAM

THE NEED FOR THE KOSMOS DESIGNATION

In the first 5 years of the Soviet space program only 15 flights were successful in attaining orbit. All had come from Tyuratam, and all had used the large standard vehicle in its several forms, the A, A-1, A-2, and A-2-e. It is possible that only one or two launch pads were in use. In a sense, despite the very considerable achievements of the program, it represented an austere operation, exploiting to the utmost the investment which had been made. By the time the first Sputnik flew, work undoubtedly was already well along in planning use of the upper stage which permitted the first Luna flights, and perhaps the Vostok manned ship was also under actual development. The time had come to move experimental flights into both practical applications flights and more ambitious exploratory missions. One obvious need was to bring into operation a simpler launch vehicle which would be more economical for modest missions. Second, the Soviet Union needed to be able to fire its launch rockets at additional inclinations, from places where these changes of azimuth would not risk dropping first stages on populated regions. Third, if the pace of such flights was to pick up, it would be useful to spread the launch range workload more widely. All of these developments would come under the rubric of the Kosmos program.

The Soviet Union was in the slightly contradictory position of describing all of its space activity as devoted exclusively to scientific purposes, codefined as peaceful in nature. At the same time, however, Western experts saw them as exploiting the concept of operational and strategic surprise, to keep the United States off balance and their world image one of successful leadership. Startling predictions were made as to what they planned to do, but without a specific time table, and enough of these missions were accomplished to create the image of purposeful success. Information on failures was kept carefully hidden for many years, and the theme was constantly expressed that these successes were the direct result of the superiority of the socialist system. Repeatedly during the early years, it was stated that there were no failures in the Soviet program.

The Soviets rationalized their control of information on the premise that they should not boast before they had accomplished deeds worth advertising, and that their use of powerful military missiles, the front line of defense against aggressive imperialism, as launch vehicles needed protection against Western spying.

At the same time that the Soviet Union was claiming a technical lead in space, they were reading in the American press about U.S. plans for further generations of U.S. military spacecraft (Pied Piper, Big Brother, Sentry, etc.) in quite a different league from the first U.S. small scientific payloads. Soviet technicians must have known that spaceflight provided new and interesting opportunities for applications of advanced technology, but it would be difficult to develop similar military applications without undercutting their own propaganda which contrasted their peaceful image with claims that the U.S. Department of Defense alone was militarizing space for purposes of world aggression.

There was a body of Soviet literature which proposed that all military flights in space should be subject to international prohibition. Observations from space were called spying, and lawyers and military figures alike spoke of the need to take countermeasures. Premier Khrushchev spoke scathingly of people who peeked into others' bedrooms, promising that U.S. satellites would meet the same fate as Gary Powers' U-2 spy plane had on May 1, 1960. If the Soviets were to protect their own freedom of action in space while not sacrificing the peaceful image they were carefully constructing, they needed an appropriate cover plan. Thus, the name Kosmos (space), accompanied by a number, came into use for about 70 percent of Soviet launches.

This "openness" of name, immediate release of orbital elements, and peaceful Kosmos label, could be contrasted with the fact that by this time half of U.S. flights were for the Department of Defense, had no name, no announced mission, and the details on orbital path were withheld for weeks or months, sometimes after the flight was over. This Soviet practice was seen as an effective propaganda ploy, even though the name, serial number, and vague description provided no significant information. The Soviet release of orbital parameters was useful, but presumably told no more than was already evident to the tracking systems of the United States and Britain.

The text of the Tass announcement of the launch of Kosmos 1 on March 16, 1962, reproduced below, is typical of the hundreds of Kosmos launches made since that time.

> A series of artificial Earth satellites will be launched from different cosmodromes of the Soviet Union during 1962. Another launching of an artificial Earth satellite was carried out in the Soviet Union on March 16, 1962. . . .
>
> The launching of the artificial Earth satellite continues the current program of studying the upper layers of the atmosphere and outer space in fulfillment of which a series of satellite launchings will be effected under this program from different cosmodromes of the Soviet Union in the course of 1962. The scientific program includes: The study of the concentration of charged particles in the ionosphere for investigating the propagation of radio waves; a study of corpuscular flows and low energy particles; study of the energy composition of the radiation dangers of prolonged space flights; study of the primary composition and intensity variation of cosmic rays; study of the magnetic field of the Earth; study of the short wave radiation of the Sun and other celestial bodies; study of the upper layers of the atmosphere; study of the effects of meteoric matter on construction elements of space vehicles; and study of the distribution and formation of cloud patterns in the Earth's atmosphere. Moreover, many elements of space vehicle construction will be checked and improved. The launching

> of sputniks of this series will be announced in separate reports. This program will give Soviet scientists new means for studying the physics of the upper atmospheric layers and outer space.[8]

When another launch occurred on April 6, it was named Kosmos 2, and reference was made to the press release for Kosmos 1.

The first three Kosmos flights came from Kapustin Yar, and they flew at an inclination close to 49°. Kosmos 4, however, announced with the same kind of a press release, was flown at the previous inclination of 65°. Three days later, Tass made the following announcement:

> The Soviet artificial Earth satellite Kosmos 4, launched on April 26, 1962, has been in orbit for more than 3 days and has flown in this period about 2 million kilometers. Throughout the world flight the systems and apparatuses on the satellite to carry out the exploration of cosmic space and the upper layers of the atmosphere worked well. [sic] In connection with the completion of the program of scientific research on April 29, at a command from Earth the successful landing of the satellite in a predetermined area of the territory of the Soviet Union was carried out. As a result of the launching of satellite Kosmos 4, valuable scientific data, which at present is being processed and studied, has been received.[9]

It became apparent that there were several separate programs, using different launch vehicles at different cosmodromes, all under the general label of Kosmos. They could announce the successful recovery of a payload on land without tying that work to a military program, as President Eisenhower did when he displayed the first Discoverer capsule after it was picked up in the ocean.

Especially with the advantage of hindsight, it is possible to sort out the Kosmos flights in almost all instances into broad categories. The public record of orbital elements is very revealing as repetitive patterns are studied, and these characteristics are compared with possible missions which would use such paths around the Earth.

The Soviet scientific community sometimes publishes experimental results on those Kosmos flights which are scientific, and subsequent flights with similar characteristics can therefore also be identified. Results of flights associated with applications such as weather and communications can similarly be identified. Manned flight precursors are especially easy to spot not only by their orbital placement and recovery, but usually by the radio frequencies used and sometimes even by the broadcast of recorded human voices.

Thus, the Kosmos category includes elements of programs devoted to science, to development of practical civil applications, and to testing precursors to manned ships to follow. Other Kosmos missions are probably failures which the Soviets do not care to identi-

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[8] Tass, Mar 16, 1962, 1701 GMT

[9] Tass, Apr 29, 1962, 1232 GMT

fy. The largest category within the Kosmos label are those Soviet satellites with military purposes. These are discussed in chapter 5.

RESOURCES FOR IDENTIFYING KOSMOS MISSIONS

As noted above, certain Kosmos missions can be identified through publication of scientific findings or by later flights with similar characteristics whose mission is announced. The nature of the orbit compared to potential applications of spacecraft in such an orbit also provides clues as to the spacecraft's purpose.

Important indicators are also supplied by the Goddard Satellite Situation Report which gives the orbital elements and decay dates on not only the payloads but associated debris as well. Abandoned debris may reveal something about the staging and mode of operation or maneuver, if any, used by the flight. Rates of orbital decay over time may reveal something of the density or shape of the objects in orbit. If final decay from orbit occurs before natural decay by air drag would dictate, it is reasonably likely that retrofire was employed in a recovery attempt, or return to Earth was deliberately arranged. If "pickaback" payloads are separated later from the main payload, this fact generally can be noted in the public register. Clearly catastrophic events such as explosions in orbit are signalled by the large amount of debris, and the dispersion from the original single orbit tells something of the violence of the explosion. Payloads which were spin stabilized early in flight and then slowed down by unwinding "yo-yo" wires with weights are identifiable because these separated weights above and below the main payload are a standard telltale with such flights.

In addition to the Goddard Satellite Situation Report, Goddard also publishes the "two lines," which are sets of data on each satellite which has been launched. The Satellite Situation Report gives data only on apogee, perigee, orbital inclination, and period, while the two lines provide additional data on right ascension of ascending node, argument of perigee, mean anomally, mean motion and revolution number from which date and hour of launch and semimajor axis can be computed.

A third valuable source of data is the Royal Aircraft Establishment [RAE] at Farnborough, England, which publishes logs of all world flights, including Soviet, and labels which objects are payloads, which are spent rocket casings, which are special capsules, and which are miscellaneous debris. Using optical and radar observations, the RAE lists the shape, weight, and dimensions of most objects to the best of their estimating ability. The RAE logs also publish the data from the Goddard "two lines."

Still more information on Kosmos flights is available from private observers. The major source of this information is the team of observers linked with the Kettering Boys School, Northants, England. Geoffrey E. Perry, the head of physics at the school, has led this effort with important support from his family, colleagues, and successive generations of pupils. In addition to Mr. Perry, his wife Jean, and his students, members of the Kettering Group are located in England (Peter Wakelin, Christopher Wood, Dave Hawkins, Robert Christy, and Isabel (Perry) Carmichael); Sweden (Sven Grahn and Jan-Ola Dahlberg); and the United States (Richard

Flagg in Florida and Mark Severence in Texas). Corresponding members of the Group are located in England (Grant Thomson, Sarah Mobbs, and Les Currington), Germany (Horst Hewel and Dieter Oslender), South Africa (Greg Roberts), New Zealand (Len Maxim), and the United States (Lindsay Winkler and Ken Johnson).

The Kettering Group concentrated first on the signal characteristics of the 8-day Soviet military recoverable photographic missions. The observed Doppler shifts made it possible to establish the flight path to a good degree of accuracy. When the flights were ready for recovery, the radio beacon was tracked, and the stages of retrofire, ionospheric blackout, parachute opening, touch down on the ground, and arrival of the pickup crew to turn off the final beacon, could be logged with great precision.

Perry's studies proceeded to identify telemetry format so that even on the first revolution it was possible to discern the nature of different flights after launch, and to predict impending launches because a spacecraft already in orbit would vacate its previous frequency in order to free it for a new spacecraft coming within the day. Since 1974, the Kettering Group has been able to classify some Soviet launches in 5 sets and subsets by applying numerical and graphical methods to two-line data.[10]

The Kettering Group has consistently provided highly professional, positive identification to many aspects of the Soviet space program from completely unclassified, private sources, which are not matched by any public release of data by the Soviet, United States, or British Governments. Mr. Perry has received many honors for his work, and was personally invested with the order of MBE by Queen Elizabeth at Buckingham Palace on March 13, 1973.

KOSMOS SCIENTIFIC MISSIONS

By the techniques discussed above, it is usually possible to distinguish between scientific and military missions. In addition to those flights with a primary scientific mission, there are a number of military flights which carry a separable scientific payload in pickaback form, and there are other scientific experiments which are incorporated as part of the main military payload. To the extent any of these categories can be identified or have been disclosed, they will be accounted for in the text to follow.

For convenience these missions will be categorized based on the launch vehicle used to place them in orbit.

Use of the B-1 for scientific flights

From 1964 to 1973, the B-1 vehicle was used to launch a standardized Kosmos scientific payload which consisted essentially of a short sealed cylinder with hemispheric ends (see figures 9 and 10). Most were spin stabilized during launch, and although some carried internal chemical batteries only, others had solar cells either on the exterior of the cylinder or on panels that fold out from the body of the spacecraft. The instrumentation and booms, if any,

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[10] Perry, Geoffrey. Pupil Projects Involving Satellites. Space Education, vol. 1, May 1984, pp. 320-323

varied according to the experiments being conducted. Weights for the satellites have never been announced, but probably ranged from 260 to 425 kilograms.

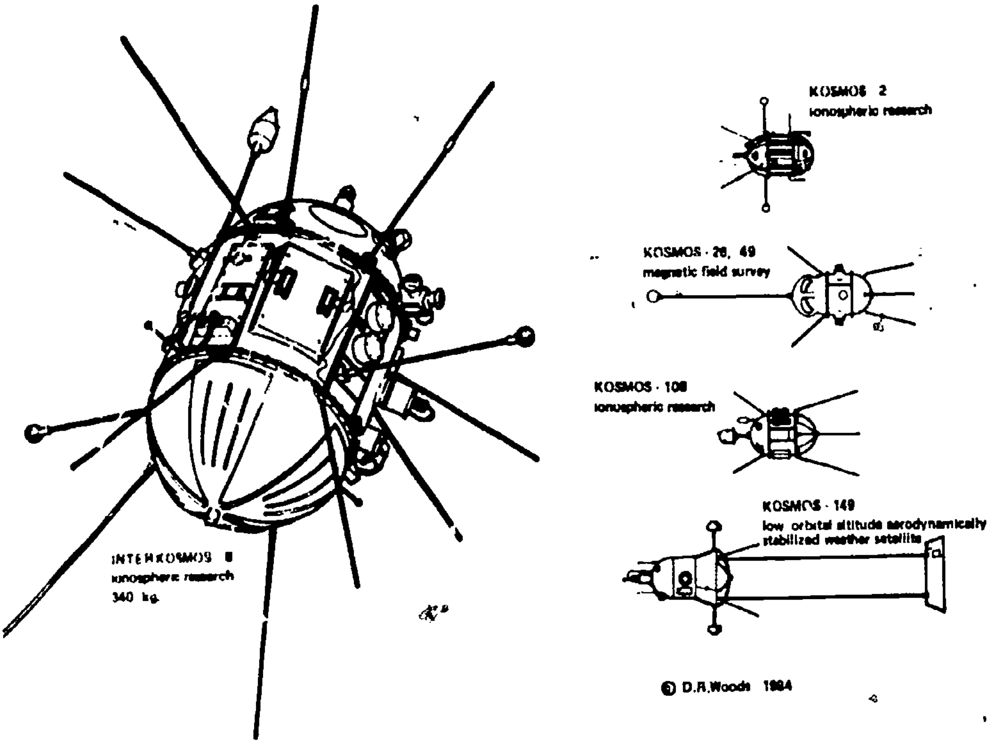

FIGURE 9.—B-class Kosmos booster launched a variety of small scientific, nonrecoverable, battery-powered satellites, as shown here. Each is based upon a standardized design of a cylindrical body with hemispherical ends.

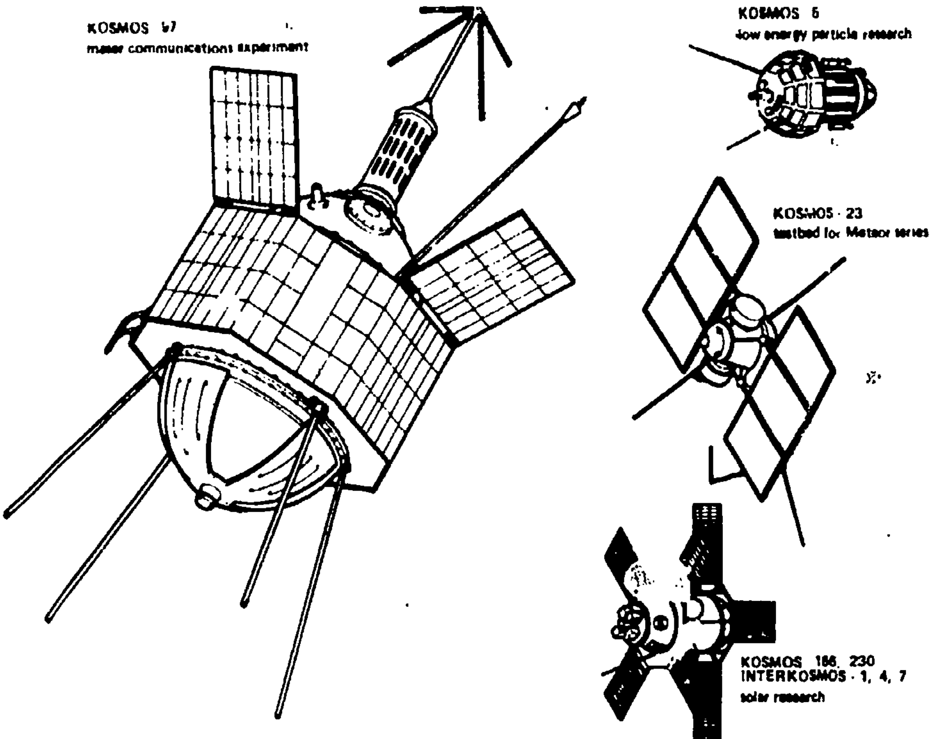

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FIGURE 10.—The B-class Kosmos booster was also used to launch a series of small scientific, nonrecoverable solar powered satellites, as shown here. Most are based upon a standardized design like the battery-powered versions, but with an octagonal shell fitted with four or eight extendable panels.

Two had a special stabilization system that depended upon use of the aerodynamics of the atmosphere still present in low orbit enough to influence vehicle performance. An annular ring was extended in orbital flight on telescoping booms well to the rear of the spacecraft. Although this was successful, it would only work for relatively short-lived low orbits.

Launches from Kapustin Yar flew initially at inclinations close to 49°, but after 1966, at about 48.4°. The nature of the mission was announced in only a few instances at the time of launch. A small number of scientific payloads were launched from Plesetsk, either at 71° or at 82°.

Since 1973, the B-1 launch vehicle has been phased out in favor of the larger C-1, and the Kosmos name was replaced by Interkosmos because the flights carry cooperative experiments of other countries of the Soviet bloc (see next section).

Table 8 categorizes the B-1 launches by inclination and orbital characteristics. The mission descriptions represent experiments or instrumentation referred to in the Soviet literature, often with added details which have become available over a period of time.

TABLE 8.—IDENTIFIABLE USE OF THE B-1 LAUNCH VEHICLE FOR SCIENTIFIC ORBITAL MISSIONS

Year and Kosmos No	Kapustin Yar 48.4–49°				Plesetsk		Mission description
	Very low	Low	Intermediate	High	71° low	82° low	
1962							
1			980-217				Electron density, propagation, geomagnetic, solar wind.
2				1,546-212			Electron density, propagation, ion composition, solar UV radiation.
3			720-229				Electron density, propagation, atmospheric density, solar and cosmic radiation.
5				1,600-203			Electron density, atmospheric density, solar and cosmic radiation, geomagnetism.
6		360-274					Cosmic radiation.
8		604-256					Electron density, atmospheric density, micrometeorites.
11			921-245				Atmospheric density, ion density, propagation.
1963							
14		512-265					Meteorology.
17			788-260				Electron density, atmospheric density, solar and cosmic radiation.
19		519-270					Atmospheric density, cosmic radiation.
23		613-240					Meteorology.
1964							
25		526-272					Cosmic radiation.
26		402-271					Magnetic fields.
49		490-260					Magnetic fields. UV radiation.
51		554-264					Luminosity of stellar background.
1965							
53				1,192-227			Cosmic radiation, neutron flux.
97				2,100-220			Quantum generator maser and atomic clock.
1966							
108			865-227				Electron density, propagation, atmospheric density, solar and cosmic radiation.
135		662-259					Gamma radiation, micrometeorites.
137				1.720-230			Radiation, proton spectrum, charged particles (Cherenkov counter).
1967							
142				1,362-214			Radio propagation.
149	297-248						Meteorology, radiation gauges, aerostabilized payload.
163		616-261					Cosmic ray telescope.
166		578 283					Solar x-ray, UV, and short wave emissions (spin stabilized)
196			887 225				Atmospheric studies.
1968							
215		426-261					8-telescope astronomy—visible, IR, UV, x-ray, spectrometer, also ocean surface brightness, photometer of upper atmosphere, emission line of oxygen (spin stabilized)
219				1.770 222			Electron spectrum of inner belt—magnetometer, scintillation counter, photospectrometer, soft proton spectrometer.
225		530 257					Electron flux study of Brazilian anomaly, cosmic rays.
230		580 290					Solar x-ray and UV (spin stabilized)
259				1.353 219			Ionospheric studies, radio propagation
261					670 217		Atmospheric and auroae studies—charged particles, plasma, fluxes of soft photoelectrons, spectra of auroral electrons [Bloc cooperation]
262			818-263				Hard radiation intensity (Geiger counters)

TABLE 8.—IDENTIFIABLE USE OF THE B-1 LAUNCH VEHICLE FOR SCIENTIFIC ORBITAL MISSIONS—Continued

Year and Kosmos No	Kapustin Yar 48.4-49°				Plesetsk		Mission description
	Very low	Low	Intermediate	High	71° low	82° low	
1969							
IK-1			640-260				Solar UV and x-ray, plus effects on upper atmosphere. [Bloc cooperation].
IK 2				1,200-206			Night ionospheric measures and magnetosphere, concentration of positive ions, electrons, electron temperature [Bloc cooperation].
1970							
320	342-240						Meteorology, reflected solar radiation, albedo, long wave radiation, cloud cover, aerostabilized payload.
321					507-289		Geomagnetism, ring currents, ionospheric measures.
335		415-254					UV radiation.
348					680-212		Atmospheric and auroae studies—photo electrons, ion temperatures, horizontal gradients. [Bloc cooperation].
IK 3				1,320-207			Cosmic rays, low frequency fluxes, charged particles, dynamic processes of radiation belts. UV and X-rays, nature and spectrum of electromagnetic oscillations. [Bloc cooperation].
356						600-240	Atmospheric and auroae studies—radiation.
IK 4		668-263					Radiation flux of whole solar disk, soft and hard x-rays, UV, background of charged particles, optical measures. [Bloc cooperation].
1971							
IK 5				1,200-205			Cosmic rays and lower frequencies, fluxes of charged particles. [Bloc cooperation].
1972							
481					540-279		Ionospheric electrons and temperatures, protons, ion concentration [Bloc cooperation].
1973							
IK 9				1,551-202			Solar radiation and ionospheric radio waves excitation by solar corona [Bloc cooperation].

Notes

1 The groupings by apogee and perigee (in kilometers) are somewhat arbitrary, but may be compared with groupings used for military missions with similar external characteristics and launched also by the B-1 vehicles.

2 The mission descriptions, often issued piecemeal even years after the flight occurred, are abbreviated, and to a degree overlap, or mix missions and instrumentation, but they give a general indication as to the areas of interest for each flight.

3 It will be noted that Interkosmos flight designations appear as well as Kosmos flights. The Soviet bloc cooperative flights are abbreviated with the prefix initials IK. Kosmos 261 and 348 although not given IK numbers were also cooperative flights. Presumably they were assigned Kosmos designators because at the time non-Soviet participants were not permitted to visit the Plesetsk launch site where these were launched.

Sources: Basic flight data from Soviet TASS bulletins. Followup mission descriptions sometimes appear as articles in the regular Soviet press. Others appear in references in the scientific literature years later, and some references are found 1 or more years later in Soviet reports to COSPAR (Committee on Space Research, International Council of Scientific Unions).

Use of the C-1 scientific flights

The C-1 launch vehicle came into use in 1964 but was used only for military missions until 1970. The preceding section noted that in some cases, it has not been possible to establish a B-1 flight as scientific rather than military until well after the event, depending upon the appearance of references in the scientific literature. Most C-1 flights can be cataloged as to military versus civilian use on the basis of their announced flight parameters, but there are exceptions, and hence any tabulation is subject to revision. For example Kosmos 381 was promptly announced as a scientific topside sounder, subsequently displayed at the Paris Air Show, and many results were published. Kosmos 385 had almost the same kind of orbit, but no mention was made of scientific findings, and subsequent flights with similar parameters have been judged to be navigation satellites. At least two C-1 launches (Kosmos 426 and 546) had characteristics suggesting they were scientific flights, but also might have been instrumentation failures or unidentified military missions. Figure 11 illustrated several types of C-class scientific payloads. Table 9 summarizes the tentative assignment of C-1 flights to the scientific category.

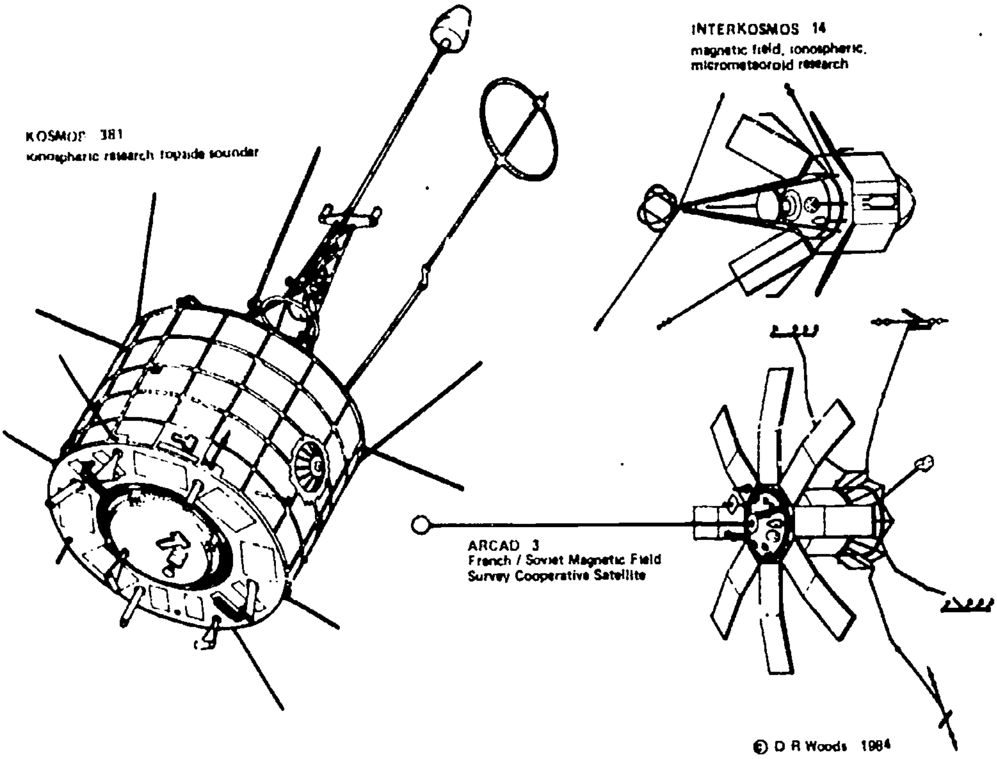

FIGURE 11.—All C-class Kosmos satellites appear to be solar powered, and based on one of three basic designs, as shown here: (a) a heavy version of the B-class booster solar-powered satellites, (b) a cylindrical solar array shell around a cylindrical core, and (c) eight deployable solar panels around a cylindrical core.

TABLE 9.—IDENTIFIABLE USE OF THE C-1 LAUNCH VEHICLE FOR SCIENTIFIC ORBITAL MISSIONS

Year and Kosmos No.	Kapustin Yar [illegible]	Plesetsk 69°	74 circular	74 eccentric	83 circular	83 eccentric	Mission
1970							
378				1.763 241			Ionospheric studies, plasmas, leaking of charged particles of different energies.

TABLE 9.—IDENTIFIABLE USE OF THE C 1 LAUNCH VEHICLE FOR SCIENTIFIC ORBITAL MISSIONS—Continued

Year and Kosmos No	Kapustin Yar 50.6-50.7	Plesetsk					Mission
		69.2	74 circular	74 eccentric	83 circular	83 eccentric	
381			1,023-985				Pulsed topside sounder on 20 frequencies and measuring electron flux.
1971							
426				2,012-394			Possible ionospheric studies.
461		524-490					Intensity, spectral composition, distribution, angular direction of gamma radiation.
Oreol 1 (Aureole 1).				2,500-410			Wideband spectrum of protons and electrons, proton intensity, ion composition of atmosphere (French).
1973							
546	630-585						Possible solar studies.
IK 10				1,477-265			Particle temperatures, energies, concentrations—electrons, ions, neutral atoms, magnetic fields, low frequency oscillations in ionosphere. (Bloc cooperation.)
Oreol 2 (Aureole 2)				1,995-407			Charged particles—protons, electrons, ion composition, numbers, energy distribution, auroras of upper atmosphere (French).
1974							
IK 11	526-484						Solar UV and x-ray, upper atmosphere study. (Bloc cooperation.)
IK 12				708-264			Atmospheric composition and structure—numbers, character, energies in ionosphere, micrometeorites. (Bloc cooperation.)
1975							
IK 13						1,714-296	Magnetosphere dynamics, processes of polar ionosphere, low frequency electromagnetic waves (Bloc cooperation.)
Anabat (Aryabhata)	619-563						X-ray astronomy, solar gamma neutrons, particle flows radiation in ionosphere (Indian)
IK 14				1,707-345			Low frequency electromagnetic wave fluctuations in magnetosphere, structure of ionosphere, micrometeoritic intensity (Bloc cooperation.)
1976							
IK 15			521-487				Systems test of new AUOS spacecraft (Bloc cooperation.)

TABLE 9 —IDENTIFIABLE USE OF THE C-1 LAUNCH VEHICLE FOR SCIENTIFIC ORBITAL MISSIONS—Continued

Year and Kosmos No	Kapustin Yar 50.6-50.7	Plesetsk					Mission
		69.2	74 circular	74 eccentric	83 circular	83 eccentric	
IK-16	523-465						X-ray of spectra of Sun, polarization of resonance lines in UV, effects on upper atmosphere. (Bloc cooperation.)
1977							
893				1,703-341			Duplicates IK-14 orbit, but rocket remained attached to payload.
900					523-460		Physical phenomena in ionosphere and magnetosphere. (Bloc cooperation.)
906	523-466						Partially duplicates IK-16 orbit, but rocket remained attached to payload.
Sneg 3 (Signe 3)	519-459						Direction of gamma ray bursts, solar UV (French).
IK 17					519-468		Energetic charged and neutral particles, micrometeorite steams, magnetosphere and upper atmosphere, laser telescope for geodesy. (Bloc cooperation.)
1978							
IK 18					786-407		Interaction of solar wind with magnetosphere, auroras, particles, ionosphere. (Bloc cooperation.)
Magion					786-407		Electrical field low frequency resonance arcund satellite, charged particles, electrons. (Czeck pickaback.)
1979							
IK-19				996-502			Structure of ionospheric wave processes, radio propagation in ionospheric plasma, solar radiation, magnetic data. (Bloc cooperation.)
Bhaskara (Bhaskar)	557-512						Earth resources, day and night, including sea state, soil and water conditions (Indian).
IK 20			523-467				Ocean resources data, including IR for water temperature, collection of data from floating surface buoys (Bloc cooperation.)

Notes

1 To the extent possible the scientific missions using the C-1 launch vehicle have been isolated for inclusion in this table Two C-1 flights do not seem to fit in the military category yet no scientific results have been found published in the literature Kosmos 426 which roughly resembles Kosmos 378 may belong in the military calibration category or it may be a payload whose instrumentation failed to function Kosmos 546 somewhat resembles Interkosmos 11 but no findings have been published so may be either a scientific payload whose instrumentation failed or may be a military calibration category flight

2 Either as a misidentification or as anomalies, 2 military type payloads of the C 1 category were listed as carrying supplemental payloads devoted to science Kosmos 256, a geodetic payload returned data on solar and cosmic radiation. Kosmos 610, an electronic ferret is said to have carried a biological experiment

3 The flights included have been grouped by year, inclination, and type of orbit, with mission data summarized from widely scattered references in Soviet scientific journals and COSPAR reports

4 Interkosmos flights are abbreviated as IK These are cooperative flights with other countries of the Soviet bloc and occasionally other countries

Sources Basic flight data from Soviet Tass bulletins Followup mission descriptions sometimes appear in the regular Soviet press Others appear in references in the scientific literature even years later, or in Soviet reports to COSPAR

Use of the A-1 and A-2 for scientific supplemental payloads

In addition to flights which serve primarily a scientific purpose, the Soviets have used spare capacity on military flights for scientific research purposes, and in the case of military photographic missions, the experiments can be recovered. Analysis of these flights is difficult, however, and depends upon Soviet announcements which often are not available until years after the flight.

In the early days when it appeared that the military photographic missions used a modified Vostok spacecraft, it was assumed that any supplemental scientific payloads were carried in the descent module. With the additon of the Soyuz-class military reconnaissance spacecraft, however, it may be that scientific experiments are carried in the main body as well as (or instead of) in the recovery capsule. Observations by the Kettering Group initially show which reconnaissance spacecraft should maneuver, which should not maneuver but return a capsule, and which should neither maneuver nor return a capsule. Missions which do not fit these profiles may carry supplemental scientific payloads, but without Soviet confirmation, little can be stated with certainty.

Among the tentative conclusions that can be drawn is that one series of military photographic flights also gave engineering support to the techniques of launch, control, and recovery for subsequent manned flights, and another group carried sensors and television cameras that gathered weather data which later led to a separate series of weather satellites in sustained, nonrecoverable flight.

On the basis of all this foregoing discussion, it will be recognized that the missions listed in tables 10 and 11 must remain tentative until the Soviets release more information, but it does at least provide a starting point for better analyses in the future.

TABLE 10 IDENTIFIABLE USE OF THE A-1, A-2, AND A-2-e FOR SCIENTIFIC ORBITAL MISSIONS

Year and name	[illegible] A	[illegible] (A-2)	[illegible] (A-2-e)	Mission
1964				
Elektron 1		7 100 406		Mapping of radiation belts, in conjunction with Elektron 2
Elektron 2		68 000 460		Other half of dual payload single launch
Elektron 3		7 040 405		Mapping of radiation belts, 6 months and 12 hours out of phase with the preceding pair Dual payload, single launch
Elektron 4		66,235 459		
1972				
[illegible]	[illegible]			Cosmic ray primaries chemical composition and energy spectrum, meteoritic particles Recovered photoemulsion bloc and ionization calorimeter Measured as high as 1,000,000,000,000 electron bolts
Prognoz 1			200 000 950	Interactions of corpuscular gamma, x ray, and solar plasma interactions with magnetosphere
Prognoz 2			200,000 550	Repeat of Prognoz 1, plus French Solar wind experiment
1973 Prognoz 3			200 000 590	Similar to Prognoz 1
1975 Prognoz 4			199 000·634	Do
1976 Prognoz 5			199 000 510	Do
1977 Prognoz 6			197,900 498	Similar to Prognoz 1, plus French and Czech experiments

TABLE 10.—IDENTIFIABLE USE OF THE A-1, A-2, AND A-2-e FOR SCIENTIFIC ORBITAL MISSIONS—Continued

Year and name	51 8 (A-2)	60 9-61 0 (A-1) 0	65 (A-2-e)	Mission
1978 Prognoz 7			202,965-483	Corpuscular and electromagnetic radiation of Sun, interplanetary medium, galactic UV and gamma, interactions with Earth electromagnetosphere. Experiments also by Hungary, Czechoslovakia, France, and Sweden.
1980 Prognoz 8			199,000-550	Similar to Prognoz 7. Experiments also by Poland, Czechoslovakia, and Sweden.

Notes

1 This table includes all flights using the 'A' class launch vehicle for scientific missions, other than those related to manned flights or biological experiments It also excludes both military and civil applications missions Some analysts in calculating the weight of announced experiments carried in the Elektron flights suggest they also had a nuclear detection or early warning military role as well

2 IK-6 is Interkosmos 6, a joint experiment of the U S S R with its bloc partners

3 The table arranges the flights by year, by name, by inclination, and showing the apogee and perigee in kilometers for each All these launches were from Tyuratam

Sources Data are from Soviet Tass bulletins.

TABLE 11.—IDENTIFIABLE OR POSSIBLE USE OF THE A-1, A-2, AND F-2 LAUNCH VEHICLES FOR KOSMOS SCIENTIFIC AND SUPPLEMENTAL PAYLOADS

Year and Kosmos No	Launch vehicle	Apogee and Perigee	Inclination	Pickaback or Maneuvering engine	RAE Capsule report	Mission description and notes
1962						
4	A 1	330 298	65	0	0	Geomagnetic, radiation, meteorological, biological data
7	A 1	369-210	65	0	0	Do.
9	A 1	358 301	65	0	0	Meteorological data.
1963 15	A 1	371-173	65	0	0	Do.
1964						
45	A 2	327 206	64 9	0	0	Do.
65	A 2	342 210	65	0	0	Do.
1965						
92	A 2	353-212	65	0	0	Meteorological and biological data.
94	A 2	293-211	65	0	0	Biological data.
1966						
109	A 2	309-209	65	0	0	Do.
122	A-1	625-625	65	0	0	Weather satellite also doing infrared studies.
125	A 1-m	250-250	65	0	0	Vehicle test also testing an ion-orientation system
134	A 2	319 214	65	0	0	Proton, electron, radiation counters.
136	A 1	305 198	64 6	0	0	Do.
1967						
143	A 1	302 204	65	0	0	Charged particles studies.
184	A 1	635 635	81 2	0	0	Weather satellite also doing ionospheric plasma studies.
1968						
208	A 2	305 207	65	P	C	Gamma flux and x-ray measurements.
224	A 2	270 200	51 8	0	0	Atmospheric composition and luminescence.
228	A-2	259 206	51 6	P	C	Ionizing radiation including cosmic rays.
232	A 2	352 202	65	0	0	Passive microwave radio telescope.
243	A 2	319 210	71 3	P	C	Do
251	A 2	270 198	65	M	0	Gamma flux radio astronomy
1969						
264	A 2	330 219	70	M	0	Extragalactic radio sources.
274	A 2	323 213	65	0	0	Neutral and ion atmospheric composition
279	A 2	280 194	51 8	0	0	Ion orientation test.
280	A 2	272 206	51 6	M	0	Charged particles and meteorology.
293	A 2	270-208	51 8	P?	C	Pickaback probably failed to separate.
309	A 2	384-203	65 4	P	C	Possible repeat of Kosmos 208 mission.
317	A 2	302 209	65 4	M	0	Charged particles measurements

TABLE 11.—IDENTIFIABLE OR POSSIBLE USE OF THE A-1, A-2, AND F-2 LAUNCH VEHICLES FOR KOSMOS SCIENTIFIC AND SUPPLEMENTAL PAYLOADS—Continued

Year and Kosmos No	Launch vehicle	Apogee and Perigee	Inclination	Pickaback or Maneuvering engine	RAE Capsule report	Mission description and notes
1970						
368	A-2	421-212	65	P	C	Biological and radiation studies.
384	A-2	314-212	72.9	P	C	Passive microwave radio telescope.
1971						
410	A-2	300-207	65	P	C	Particle flux, excess radiation measurements.
428	A-2	271-208	51.8	P	C	X-ray spectrometer, gamma flux, electron flux, cosmic ray measurements.
443	A-2	325-211	65.4	P	C	Particle flux and excess radiation measurements.
470	A-2	272-195	65.4	P	C	Mapping, geodesy, Earth resources.
1972						
477	A-2	328-212	72.9	P	C	Particle flux and excess radiation measurements.
484	A-2	236-203	81.3	P	C	Solar radiation and cosmic ray study.
490	A-2	310-212	65.4	P	C	High energy electron flux and cosmic rays.
502	A-2	284-206	65.4	P	C	Mapping, geodesy, Earth resources.
518	A-2	330-208	72.9	P	C	Science?
525	A-2	292-208	65.4	P	C	Do.
541	A-2	371-242	81.4	P	C	Mapping, geodesy, Earth resources.
1973						
552	A-2	337-211	72.9	P	C	Science?
555	A-2	253-216	81.3	P	C	Do.
561	A-2	317-215	65.4	P	C	Gamma ray telescope for galactic studies.
576	A-2	356-212	72.9	P	C	Mapping, geodesy, Earth resources.
596	A-2	310-211	65.4	P	C	
616	A-2	355-214	72.9	P	C	Do.
1974						
629	A-2	315-202	62.8	P	C	Science?
635	A-2	350-212	72.9	P	C	Do.
664	A-2	364-212	72.9	P	C	Mapping, geodesy, Earth resources.
669	A-2	244-210	81.3	P	C	Helium-cooled sensors.
692	A-2	315-201	62.8	P	C	Science?
693	A-2	271-215	81.3	P	C	Mapping, geodesy, Earth resources.
1975						
720	A-2	283-223	62.8	P	C	Do.
721	A-2	241-210	81.3	P	C	Science?
728	A-2	350-211	72.8	P	C	Plasma electrojet accelerator test.
731	A-2	313-207	65	P	C	Gamma ray telescope for galactic studies.
747	A-2	309-197	62.8	P	C	Science?
759	A-2	281-234	62.8	P	C	Mapping, geodesy, Earth resources.
769	A-2	331-211	72.9	P	C	Science?
776	A-2	310-203	62.8	P	C	Do.
780	A-2	298-206	65	P	C	Do.
784	A-2	252-216	81.3	P	C	Do.
1976						
811	A-2	361-212	72.9	P	C	Mapping, geodesy, Earth resources.
815	A-2	254-218	81.3	M	C	
817	A-2	347-178	65	M	C?	
833	A-2	335-189	62.8	M	C?	
835	A-2	338-180	65	M	C?	
837	A-2	342-189	62.8	M	C?	
848	A-2	325-214	62.8	P	C	Science?
852	A-2	354-179	65	M	C?	
855	A-2	366-212	72.9	P	C	Mapping, geodesy, Earth resources.
856	A-2	322-210	65	P	C	Science?
865	A-2	350-212	72.9	P	C	Do.
1977						
[illegible]	A-2	[illegible]	[illegible]	M	[illegible]	
898	A-2	258-[illegible]	81.[illegible]	P	C	[illegible]
912	A-2	257-219	81.4	P	C	Earth resources.
914	A-2	327-210	65	P	C	Science?
916	A-2	[illegible]	62.8	P	[illegible]	Do.

TABLE 11.—IDENTIFIABLE OR POSSIBLE USE OF THE A-1, A-2, AND F-2 LAUNCH VEHICLES FOR KOSMOS SCIENTIFIC AND SUPPLEMENTAL PAYLOADS—Continued

Year and Kosmos No	Launch vehicle	Apogee and Perigee	Inclination	Pickaback or Maneuvering engine	RAE Capsule report	Mission description and notes
948	A-2	265-217	81.4	P	C	Earth resources.
966	A-2	316-210	65	P	C	Science?
973	A-2	348-210	71.4	P	C	Do
1978						
988	A-2	363-210	72.8	P	C	Mapping, geodesy, Earth resources.
989	A-2	354-178	65	M	C?	
999	A-2	376-180	71.4	M	C?	
1004	A-2	311-213	62.8	P	0	Science?
1010	A-2	257-218	81.4	M	C	
1032	A-2	249-218	81.4	P	C	Do.
1033	A-2	268-223	81.4	P	C	Earth resources.
[illegible]	A-2	353-212	72.9	P	C	Mapping, geodesy, Earth resources.
1061	A-2	333-211	62.8	P	C	Science?
1069	A-2	290-244	62.8	P	C	Mapping, geodesy, Earth resources.
1979						
1070	A-2	316-214	62.8	P	C	Science?
1099	A-2	274-224	81.4	P	C	Earth resources.
1102	A-2	288-222	81.4	P	C	Do
1105	A-2	281-223	81.4	P	C	Do.
1106	A-2	264-222	81.4	P	C	Do.
1107	A-2	328-209	72.9	P	C	Science?
1108	A-2	272-224	81.3	P	C	Earth resources.
1113	A-2	350-180	65	M	C	
1115	A-2	263-222	81.4	P	C	Do.
1119	A-2	267-222	81.3	P?	0	Pickaback failed to separate
1123	A-2	266-221	81.4	P	C	Earth resources.
1139	A-2	357-212	72.9	P	C	Mapping, geodesy, Earth resources.
1980						
1180	A-2	295-240	62.8	P	C	Science?
1201	F-2	274-220	82.3	P	C	Earth resources.
1207	F-2	282-218	82.3	P?	0	Do
1211	F-2	261-215	82.4	P	0	Mapping, geodesy, Earth resources.
1212	F-2	275-[illegible]	82.3	P	C	Science?

Notes

1 This table includes launches in the A class (and a few recent flights which may use the F-2) whose primary payload is of the design of the military reconnaissance photographic recoverable type. The flights selected for inclusion are those which seem to carry a supplemental payload which is often for scientific purposes. Manned precursor flights and those wholly dedicated to biology are excluded. A very few other nonrecoverable flights are included where the experiment listed was clearly supplemental. In summary, the biological experiment exceptions are Kosmos 110, 605, 690, 782, 936, and 1129, with the latter 5 each carrying a pickaback capsule. The nonrecoverable flights with supplemental experiments are Kosmos 122, 125, and 184.

2 The Soviet Union has identified supplemental experiments, usually after the fact in scientific literature, frequently in the early years, and since then only sporadically, with none after 1975. From 1968 on, most but not all of these supplemental payloads separated a pickaback capsule toward the end of the flight. These separated parts have not been acknowledged by the Soviet Union, although they are tracked by Western facilities. Occasionally it is hard to distinguish between a pickaback payload and a small maneuvering engine which may also be cast off late in the flight. The distinction was relatively easy to make when certain characteristic telemetry could be read by G.E. Perry of the Kettering Group, but newer signal formats now obscure these data. Repetitive patterns and analogy have had to be used to sort out some of the flights on which there is not direct evidence. It is possible there are a few misidentifications within the table, and one can only hope errors in included flights approximately match other errors in excluded flights. The absence of identified supplemental payloads mentioned by Soviet sources may mean either that they are slow to publish findings, or that the supplementals are now military in nature.

3 The table groups flights by year, shows the launch vehicle, with apogee, and perigee in kilometers and inclination in degrees. To the extent possible the missions are classified as to whether they separated nothing (0), a pickaback (P), or a maneuvering engine (M). The adjacent column for reference gives the Royal Aircraft Establishment (RAE) assessment as to whether a capsule (pickaback) (C) was or was not (0) distinguished. Finally, such mission notes are provided as ultimately reported by the U.S.S.R., or as determined by analogy with other flights.

Sources: Basic flight data are from Soviet TASS bulletins. Mission listings have emerged gradually over the years in scattered Soviet scientific literature. Classifications have been aided by drawing on the Royal Aircraft Establishment Revised Tables of Earth Orbital Satellites (several volumes, Farnborough, Hants.) and on the identification work of G.E. Perry of the Kettering Group, further supplemented by surmises based upon maneuvers and separated objects plus analogies.

PRECURSOR FLIGHTS WITHIN KOSMOS

Tables 12 and 13 provides a checklist of Kosmos flights which almost certainly were engineering tests and development flights leading to operational systems which carried other names. This class in some small degree may overlap space failures.

TABLE 12.—PRECURSOR FLIGHTS CALLED KOSMOS

Meteor A-1	Voskhod A-2	Soyuz A-2	STP A-2	Soyuz-T A-2	Venera A-2-e	Molniya A-2-e	Zond A-2-e	Manned Lunar Landing A-2-m
44	47	133	638	670	21	41	159	379
58	57	140	672	772				398
100		186		869				434
118		188		1001				
122		212		1074				
144		213						
156		238						
184		455						
206		573						
226		613						
		656						

TABLE 13.—PRECURSOR FLIGHTS CALLED KOSMOS

Reentry D-1	Tug? D-1	Statsionar D-1-e	Zond D-1-e	Manned Lunar Landing D-1-m
881-882	929	637	146	382
997-998			154	
1100-1101				

FLIGHT MISSION FAILURES DISGUISED AS KOSMOS

Table 14 is a list of mission failures which received Kosmos names. Their missions are discussed in the appropriate sections of the three volumes of this report, so will not be described here.

TABLE 14.—PROBABLE MISSION FAILURES DESIGNATED KOSMOS

Soyuz A-2	Mars A-2-e	Venera A-2-e	Luna A-2-e	Interkosmos C-1	Salyut D-1	Luna D-1-e	Mars D-1-e	FOBS F-1-r
(04/05/75)	(10/10/60)	02/04/61	01/04/63	(06/04/75)	557	300	419	09/17/66
	(10/14/60)	08/25/62	60			305		11/02/66
	10/24/62	09/01/62	111					
	11/04/62	09/12/62						
		27						
		96						
		167						
		359						
		482						

Notes

This table groups Kosmos precursor flights and failures by probable program and launch vehicle. It provides no more than a handy checklist, with details, analysis, and qualifications provided in the appropriate sections of program description.

SUMMARY OF KOSMOS FLIGHTS

Table 15 summarizes those Soviet flights which have carried the name Kosmos, have carried other names, or remain unacknowledged, by various classes of missions for the time span 1957–80.

TABLE 15.—SUMMARY RECAPITULATION OF KOSMOS, OTHER NAME, AND UNACKNOWLEDGED SOVIET SPACE PAYLOADS BY MISSION CATEGORY, 1957–80

Mission	Kosmos	Other name	Unacknowledged	Total
Primarily civilian:				
Launch platforms		1	202	203
Science	42	44	80	166
Engineering		2		2
Vehicle tests	14	2		16
Communications	6	98		104
Weather	15	36		51
Geodesy	18			18
Earth resources	3			3
Man-related	38	21		59
Manned		51		51
Lunar man-related	3	5		8
Lunar manned				
Moon (automated)	4	24	6	34
Inward planets	6	13	8	27
Outward planets	1	9	6	16
Subtotal	150	306	302	758
Primarily military:				
Reconnaissance	501			501
Calibration	119			119
Elint ferret	67			67
Navigation	57			57
Tactical communications	247			247
Early warning	20			20
FOBS	16		2	18
Ocean surveillance	26			26
Targets for ASAT	16			16
ASATS	17			17
Subtotal	1,086		2	1,088
Total	1,236	306	304	1,846

Notes

1 Mission categories are as defined in tables 10 and 11 in part 1 of the study. The total column also matches the numbers given in those tables.

2 The identification of Kosmos, other named missions, and unmanned flights is summarized from appendix III of part 1 of the study.

THE INTERKOSMOS PROGRAM

OVERVIEW OF INTERKOSMOS SCIENTIFIC MISSIONS

The Interkosmos program was established in 1967 as a mechanism for fostering cooperation in space research between the Soviet Union and its allies. The original members, in addition to the Soviet Union itself, were Bulgaria, Cuba, Czechoslovakia, the German Democratic Republic, Hungary, Mongolia, Poland, and Romania. In 1979, Vietnam became the 10th member.

Table 16 lists the scientific Interkosmos flights, as well as other flights which have included international participation. Countries outside the Soviet Bloc have also cooperated with the Soviet Union in space science (primarily France and Sweden, and in three instances, the United States). As shown in the table, the Interkosmos scientific flights originally used the B-1 vehicle from Kapustin Yar. The exceptions were Interkosmos 6, a recoverable flight launched from Tyuratam with the A-2 vehicle, and Interkosmos 8, which was launched from Plesetsk. Cooperative flights from Plesetsk had occurred in 1968 and 1970, but since the site was not open even to Soviet Bloc technicians, the payloads were labeled as Kosmos. Beginning with Interkosmos 10, the C-1 vehicle, with higher capabilities, replaced the smaller B-1, for launches both from Plesetsk and Kapustin Yar.

TABLE 16.—SUMMARY LIST OF SOVIET ORBITAL AND ESCAPE FLIGHTS WHICH CARRIED EXPERIMENTS OF OTHER NATIONS

Launch date	Flight name	Launch vehicle	Launch site	Apogee	Perigee	Inclination	Hardware participating nations
1968							
Dec. 19	Kosmos 261	B-1	PL	670	217	71	Bulgaria, Czech., G.D.R., Hungary, Poland, Romania, U.S.S.R.
1969							
Oct 14	IK 1	B-1	KY	640	260	48.4	Czech., G.D.R., U.S.S.R.
Dec 25	IK-2	B 1	KY	1,200	206	48.4	Bulgaria, Czech., G.D.R., U.S.S.R.
1970							
June 13	Kosmos 348	B-1	PL	680	212	71	Bulgaria, Czech., G.D.R., Hungary, Poland, Romania, U.S.S.R.
Aug 7	IK 3	B-1	KY	1,320	207	49	Czech., U.S.S.R.
Oct 14	IK-4	B-1	KY	668	263	48.5	Czech., G.D.R., U.S.S.R.
Nov. 10	Luna 17	D-1-e	TT	Lunar lander			France, U.S.S.R.
1971							
May 28	Mars 3	D-1-e	TT	Mars orbiter			France, U.S.S.R.
Dec 2.	IK-5	B-1	KY	1,200	205	48.4	Czech., U.S.S.R.
Dec. 27.	Oreol 1	C-1	PL	2,500	4	74	France, U.S.S.R.
1972							
Apr 4	MAS-1	A-2-e	PL	39,260	480	65.6	France, (pickaback on U.S.S.R.)
Apr. 7	IK-6	A-2	TT	256	203	51.8	Czech., Hungary, Mongolia, Poland, U.S.S.R.
June 29	Prognoz 2	A-2-e	TT	200,000	550	65	France, U.S.S.R.
June 30	IK 7	B-1	KY	568	267	48.4	Czech., G.D.R., U.S.S.R.
Nov 30	IK 8	B 1	PL	679	214	71	Bulgaria, Czech., G.D.R., U.S.S.R.
1973							
Jan 8	Luna 21	D-1-e	TT	Lunar lander			France. U.S.S.R.
Apr 19	IK 9	B-1	KY	1,551	202	48.5	Czech., Poland, U.S.S.R.
Aug 5	Mars 6	D 1-e	TT	Mars lander			France, U.S.S.R.
Aug 9	Mars 7	D 1-e	TT	Mars lander			France, U.S.S.R.
Oct 31	AIK 10	C 1	PL	1,477	264	74	Czech., G.D.R., Ukraine, U.S.S.R.
Dec 26	Oreol 2	C-1	PL	1,995	407	74	France, U.S.S.R.
1974							
May 17	IK 11	C 1	KY	526	484	50.7	Czech., G.D.R., U.S.S.R.
Oct 31	IK 12	C 1	PL	708	264	74.1	Bulgaria, Czech., G.D.R., Hungary, Romania, U.S.S.R.
1975							
Mar 27	IK 13	C-1	PL	1,714	296	83	Czech., U.S.S.R.
Apr 19	Aryabat	C-1	KY	619	563	50.7	India, U.S.S.R.

TABLE 16.—SUMMARY LIST OF SOVIET ORBITAL AND ESCAPE FLIGHTS WHICH CARRIED EXPERIMENTS OF OTHER NATIONS—Continued

Launch date	Flight name	Launch vehicle	Launch site	Apogee	Perigee	Inclination	Hardware participating nations
June 5	MAS-2	A-2-e	PL	40,890	450	63	France (pickaback on U.S.S.R.)
July 15	Soyuz 19	A-2	TT	225	223	51.8	U.S.S.R., U.S.A.
Nov. 25	Kosmos 782	A-2	PL	405	227	62.8	U.S.S.R., Czech., U.S.A., France, Romania.
Dec. 11	IK-14	C-1	PL	1,707	345	74	U.S.S.R., Czech., Bulgaria, Hungary.
1976							
June 19	IK-15	C-1	PL	521	487	74	U.S.S.R., Hungary, G.D.R., Poland, Czech.
July 27	IK-16	C-1	KY	523	465	50.6	U.S.S.R., G.D.R., Czech., Sweden.
Sept. 15	Soyuz 22	A-2	TT	280	250	65	U.S.S.R., G.D.R.
1977							
Mar 29	Kosmos 900	C-1	PL	523	460	83	U.S.S.R., G.D.R., Czech.
June 17	Sneg 3	C-1	KY	519	459	50.7	France.
Aug. 3	Kosmos 936	A-2	PL	419	224	62.8	U.S.S.R., Czech., U.S.A., France.
Sept 22	Prognoz 6	A-2-e	TT	197,900	498	65	U.S.S.R., France, Czech.
Sept. 24	IK-17	C-1	PL	519	468	83	U.S.S.R., Hungary, Romania, Czech.
Sept 29	Salyut 6	D-1	TT	360	345	51.6	U.S.S.R., G.D.R.
1978							
Jan 10	Soyuz 27	A-2	TT	350	330	51.6	U.S.S.R., France.
Mar 2	Soyuz 28	A-2	TT	353	334	51.6	U.S.S.R., Czech.
June 27	Soyuz 30	A-2	TT	360	336	51.6	U.S.S.R., Poland.
Aug 26	Soyuz 31	A-2	TT	354	339	51.6	U.S.S.R., G.D.R.
Sept. 9	Venera 11	D-1-e	TT	1.11 a.u.	0.70 a.u.	2.3	U.S.S.R., France.
Sept 14	Venera 12	D-1-e	TT	1.11 a.u.	0.70 a.u.	2.3	U.S.S.R., France.
Oct 24	IK-18	C-1	PL	786	407	83	U.S.S.R., Hungary, G.D.R., Poland, Romania, Czech.
Oct. 24	Magion	C-1	PL	786	407	83	Czech. (pickaback on U.S.S.R.)
Oct 30	Prognoz 7	A-2-e	TT	202,965	483	65	U.S.S.R., France.
1979							
Jan 25	Meteor 1 29	A 1	TT	656	628	98	U.S.S.R., G.D.R.
Feb 25	Soyuz 32	A-2	TT	338	308	51.6	U.S.S.R., France.
Feb 27	IK-19	C-1	PL	996	502	74	U.S.S.R., Bulgaria, Hungary, Poland, Czech.
Apr 10	Soyuz 33	A-2	TT	353	292	51.6	U.S.S.R., Bulgaria.
May 13	Progress 6	A-2	TT	340	327	51.6	U.S.S.R., Bulgaria.
June 7	Bhaskara	C 1	KY	557	512	50.7	India.
Sept. 25	Kosmos 1129	A-2	PL	406	226	62.8	U.S.S.R., Czech., U.S.A., France.
Nov 1	IK-20	C-1	PL	523	467	74	U.S.S.R., Hungary, G.D.R., Romania, Czech.
1980							
May 26	Soyuz 36	A-2	TT	355	328	51.6	U.S.S.R., Hungary
July 23	Soyuz 37	A-2	TT	355	343	51.6	U.S.S.R., Vietnam, G.D.R.
Sept. 18	Soyuz 38	A-2	TT	355	343	51.6	U.S.S.R., Cuba, G.D.R., Bulgaria.

TABLE .RY LIST OF SOVIET ORBITAL AND ESCAPE FLIGHTS WHICH CARRIED EXPERIMENTS OF OTHER NATIONS—Continued

Launch date	Flight name	Launch vehicle	Launch site	Apogee	Perigee	Inclination	Hardware participating nations
Dec. 25	Prognoz 8	A-2-e	TT	199,000	550	65	U.S.S.R., Poland, Sweden, Czech.

Notes

1 This table is limited to flights which reached Earth orbit or escape; it does not include launch failures or suborbital rocket probes. Cooperative flights of the latter type have included the Vertical series for Interkosmos, the Araks conjugate point experiments launched by the French on Eridan at Kerguelen, and a variety of lesser experiments at such places as the Thumba range in India and at Wallops Island, VA.

2 The abbreviation IK refers to Interkosmos. MAS refers to "minor autonomous satellite," called SRET by the French. Oreol is called Aureole by the French. Ariabat is called Aryabhata by the Indians; Bhaskara is called Bhaskar by the Indians. Sneg is called Signe by the French.

3 Launch sites are identified as TT—Tyuratam, PL—Plesetsk, or KY—Kapustin Yar. Apogee and perigee are in kilometers, inclination in degrees.

4 In addition to the hardware contributing nations listed, usually in the case of Interkosmos flights and biological flights, other members of Interkosmos either read out data and/or interpret the results.

Sources: Flight data are from Soviet TASS bulletins. Launch sites and vehicles are from app. A. Participating country lists are from TASS or review articles in the Soviet general press.

Interkosmos 15 introduced a new satellite bus, the Automatic Unified Orbital Station [AUOS], which carries a larger payload and an advanced computer system capable of processing data before transmission to Earth. All launches in the Interkosmos series since then have used the AUOS design, with the exception of Interkosmos 16.

INTERKOSMOS AND RELATED FLIGHTS: 1968–75

Kosmos 261 and 348

Kosmos 261 was launched on December 19, 1968, to study the upper atmosphere and the nature of the northern lights, including study of electrons and protons in the upper atmosphere, the electronics of super thermal energy, and changes in the density of the atmosphere during auroral activity. Seven Soviet Bloc countries participated in the mission. However, only Soviet technicians and scientists were allowed at Plesetsk for the launch of Kosmos 261 and the follow-on launch of Kosmos 348 in 1970. Plesetsk was not opened to non-Soviet observers until 1972.

Interkosmos 1

Interkosmos 1 was launched on October 14, 1969, carrying equipment from the German Democratic Republic, the Soviet Union, and Czechoslovakia. Bulgaria, Hungary, Poland, and Romania participated in analysis of the data. The purpose of the flight was to study the effects of solar ultraviolet and x ray radiation on the structure of the upper atmosphere.

Interkosmos 2

Launched December 25, 1969, Interkosmos 2 carried instruments from Bulgaria, Czechoslovakia, the German Democratic Republic, and the Soviet Union. Cuba joined the list of countries sharing in data analysis. The flight studied the concentration of electrons and positive ions in the Earth's ionosphere, the electronic temperature near the payload, and the mean electron concentration between the payload and the ground receiving stations. The principal tracking stations included two in Poland and seven in the Soviet Union.

Interkosmos 3

Interkosmos 3 was launched on August 7, 1970, with Czechoslovakian and Soviet experiments. It studied the interactions between solar activity and the radiation belts of Earth, and the nature and spectrum of low frequency electromagnetic oscillations in the upper ionosphere.

Interkosmos 4

The next in this series of satellites was Interkosmos 4, launched on October 14, 1970. Equipment from the German Democratic Republic, Czechoslovakia, and the Soviet Union was carried. The mission was basically a repeat of Interkosmos 1, but with more sensitive instruments for measuring a wider range of energies.

Interkosmos 5

Interkosmos 5 was launched on December 2, 1971, and continued the work of Interkosmos 3 in the study of charged particles and low frequency electromagnetic waves. Czechoslovakia and the Soviet Union provided the equipment, and synoptic readings were taken at ground stations in Czechoslovakia, the Soviet Union, and the German Democratic Republic.

Interkosmos 6

Launched on April 7, 1972, Interkosmos 6 was the only Interkosmos payload to use the large A-1 launch vehicle which could carry a larger payload and permitted payload recovery. Interkosmos 6 studied the chemical composition and energy spectrum of cosmic rays. The photoemulsion unit and ionization calorimeter used for these studies were made in the Soviet Union according to specifications developed in Hungary, Mongolia, Poland, Romania, Czechoslovakia and the Soviet Union. A meteorite experiment was also carried and was developed and manufactured in Hungary, Czechoslovakia and the Soviet Union. The payload was recovered after 4 days.

Interkosmos 7

Interkosmos 7 was launched on June 30, 1972, and continued the studies begun on Interkosmos 1 and 4 on short wave radiation and hard x rays from the Sun. It carried equipment made in the German Democratic Republic, Czechoslovakia and the Soviet Union, and observed many solar flares not seen from Earth stations.

Interkosmos 8

Launched on December 1, 1972, Interkosmos 8 was the first Interkosmos satellite launched from Plesetsk. The satellite carried an ion trap and Langmuir probe made in Bulgaria, a Mayak transmitter and recorder from the German Democratic Republic, a high frequency probe from Czechoslavakia, and an ionospheric gas discharge counter and other equipment from the Soviet Union. Specialists from the participating East European countries were allowed at Plesetsk for the first time to observe the launch.

Interkosmos 9/Kopernik 500

The ninth launch in the Interkosmos series, Kopernik 500, named in honor of the 500th birthday of Copernicus, came on April 19, 1973. Its mission was to measure solar radiation and the ionosphere, and the equipment was developed by the Soviet Union and Poland (the country where Copernicus was born). The telemetry system was Czech and data were received at ground stations in the Soviet Union and Czechoslovakia.

Interkosmos 10

Interkosmos 10 was the first in the Interkosmos series to use the C-1 launch vehicle and was launched from Plesetsk on October 30, 1973. The payload carried East German and Soviet equipment to determine the concentration and temperature of ionospheric electrons, Soviet apparatus to measure magnetic field variation, and Czech equipment to study low frequency electric oscillations of plasma.

Interkosmos 11

Interkosmos 11 was launched May 17, 1974, and was the first C-1 Interkosmos launch from Kapustin Yar. The satellite continued studies of the solar ultraviolet and x ray radiation and took measurements in the upper atmosphere. The experiments were provided by the German Democratic Republic, the Soviet Union and Czechoslovakia.

Interkosmos 12

Launched on October 31, 1974, Interkosmos 12 continued studies of the atmosphere and ionosphere and flow of micrometeorites. It carried a micrometeorite analyzer made by Hungary, the Soviet Union and Czechoslovakia, an East German instrument to measure electron concentration, Bulgarian and Soviet equipment to measure positive ion and electron temperature, Soviet and Czech mass spectrometers, a Romanian mass spectrometer calibrator, an East German memory unit and a Czech Mayak radio transmitter.

Interkosmos 13

Interkosmos 13 was launched March 27, 1975, to study dynamic processes in the magnetosphere and the polar ionosphere. It carried equipment from the Soviet Union and Czechoslovakia.

Interkosmos 14

Launched on December 11, 1975, Interkosmos 14 carried equipment from Bulgaria, Hungary, Czechoslovakia, and the Soviet Union to study low-frequency electromagnetic fluctuations in the magnetosphere and to measure micrometeoritic intensity.

INTERKOSMOS 15—TEST OF THE NEW AUOS PAYLOAD

Interkosmos 15 was launched on June 19, 1976, from Plesetsk with a C-1 vehicle. The satellite was placed in a 521 by 487 km orbit, inclined at 74°, with a period of 94.6 minutes. This mission tested a new payload called the automatic universal orbital station [AUOS] which carried a greater volume and weight of scientific equipment than previous Interkosmos payloads, and could be controlled at any point in its orbit, not just over the ground command stations. A new unified telemetric system [YeTMS], for digital data transmission, was also tested. The YeTMS used an advanced computer designed to process the data before it was transmitted to ground stations.[11] Hungary, Poland, the German Democratic Republic, Czechoslovakia, and the Soviet Union jointly developed and produced the telemetric system. Data were received in Hungary, East Germany, Czechoslovakia, the Soviet Union, and later in Bulgaria and Cuba.[12] The AUOS and YeTMS introduced a new generation of Interkosmos satellites.

INTERKOSMOS 16

Interkosmos 16 was launched with a C-1 vehicle on July 27, 1976, from Kapustin Yar into a 523 by 465 km orbit inclined at 50.6°, with a 94.4 minute period. The satellite continued studies of ultraviolet and x ray radiation from the Sun and the effect of this radiation on the Earth's upper atmosphere.

In addition to the Soviet Bloc countries, Sweden participated in this mission by providing equipment for research on the polarization of resonance lines in the far ultraviolet region. Equipment on Interkosmos 16 included: a multichannel photometer made in Czechoslovakia for research on solar flares in the energy region 0.3 to 60 KeV, a photometer made in east Germany to measure the concentration of molecular oxygen in the Earth's upper atmosphere, a spectropolarimeter made in Sweden for research on solar flares, and a Soviet made spectroheliograph for research on x ray linear spectrum flares and active formation on the Sun.[13] Simultaneous ground observations of the Sun were made by Bulgaria, Hungary, the German Democratic Republic, Czechoslovakia and the Soviet Union.

Interkosmos 16 was the last in a series of launches for solar research, which had included Interkosmos 1, 4, 7, 11, 16, and Vertikal 4.

INTERKOSMOS 17

Interkosmos 17 was launched September 24, 1977, from Plesetsk. A C-1 vehicle put the satellite into a 519 by 468 km orbit inclined at 83°, with a period of 94.4 minutes. Experiments on the satellite continued research begun on Interkosmos 3, 5, and 13 on the relationship between solar activity and the Earth's upper atmosphere. It carried equipment developed by the Soviet Union, Hungary, Romania, and Czechoslovakia to study the distribution of energetic charged and neutral particles and micrometeorite streams in near-Earth space.[14]

Interkosmos 17 used the AUOS and YeTMS equipment tested on Interkosmos 15. Equipment included differential proton and electron detectors for registering weak cosmic rays, both made by the

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[11] Izvestiya, Moscow, June 22, 1976, p 4
[12] Pravda, Moscow, June 21, 1976, p 1
[13] Yezhegodnik Bolshoy Sovetsky Entsiklopedii, 1977 Moscow P 495.
[14] Krasnaya Zvezda, Sept 27, 1977, p 3

Soviet Union; a device for measuring the temperature of ionospheric electrons, made by the Soviet Union and Czechoslovakia; a spectrometer for high energy electrons made by the Soviet Union and Romania; a device for measuring neutron streams with low-level energy made by the Soviet Union and Czechoslovakia; and a device for measuring isotopes of solar streams captured by the Earth's radiation fields, made by Czechoslovakia. Other equipment gathered data relative to manned space flight including an electric analyzer made in the Soviet Union and Czechoslovakia for measuring low energy protons and electrons, and two dosimeters developed by Czechoslovakia, Bulgaria and the Soviet Union for measuring radiation absorption by different materials.[15]

INTERKOSMOS 18 AND MAGION

Interkosmos 18 was a dual launch of the Interkosmos 18 satellite plus the smaller Magion satellite developed by Czechoslovakia (see figure 12). The two spacecraft were launched on October 24, 1978, by a C-1 launch vehicle from Plesetsk.

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[15] Yezhegodnik Bolshoy Sovetskoy Entsiklopedii. 1978. p 490

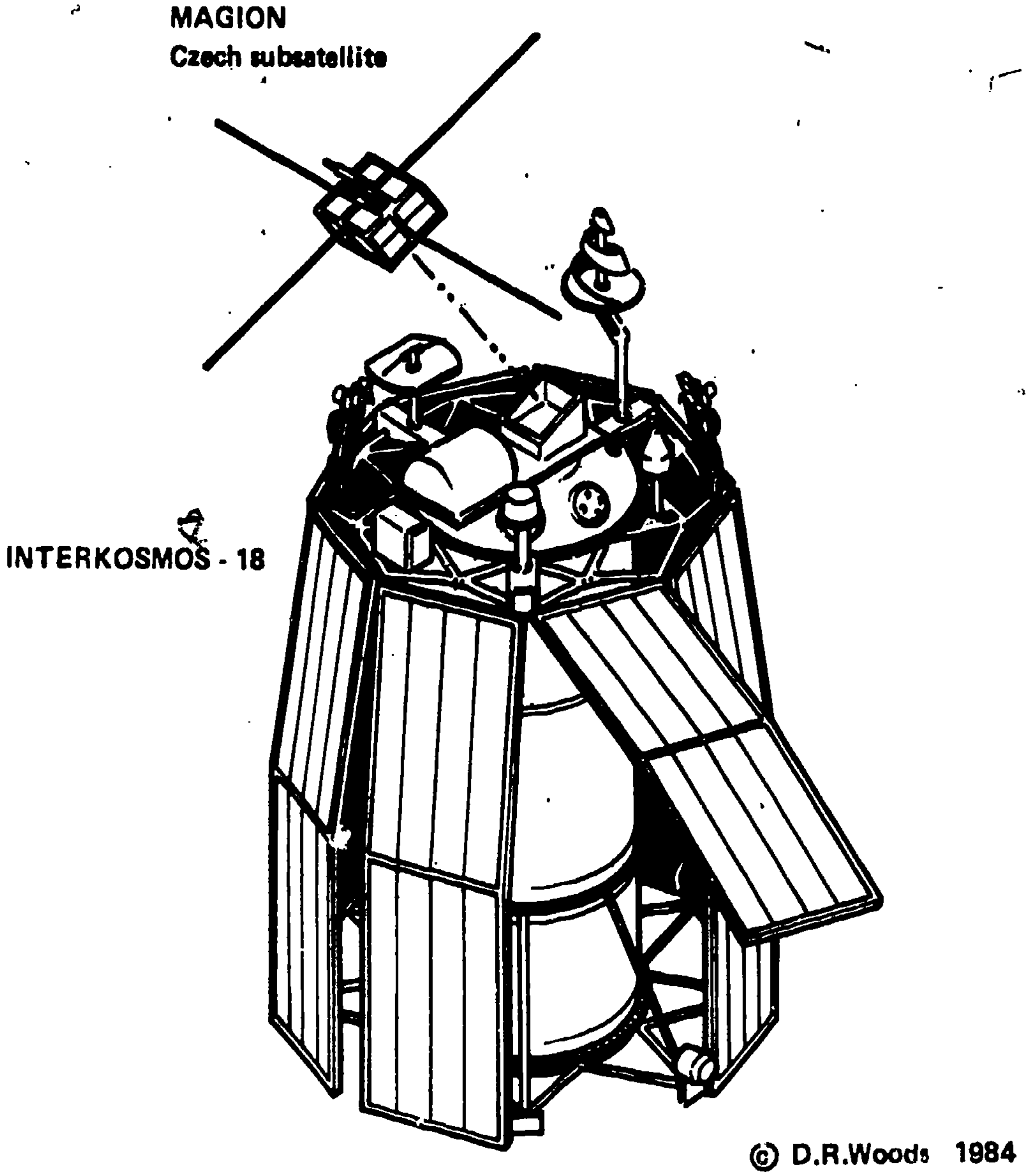

FIGURE 12.—The current Interkosmos satellite series (from Interkosmos-15 on) has used a standardized design consisting of eight deployable solar panels around a cylindrical core. They are either Earth-oriented with a gravity gradient boom, or are solar oriented as was Interkosmos-18, shown here. The small Czech subsatellite was separated on the 21st day in orbit.

The two satellites went into a 786 by 407 km orbit inclined at 83°, with a 96.4 minute period. Interkosmos 18, which used an AUOS bus and a YeTMS system, conducted studies of the electromagnetic relationships between the Earth's magnetosphere and ionosphere and of low-frequency radio waves in the circumterrestrial plasma. The onboard equipment included a three component SG-R magnetometer made in Romania and the Soviet Union; a charged particle electrostatic analyzer made in the Soviet Union to measure the energy spectra and the distribution of electrons and protons; a low-frequency analyzer made in Czechoslovakia and the Soviet Union to measure the components of electromagnetic fields; a Soviet-made plasma electric parameter analyzer; Langmuir probes made in East Germany to measure density and temperature of plasma electrons; a device made by the Soviet Union and Czechoslovakia to measure electron temperatures; a flat ion trap made in East Germany to determine ion temperatures, concentration and mass composition; and a mass spectrometer made in Czechoslovakia and the Soviet Union.

The 15 kilogram Magion satellite separated from Interkosmos 18 on November 14, 1978. Magion flew in a trajectory very close to the parent satellite and conducted similar studies of low-frequency electromagnetic fields in near-Earth space. Magion carried a new experiment called "MAGIK" (for MAGnetic InterKosmos). Comparisons between the measurements made by Interkosmos 18 and Magion allowed scientists to separate temporal factors from spatial factors. Magion was the first artificial satellite to be developed and built by Czechoslovakia; only the electric power and heat regulatory systems were built by the Soviets.[16] Transmissions from Magion at 137 MHz consisted of pulses which were interrupted by musical tones at time when the satellite was transmitting to ground stations in Czechoslovakia.

INTERKOSMOS 19

Interkosmos 19 was launched on February 27, 1979, carrying equipment developed in Bulgaria, Hungary, Czechoslovakia, and the Soviet Union. The satellite was launched by a C-1 launch vehicle from Plesetsk into a 996 by 502 km orbit, inclined at 74°, with a period of 99.8 minutes. Experiments continued research on the Earth's ionosphere, wave processes and radio propagation in ionospheric plasma. Interkosmos 19 carried a Soviet designed ionospheric station and an instrument to study photoelectric pulses and electron showers, a Bulgarian optical spectrometer to record atmospheric glows in polar and equatorial regions, a Bulgarian instrument to study electron concentration and temperatures in the upper atmosphere, a Soviet Mayak transmitter, a Polish radio spectrometer, and a Soviet plasma analyzer. High and low frequency probes developed by Czechoslovakia for measuring electron temperatures and the distribution of thermal electrons were also carried.

Data from Interkosmos 19, Interkosmos 18, Magion, and two American satellites were jointly analyzed by scientists in the Soviet

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[16] Izveztiya, Moscow Nov. 16, 1978, p. 3.

Union, the United States, and Japan. The Soviets combined the results from Interkosmos 18, Magion, and Interkosmos 19 in a program they called "International Investigations of the Magnetosphere." [17]

From January to April 1979, the Soviet Union joined Sweden, France, and Austria in conducting the synchronous auroral multiple balloon observation [SAMBO] experiment for further magnetospheric research. The four countries launched balloons and rockets from Kiruna, in northern Sweden, and data from the satellites, balloons, and rockets were coordinated with ground observations for mapping the geophysical parameters of plasma, magnetic and electrical fields at different altitudes.

INTERKOSMOS 20

Interkosmos 20 was launched from Plesetsk on November 1, 1979, by a C-1 vehicle into a 523 by 467 km orbit, inclined at 74°, with a period of 94.4 minutes. The primary mission was oceanographic research, and the spacecraft served as an information relay between buoys and platforms placed in various parts of the ocean, and the control center at Tarusa. Data was gathered on zones of biological productivity in the ocean and sea surface temperatures. The equipment was developed in Hungary, the German Democratic Republic, Czechoslovakia, and the Soviet Union. Interkosmos 20 was the first applications satellite in the Interkosmos series. [18]

THE PROGNOZ PROGRAM

The Prognoz series was developed to conduct solar research for scientific purposes, as well as for weather reporting and solar flare prediction for planning manned flights (see figure 13). Kosmos 159, launched May 17, 1967, may have been the first Soviet solar research satellite, but no results were noted in the literature, and the flight was not repeated.

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[17] Izvestiya, Moscow, Mar. 1, 1979, p. 3.

[18] Izvestiya, Moscow, Nov. 3, 1979, p. 3.

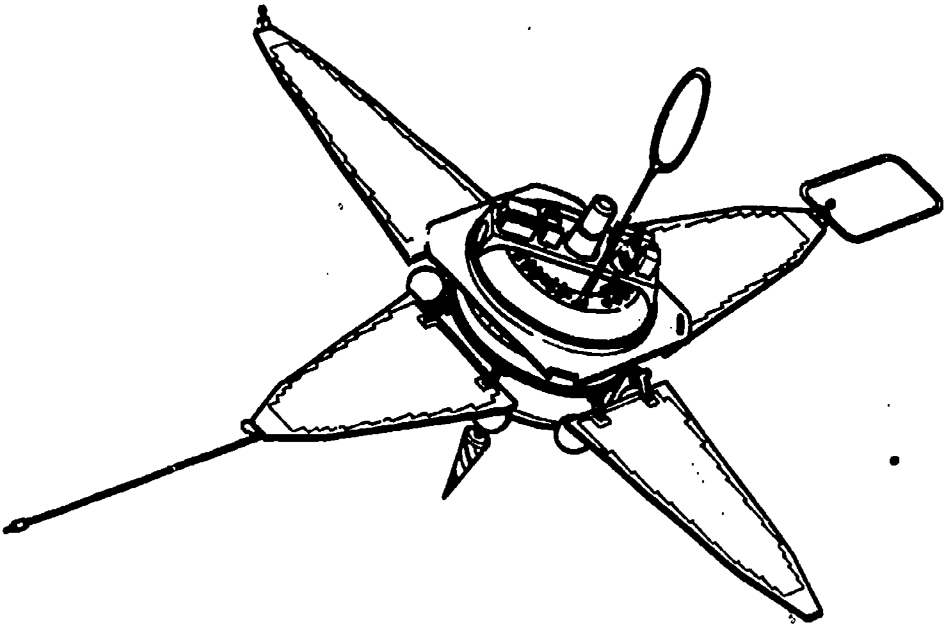

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FIGURE 13.—Prognoz 1-8 were 0.7 to 0.9 metric ton satellites launched into highly elliptical orbits with periods of just under 100 hours. They were used for geophysical studies.

PROGNOZ 1-4

Prognoz 1 was launched from Tyuratam on April 14, 1972, by an A-2-e booster into a highly elliptical orbit (200,000 by 950 km), inclined at 65°. The satellite, with a mass of 845 kilograms, carried equipment for studies on corpuscular, gamma, x ray, and solar plasma interactions with the magnetosphere.

The spin stabilized spacecraft was a pressurized cylinder with hemispherical ends, four solar panels, and various external instruments and antennas. Experiments included an x ray spectrometer and proportional counter for the 1,500 to 30,000 electron volt range; a scintillation spectrometer for gamma rays in the 30,000 to 350,000 electron volt range; a spectrometer for measuring the proton flux in the 1 to 35 million electron volt range; a Cherenkov counter for measuring electrons in the 40,000 to 140,000 electron volt range; a scintillation spectrometer for measuring protons in the 30,000 to 210,000 electron volt range; a device for measuring the solar wind; a device for studying radio emissions in the 1.6-8 kiloHertz range and the 100-700 kiloHertz range; a magnetometer; orientation detectors; and dosimeters.

Prognoz 2, launched June 29, 1972, apparently was a repeat of the earlier flight. In addition to the equipment flown on Prognoz 1, it carried a French solar wind experiment.

Prognoz 3 was launched on February 15, 1973, and carried instrumentation similar to its predecessors.

A report in early 1974 implied that all three payloads were still active, and that the devices were calibrated periodically, but a report on February 16, 1974, as Prognoz 3 began its second year, mentioned only that satellite as still being active. At that time, there had been 160 radio sessions with Prognoz 3.

Almost 3 years after the launch of Prognoz 3, the program was renewed with the launch of Prognoz 4 on December 22, 1975. The satellite was described as being similar to its predecessors, except that its mass was a little greater (905 kilograms).

PROGNOZ 5

Prognoz 5 was launched on November 25, 1976, into a 199,000 by 510 km orbit, inclined at 65°, with a period of 95 hours and 13 minutes. It carried instruments for studying corpuscular and electromagnetic radiation from the Sun and solar plasma, and magnetic fields in near-Earth space to determine the effect of solar activity on the interplanetary medium and on the Earth's magnetosphere. Two French experiments measured the electron flux in solar wind, and helium and hydrogen concentrations. Prognoz 5 carried a radio transmitter which operated at 928.4 MHz.[19]

PROGNOZ 6

Prognoz 6 was launched September 22, 1977, and was virtually identical to earlier Prognoz flights. The spacecraft was launched into a 197,900 by 498 km orbit, inclined at 65°, with a period of 94 hours and 48 minutes.

In addition to the types of experiments carried on earlier Prognoz missions, this spacecraft carried the French Galatika 1 experiment for research on galactic ultraviolet rays.[20] The Soviet Union and France also performed joint research on the interplanetary environment, the concentration of hydrogen and natural helium, and the corpuscular content of solar plasma.[21] Czechoslovakia contributed equipment for studying the proton and electron content of solar flares. Similar data on solar flares was collected by Prognoz 5 and Venera 11 and 12. The integral peak flux and density dependence was analyzed in relation to kinetic energy. Prognoz 6 found that the number of high energy protons undergoing stochastic particle propagation depended on the speed of the shock wave.[22] Prognoz 6 detected a rare solar flare with energy levels higher than 500 MeV,[23] and gathered gamma ray data in coordination with Prognoz 7, Signe 3 and Venera 11 and 12 as a part of the Signe II MP program (Solar International Gamma Ray and Neutron Experiments).[24] Both Prognoz 6 and 7 carried RGS–1M radiation measuring instruments which had an analyzer of fine temporal structure for the study of solar x-ray flares. Prognoz 6 also carried an AYaKS spectrometer which detected nine ion-rich events associat-

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[19] Tass. Nov 25, 1976. 1427 GMT

[20] Tass, Sept 22, 1977. 1140 GMT.

[21] Yezhegodnik Bolshoy Sovetskoy Entsiklopedii, 1978, Moscow, p. 489.

[22] International Cosmic Ray Conference, Paris, France, 1981. Conference Papers, vol. 3, p. 69-72.

[23] Kosmicheskiye Issledovaniya, vol 18, No. 5. Pp. 801-804.

[24] CNES. Space Science Instrumentation, vol. 5, December 1970, p. 73-79.

ed with solar flares. Ion-rich events occurred when there was a wide range in the kinetic energies of accelerated nuclei.[25]

PROGNOZ 7

On October 30, 1978, Prognoz 7 was launched to continue the work of previous Prognoz flights. The spacecraft was placed into a 202,965 by 483 km orbit, inclined at 65°, with a period of 98 hours and 8 minutes. Equipment included a Swedish electromagnetic analyzer [PROMICS], a Soviet magnetometer, a Czech x-ray photometer, and the French Galaktika 2 instrument for recording spectra of ultraviolet radiation sources. Czechoslovakia, Bulgaria, and the Soviet Union cooperated on a set of experiments on the distribution of ion streams in the solar wind.

Prognoz 7 also carried equipment developed by the Soviet Union and France to conduct research on x-ray and gamma radiation, corpuscular emissions from the Sun and high energy particles in the upper atmosphere of the Earth.[26] Data analysis from the gamma ray experiments on Prognoz 7 was coordinated with observations by similar experiments on the U.S. Pioneer Venus Orbiter, the Soviet Venera 11 and 12 spacecraft, and International Sun-Earth Explorer-3 [ISEE-3], a joint program involving the United States and the European Space Agency. On April 6, 1979, Prognoz 7 and other spacecraft recorded a gamma ray burst with a single spike of 0.2 seconds duration and a spectral feature near 400 KeV.[27]

In coordination with Venera 11 and 12, Prognoz 7 studied the effects of solar wind propagation in the interplanetary plasma. The instruments used to measure the solar wind's heavy ion content included an electrostatic ion analyzer in an SKS plasma spectrometer. The wind's parameters were measured at a velocity of 280 to 330 kilometers per second, with an ion concentration of approximately 8-40/cubic centimeters, proton temperatures of approximately 20,000 to 50,000 K, and alpha particle temperatures in the same range or lower. During the period of the study, a high concentration of heavy ions in the solar wind was noted.[28]

Prognoz 7 gathered data on the nature of the Earth's plasma mantle, particularly the high latitude boundary layer, which indicated that the northern component of the interplanetary magnetic field alters the upper layer structure of the plasma mantle. The inner part of the boundary was relatively unaffected.[29]

Prognoz 7 also studied the solar wind, with special emphasis on the region of interaction between the slow solar wind and a fast flux (possibly from a low-latitude coronal hole). Data showed that a boundary separated the region into a bow shock wave with a dense, hot, turbulent magnetoplasma and a reverse shock wave with a strong, regular magnetic field and a cold plasma. Momentum acquired by the slow wind in the bow wave is four times greater than the momentum lost by the fast flux in the reverse wave.[30]

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[25] Izvestiya Seriia Fizicheskaia, vol 45, April 1981, p 502-608.
[26] Yezhegodnik Bolshoy Sovetskoy Entisklopedii, 1979, Moscow. P. 457.
[27] Astrophysical Journal, vol 245, Apr. 15, 1981, pp. 263-266.
[28] Kosmicheskiye Issledovaniya, vol 18, No. 5. Pp. 761-766.
[29] Kosmicheskiye Issledovaniya, vol. 20, March-April 1982, pp. 289-296
[30] Kosmicheskiye Issledovaniya, vol 20, July-August 1982, pp. 566-571.

PROGNOZ 8

Prognoz 8 was launched on December 25, 1980, carrying instruments from the Soviet Union, Poland, Czechoslovakia, and Sweden. The spacecraft was placed into a 199,000 by 550 km orbit, inclined at 65°, with a period of 95 hours and 23 minutes. Its mission was to study the influence of the Sun's particle and electromagnetic radiation and plasma streams on interplanetary space and Earth's magnetrosphere.[31]

The equipment on Prognoz 8 included: a spectrometer made by the Soviet Union, a charged particle detector made by the Soviet Union and Czechoslovakia, two spectroanalyzers also made by the Soviet Union and Czechoslovakia, an ultralow energy spectrometer made by the Soviet Union and Poland, two magnetometers made by the Soviet Union, and an x-ray solar photometer made by the Soviet Union and Czechoslovakia,[32] and a PROMICS charged particle experiment (similar to the one on Prognoz 7) made by Sweden.[33]

The spacecraft returned data on solar wind interaction with the Earth's magnetosphere and on the structure of the boundaries of the magnetosphere. The Soviets hoped this information would contribute to an understanding of the ability of solar particles to penetrate spaceship cabins, and they use information on the Sun and the magnetosphere to forecast favorable times for launching spacecraft.[34]

THE SOVIET LUNAR PROGRAM

First Generation Lunar Flights

LUNA 1

At the end of 1958, the Soviets announced that their first lunar mission would come soon, and on January 2, 1959, Luna 1 was launched. The vehicle launched to the Moon had a total mass of 1,472 kilograms, which included the spacecraft itself, whose mass was 361.3 kilograms, plus the final stage of the carrier rocket, with a mass of 1,111 kilograms (see figure 14).

The payload included a few geophysical instruments in a spherical container, and a package of various metallic emblems with the Soviet coat of arms. Its high velocity, coupled with the inclusion of the Soviet emblems, led to the conclusion in the West that the spacecraft was intended to strike the Moon, but it missed its target, and flew by the Moon at a distance of 5,000 to 6,000 kilometers. Its orbit was deflected by lunar gravity, and it became the first artificial satellite of the Sun. Luna 1's batteries were depleted by January 5, when it was 600,000 kilometers from Earth. Yurity Gagarin acknowledged later that the mission had, in fact, been to strike the Moon.[35]

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[31] Tass. Dec 25. 1980 1613 GMT

[32] Yezhegodnik Bolshoy Sovetskoy Entsiklopedii, 1981. Moscow, p 479

[33] Grahn. Sven and Claes-Goran Borg The Sky is not the Limit: SSC and the Swedish Space Effort Stockholm Swedish Space Corp., 1982, p. 49.

[34] Tass. Feb. 18, 1981 1356 GMT

[35] Reuter, Moscow, July 29, 1961, quoting his letter to the magazine. Soviet Lithuania.

LUNA 2

On September 12, 1959, the Soviets launched Luna 2 in a second attempt to strike the Moon, and this time it was successful, hitting the Moon about 435 kilometers from its visible center the next day (see figure 14).

LUNA 3

A much more complex spacecraft operation was launched on October 4, 1959. Luna 3, referred to as an Automatic Interplanetary Station, flew past the Moon at about 7,000 kilometers (see figure 14). The spacecraft then stabilized itself and took pictures of the far side of the Moon, which had never been seen before. The photographs were developed on board, and then transmitted back to Earth in facsimile form on October 18 when the probe's barycentric orbit brought it close to the Earth again. A second attempt to transmit at a point closer to Earth was not accomplished.

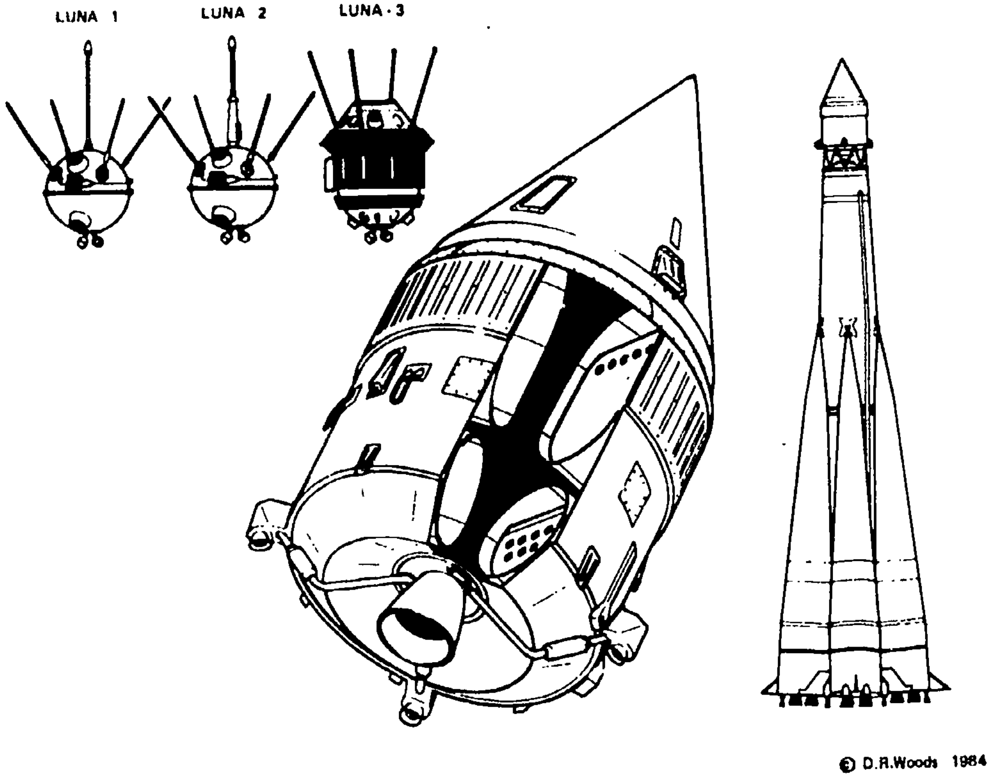

FIGURE 14.—The Luna-1, -2, and -3 spacecraft, launched in 1959, accomplished several spectacular firsts for the Soviet Union—Luna-1: first lunar fly-by and first solar orbit; Luna-2: first lunar impact; Luna-3: first photographs of Moon's far side.

The pictures were very indistinct, but through computer enhancement, the Soviets were able to prepare a tentative atlas of the far side of the Moon. Some individuals charged that the pictures were forgeries, but they were proven wrong when some of the same features eventually were found in later pictures taken by

U.S. Lunar Orbiter spacecraft. For example, Lunar Orbiter 4 found the Tsiolkovskiy crater originally discovered in the Luna 3 pictures.

Luna 3 was equipped with solar panels instead of batteries, so had a much longer active life than its predecessors. After 198 days in space, however, its orbit had brought the spacecraft through the Earth's atmosphere enough times that the orbit decayed through atmospheric drag.

SECOND GENERATION LUNAR FLIGHTS

CHANGE OF TECHNOLOGY

The first generation of lunar flights had used the A-1 launch vehicle for direct injection into flight toward the Moon, thereby limiting the amount of payload that could be carried to about 400 kilograms.

In 1960, a new upper stage was introduced for the planetary program which enabled the Soviets to increase the mass of the payload sent to the Moon to 1,400 kilograms, not including the weight of the escape rocket. (For further information on launch vehicles and upper stages, see part 1, chapter 1 of this report.) As a result, a more ambitious lunar exploration program could begin.

1963 LUNAR FLIGHTS—LUNA 4

The first improved lunar rocket was launched on January 4, 1963, but it failed to leave Earth orbit. The Soviets did not acknowledge the failure, and it went unannounced until the United States disclosed it in connection with five Soviet planetary failures also stranded in orbit in 1962.[36]

Luna 4, with a payload mass of 1,422 kilograms, was launched successfully on April 2, 1963. Unfortunately, it missed the Moon by 8,500 kilometers, and entered a barycentric orbit around the Earth.

1965 LUNAR FLIGHTS—KOSMOS 60, LUNA 5-8

On March 12, 1965, a lunar mission was launched, but it failed to leave Earth orbit. The Soviets designated it Kosmos 60.

Luna 5 was launched on May 12, but its retrorocket system failed, and it impacted the Moon in the Sea of Clouds.

Luna 6 was launched in June, but a midcourse correction maneuver failed and it missed the Moon by 160,000 kilometers. Although it may have gone into a barycentric orbit, it probably entered a heliocentric orbit.

Luna 7 was launched on October 4, but retrofire and cutoff occurred too early and it did not survive its impact in the Sea of Storms.

Luna 8 was launched on December 3, but this time retrofire was late, and it also did not survive impact in the Sea of Storms.

Throughout these flights, the Soviets never described their exact missions, but Western experts assumed that they were meant to make survivable landings on the Moon. The Soviets finally con-

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[36] Letter of June 6, 1963, from Ambassador Adlai E. Stevenson to the Secretary General of the United Nations

firmed this in 1966, after they had achieved successes with this type of mission.[37]

1966 LUNAR FLIGHTS—LUNA 9–13 AND KOSMOS 111

Luna 9

Luna 9 was launched on January 31, 1966, and a day later the Soviets announced that it was an attempt to make a soft landing on the Moon (see figures 15 and 16). This time they were successful, and at 21:45:30 hours Moscow time on February 3, 1966, Luna 9 became the first spacecraft to make a survivable lunar landing, setting down in the Sea of Storms at 7°8′ N., 64°22′ W.

The Soviets released more details about the spacecraft now that they had a success. The payload had a mass of 1,538 kilograms, and consisted of three basic parts: the automatic lunar station itself which was to make the survivable landing on the Moon; motor units for making midcourse corrections in trajectory and for braking on approach to the Moon; and compartments containing equipment to control the flight.

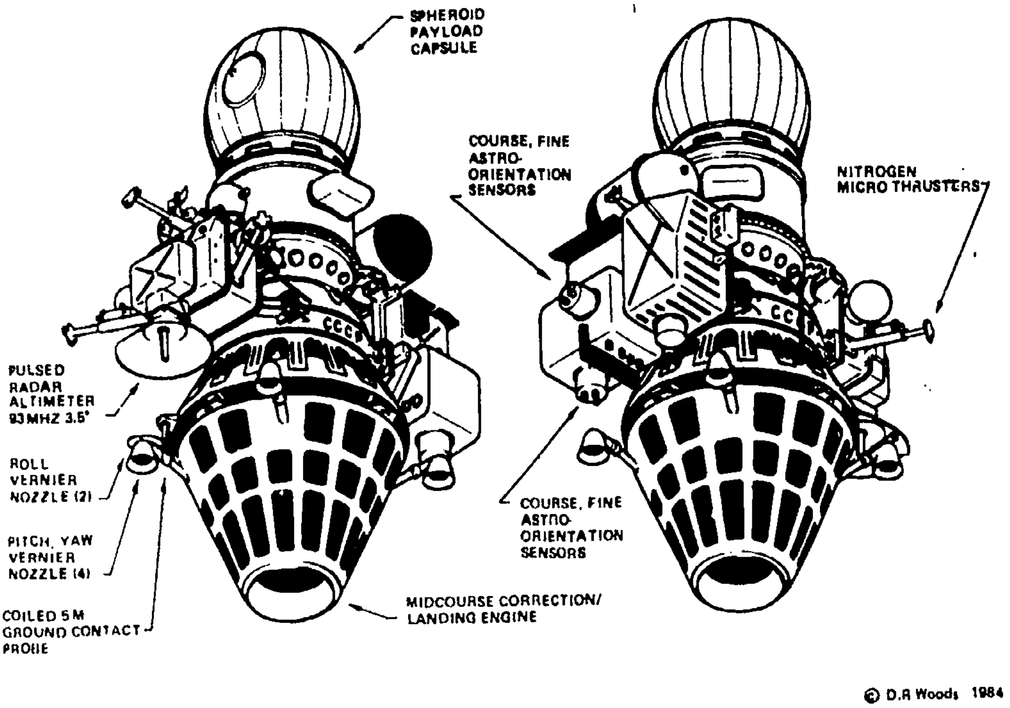

FIGURE 15.—Luna-9 made the first successful soft lunar landing in 1966. The standardized core was fitted with two strap-on side modules that were cast off just before the start of powered descent. A 5-meter long ground contact probe shut off the engine and separated the capsule at the surface.

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[37] Tass, Apr 1, 1966 0756 GMT

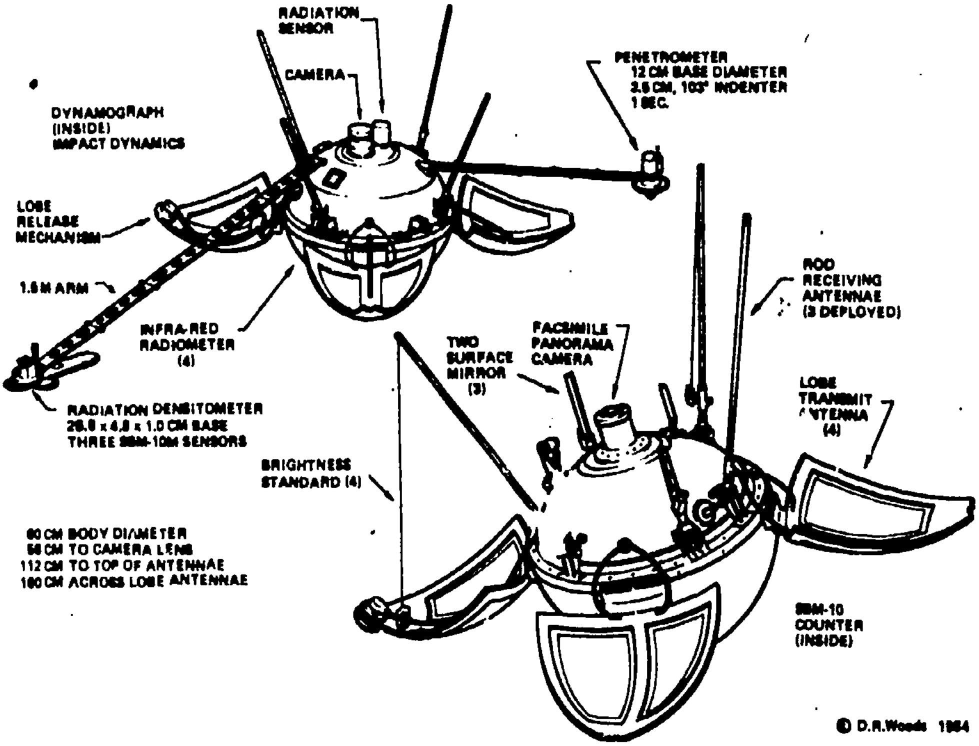

FIGURE 16.—Only two soft lunar landing attempts were successful using the A-2-e launch vehicle: Luna 9 and Luna 13. Using battery power, they returned several full panoramas of their immediate surroundings on the lunar surface.

The lunar station had a total mass of about 100 kilograms, and was a hermetically sealed container with radio equipment, a program timing device, thermal regulation systems, scientific experiments, power sources, and a television camera (which weighed 1.5 kilograms). The spacecraft had shock absorbers to soften the impact upon landing, after which four petals which had protected the television system were opened outwards. The extended petals stabilized the craft on the surface. Spring controlled antennas could then flip into their operating positions, and the TV camera's rotatable mirror system enabled a panoramic survey of the surroundings.

The propulsion unit consisted of a rocket chamber with a pumping system for the propellants, flight stabilization controls and fuel tanks. The control compartments contained a complex of gyroscopic and control instruments, electronic-optical devices for orientation of the station in flight, a system for radio control in orbit, a program timing device, a radio system for the soft landing, power sources, and orientation motors.

At an altitude of about 8,300 kilometers, the craft assumed a vertical position in relation to the Moon, and maintained this position using sensors. At 75 kilometers (45 seconds before touchdown), the two compartments which contained the braking motors were jettisoned, and the retrorocket was activated. Just at touchdown, the automatic station separated from its motor, which then landed nearby. The equipment was deployed in 4 minutes 10 seconds, whereupon radio transmissions began, but it took about 7 hours for the television transmission to start.

The Soviets did not immediately release the pictures from Luna 9, but by hooking up a press wire facsimile machine, observers at Britain's Jodrell Bank radio observatory were able to make the first views public. The British picture lacked calibration data, however, and distorted the scale in one dimension. Although the Soviets were reportedly irritated at this unauthorized release, it helped establish their credibility.

The batteries were exhausted on February 6 after seven radio sessions totalling 8 hours 5 minutes. Three television sessions were held, two on February 4 and one on February 5, which provided a panoramic view of the lunar surface when assembled. The pictures showed rocks near the spacecraft, and the horizon at a distance of 1.5 kilometers. The Soviets stated that each picture series involved nine positions of the mirror.

Kosmos 111

Kosmos 111 was launched on March 1, 1966, but failed to leave Earth orbit. It is generally assumed that it was intended to be a lunar orbiter mission, but it could have been another lander.

Luna 10

On March 31, 1966, Luna 10 was launched, and this spacecraft was similar to Luna 9 except that the lander section was replaced by an orbiter and this became the first spacecraft to enter lunar orbit (see figure 17). The payload mass sent to the Moon was 1,600 kilograms, but once the spacecraft entered lunar orbit, the main propulsion unit was separated from the payload, leaving a payload with a mass of 245 kilograms. The initial lunar orbit was about 1,017 by 350 km, inclined at 71°54′ to the lunar Equator, with a period of 178.25 minutes.

Luna 10 was not equipped with an imaging system, but had a variety of instruments to return data on meteorite impacts on the spacecraft, thermal characteristics of the Moon, the Moon's magnetic field (if any), and irregularities of the Moon's gravitational field. The instruments included a meteorite particles recorder; a gamma spectrometer for measuring energy levels between 0.3 and 4 million electron volts; a magnetometer with three channels at reciprocally right angles; instruments for studing solar plasma; a recorder for infrared emissions from the Moon; and devices to measure radiation conditions in the Moon's environment. Gravitational studies were conducted based on tracking of the satellite as it orbited the Moon. By programming certain semiconductors to oscillate at particular frequencies, the Soviets arranged for the spacecraft to send back music ("The Internationale") to Earth.

The spacecraft was battery-powered, and using the electricity carefully, the payload was kept active until May 30, 1966. By this time, there had been 460 orbits of the Moon, and 219 active transmissions of data. By placing the payload in an orbit inclined at 72°, it was able to take readings over much of the surface over a period of time.

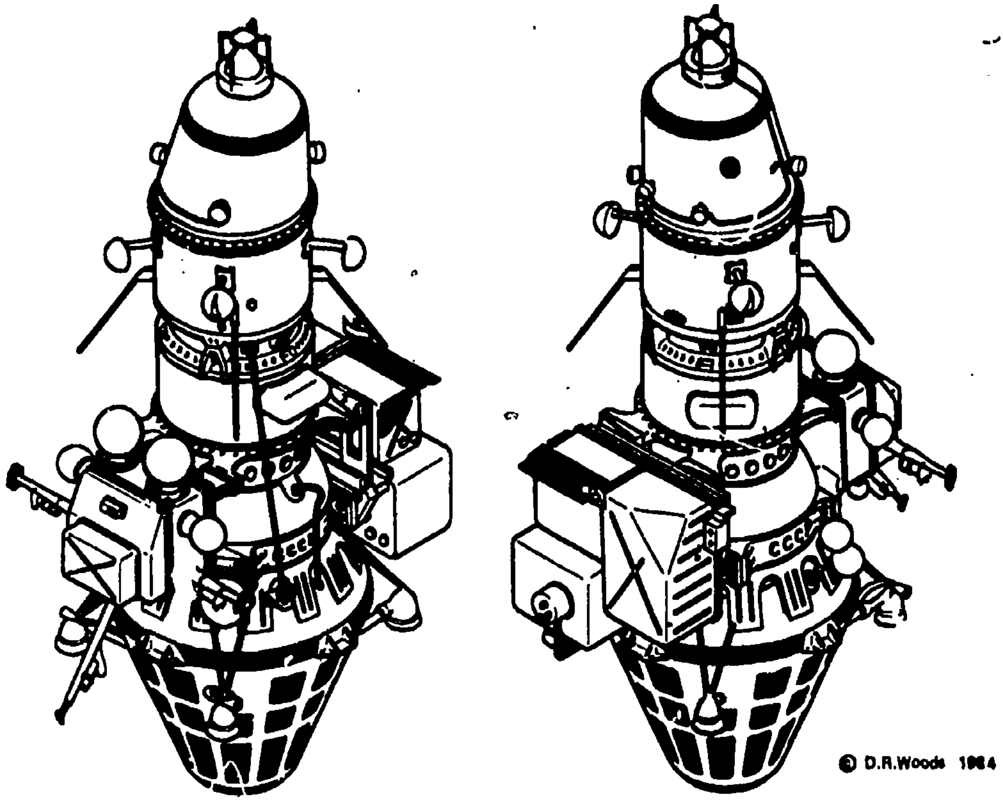

FIGURE 17.—Luna 10 was the first satellite to orbit the Moon.

Data from Luna 10 showed that the Moon had a magnetic field about 0.001 percent the strength of that around Earth. Cosmic ray background levels were expectedly high, and the natural radiation of lunar rocks resembled that of basalt on Earth, although some of the radiation was believed to come from interactions with cosmic rays, rather than natural radioactivity of the rocks. The intensity of meteoritic impacts in lunar orbit was higher than in interplanetary space.

Luna 11

Luna 11 was launched on August 24, 1966, with a total payload mass of 1,640 kilograms, and it entered lunar orbit on August 28. The orbit was 1,200 by 600 km, inclined at 27°, with a period of 178 minutes.

Less was said about this flight in the Soviet media, and most of the early bulletins simply reported that communications were stable, and the number of orbits that had been accomplished. A month after launch, the mission was described as studying gamma and x ray emissions to determine more exactly the chemical composition of the Moon, gravitational anomalies, the concentration of meteoritic streams, and the intensity of hard corpuscular radiation near the Moon. The Soviets announced that the batteries had been depleted by October 1, 1966, after 137 radio sessions, and 277 orbits of the Moon.

No picture has ever been released of this Luna 11, and very little has been published about the findings. An early Soviet announcement vaguely implied that this was improved version of Luna 10, and signals intercepted by Jodrell Bank suggested that it was intended to return television pictures from lunar orbit.[38] This combination of facts suggested that Luna 11 resembled Luna 12, the next in the series, but did not accomplish all of its planned functions.

Luna 12

On October 22, 1966, Luna 12 was launched, and it entered lunar orbit on October 25. The initial orbit was announced as 1,740 by 100 kilometers, with an "equatorial" inclination and a period of 205 minutes. A later announcement said it was 1,200 by 133 kilometers, inclined at 10°.

On October 29, Luna 12 returned pictures of the lunar surface by radio facsimile. No mass was announced for this payload, but it was probably close to that announced for Luna 11. The appearance of Luna 12 differed from Luna 10 mostly because of the large radiator covering much of the instrument compartment (see figure 18).

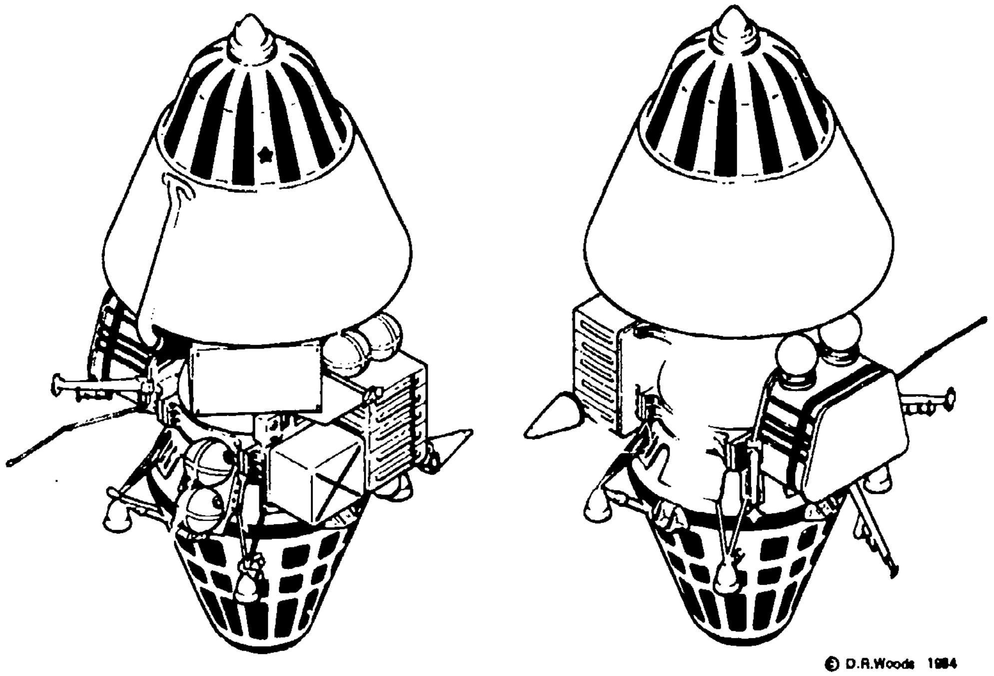

FIGURE 18.—Luna-12 retained the two side modules for use in lunar orbit. One was for altitude control and the other for photo-TV apparatus to survey the lunar surface. It transmitted for 85 days using on-board batteries.

Pictures apparently were first transmitted to Earth at a fast data rate for a quick scan at the deep space tracking facility, and then retransmitted at a slower rate to maximize the detail for more thorough study later. The pictures contained 1,100 lines of scan, to give a maximum resolution of 15 to 20 meters. The number

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[38] Reuters, Moscow, Aug. 30, 1966, reported in the New York Times, Aug. 31, 1966.

of pictures that were taken is unknown, and only two or three have been made public. Radio transmissions ended on January 19, 1967, after 602 orbits of the Moon, and 302 radio sessions with Earth.

Luna 13

Luna 13 was launched on December 21, 1966, and landed on the Moon on December 24 in the Sea of Storms at 18°52′ N., 62°0.3′ W. Radio transmissions began 4 minutes after landing, and television transmissions commenced the next day. Luna 9 had landed in a mountainous area, while Luna 13 landed in a lunar seabed, but the surroundings were much the same. Luna 13 carried two telescoping arms that could swing outward and down from the craft to thump the lunar surface so sensors could judge its density and firmness. The arm could develop a pressure of 23.3 kilograms per square meter to force a rod into the soil. The lunar soil was decribed as having a depth of 20 to 30 centimeters, with the general density at the landing site not more than 1 gram per cubic centimeter, much less than typical Earth soil. Little radioactivity in the soil was detected. It was also determined that the lunar surface reflects about 25 percent of particles of space radiation which fall upon it, which was consistent with the Luna 9 data.

The Soviets revealed that the camera and television system required about 100 minutes to transmit an entire panoramic view of the surroundings. There were no further reports, and it is likely that the batteries were depleted before the end of December 1966.

1968 LUNAR FLIGHT—LUNA 14

Luna 14 was launched on April 7, 1968, 16 months after Luna 13. On April 10, the spacecraft entered an 870 by 160 km lunar orbit, inclined at 42°, with a period of 160 minutes. No mass figures and no pictures were released, but the experiments most closely resembled those of Luna 10. Two years later, the Soviets announced that Luna 14 and Luna 12 had carried out tests of the type of electric motor used to provide locomotion on Lunokhod 1 in 1970.

THIRD GENERATION LUNAR FLIGHTS

The payload mass that could be carried on the second generation lunar missions was still too small to carry out the types of missions the Soviets had in mind. The introduction of the D class launch vehicle with added upper stages provided the opportunity to do more (see figures 19 to 21).

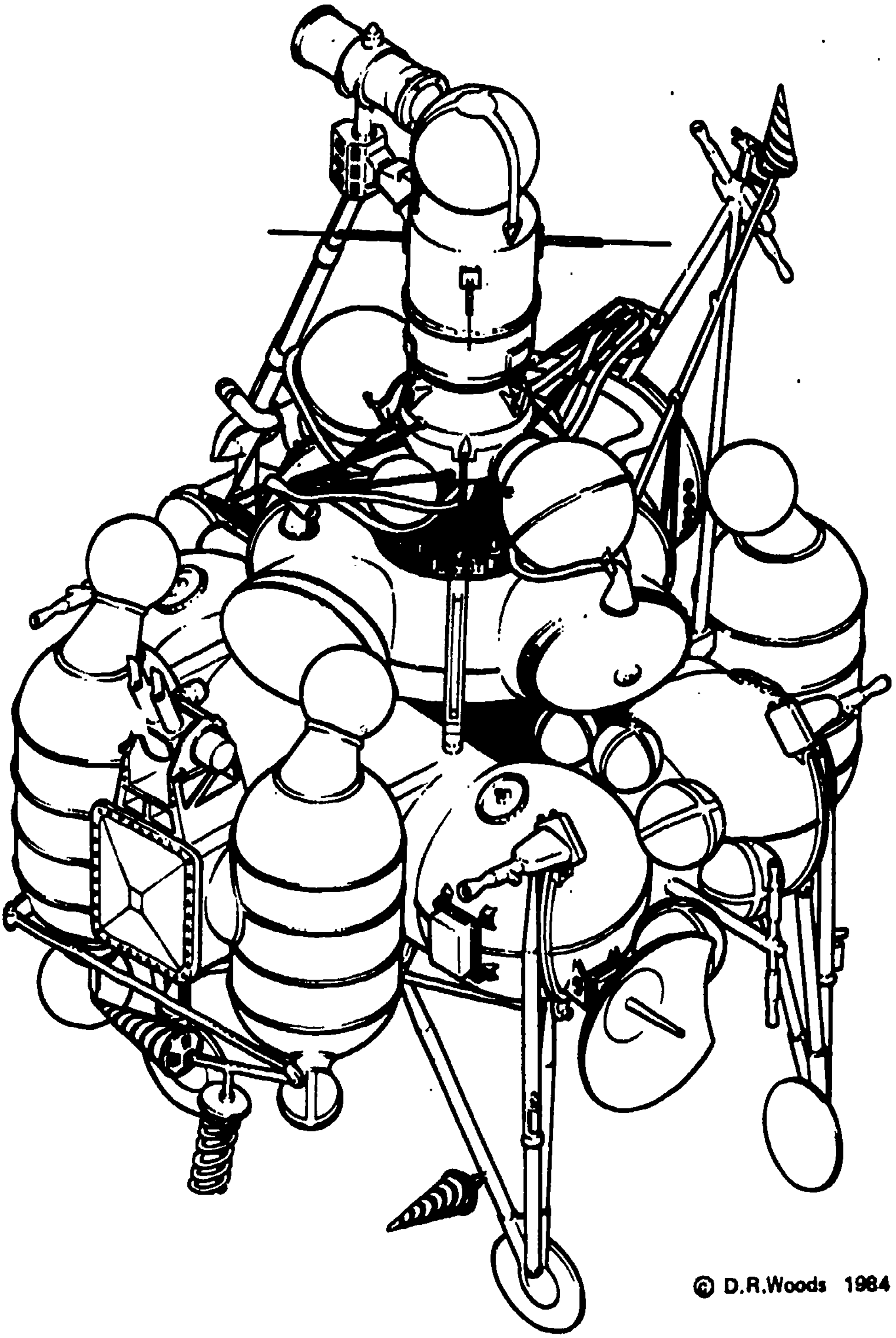
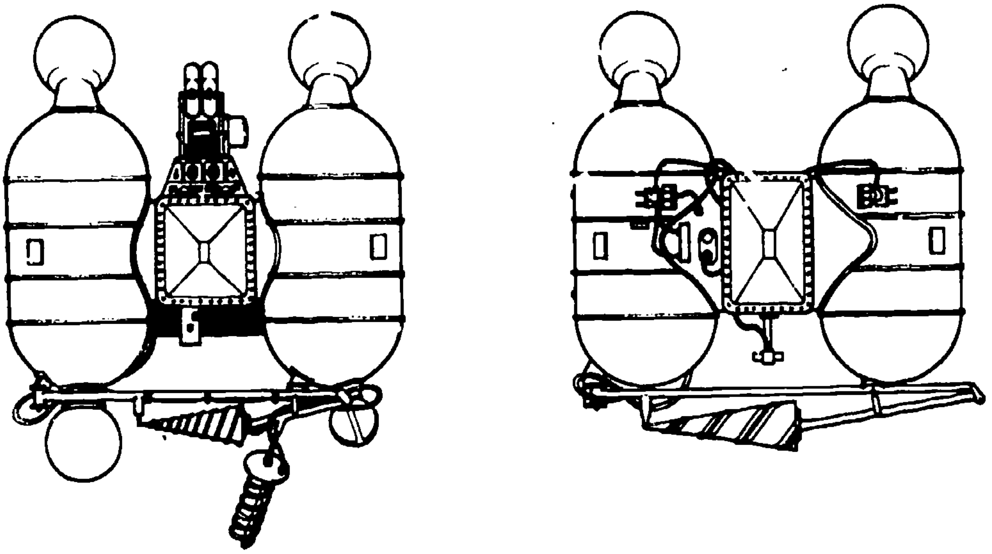


FIGURE 19.—The Luna soil sample return spacecraft consisted of two engines and three sets of propellant tanks. The cylindrical lunar orbit insertion stage tanks were cast off before descent. Four large spherical tanks in the base were used for descent to the lunar surface. The ascent stage used three spherical tanks to return the spherical reentry capsule to Earth.



INSERTION STAGE CAST-OFF MODULE-1
FITTED WITH ASTRO-ORIENTATION SENSORS

INSERTION STAGE CAST-OFF MODULE-2
FITTED WITH NITROGEN MICRO-THRUSTERS

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FIGURE 20.—The heavy Luna series all use cylindrical propellant tanks for lunar orbit insertion. Once in orbit, if the spacecraft is scheduled to descend to the surface, they are cast off, to reduce total weight.

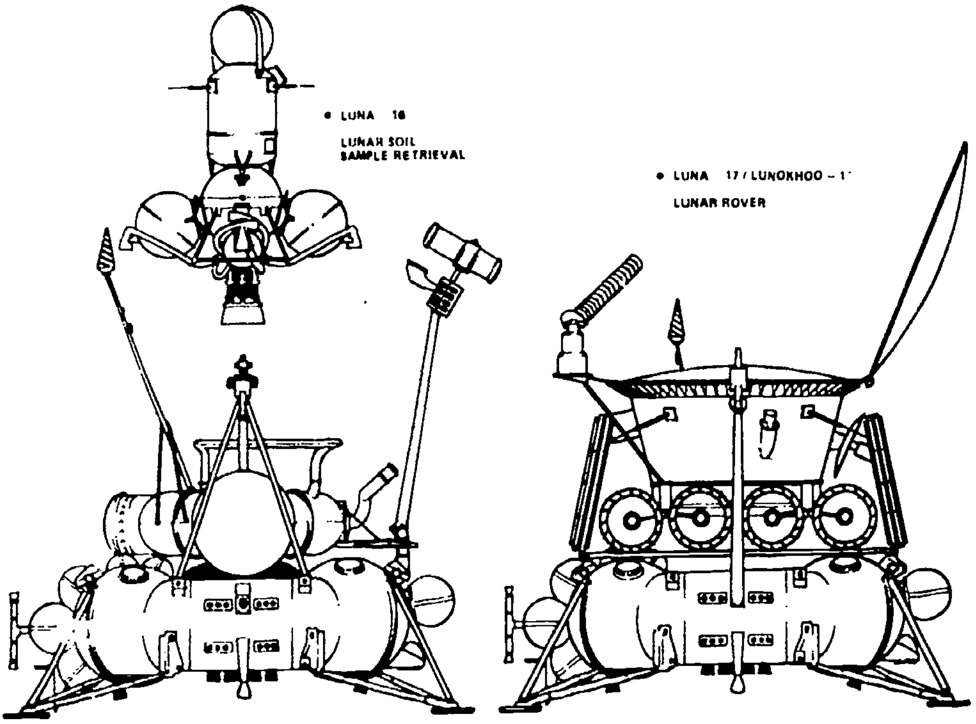

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FIGURE 21.—The standardized heavy Luna spacecraft can deliver a soil sample return payload (i.e., Luna-16), on a lunar rover vehicle (i.e., Luna-17/Lunokhod-1) to the surface.

1969 LUNAR FLIGHTS—LUNA 15, KOSMOS 300 AND KOSMOS 305

In late June and early July 1969, 6 months after the United States had successfully placed three men in lunar orbit with the Apollo 8 mission, and just before the Apollo 11 mission was to be launched, there were rumors in Moscow that the Russians were about to do something spectacular related to lunar exploration. Several accounts suggested that a launch of the big "G" vehicle was imminent, and there were rumors that a launch was made but it failed to reach orbit.

Luna 15

Despite this possible setback, a different kind of important launch came on July 13 when Luna 15 was launched using the D-1-e vehicle. The spacecraft entered luner orbit on July 17, just 2 days ahead of the U.S. Apollo 11 mission. Although there is no conclusive proof, it is often speculated in the West that this mission was intended to bring a sample of the lunar surface back to Earth before the Apollo 11 astronauts returned.

There was some concern in the United States as to whether this somewhat mysterious flight, whose detailed mission had not been revealed, would interfere with the U.S. manned mission. U.S. astronaut Frank Borman, who had recently been in the Soviet Union, made a personal appeal to Soviet officials to release the orbital elements, and asked for assurances that the flight would not interfere with the Apollo mission. The Soviets responded that Luna 15 was in an orbit 203 by 55 kilometers, with a period of 120.5 minutes, and there was no intention of endangering the Apollo flight.

On July 19, Tass announced that the orbit had changed, and had an inclination of 126°, 221 by 95 kilometers, with a period of 123.5 minutes. On July 20, this was modified again to an inclination of 127°, 110 by 16 kilometers, with a period of 114.0 minutes. This indicated that the spacecraft was either going to land, or take high resolution pictures of future landing sites.

The next Soviet announcement came on July 21, while Neil Armstrong and Buzz Aldrin were on the lunar surface, and reported that Luna 15 had fired a retrorocket and had "reached" the luner surface in the "preset" area. There seemed little doubt from the wording of the Soviet statements that Luna 15 was intended to make a soft landing on the Moon to conduct further experiments, and in this it failed. The Jodrell Bank observatory estimated from the Doppler shift of signals that the payload impacted the surface of the Moon with a residual speed of about 480 kilometers an hour, which would seem a good confirmation that the mission was to slow it for a landing, not merely redirect it to impact.

Even with the advantage of hindsight, there is no conclusive answer as to the intended mission of Luna 15. There had been rumors that the Soviets would attempt an automated sample return flight, a mission accomplished later by Luna 16, but it is also possible that this flight might have been intended to land a roving vehicle as did Luna 17. Luna 15 and Luna 17 both flew in retrograde orbits while Luna 16 flew a posigrade orbit. Luna 15 and Luna 17 made landings in daylight portions of the Moon, while Luna 16 made a landing in the night portion. Moreover, the motors for the Lunokhod drive had already been tested on Luna 12 and Luna 14. If the Soviets were trying to beat the Americans in returning a lunar sample to Earth, they were cutting it very close by lingering 4 days in lunar orbit before collecting the sample, although an unmanned vehicle might have made a faster return flight.

Kosmos 300

On September 23, 1969, Kosmos 300 was launched and the time of launch and the nature of the debris in Earth orbit both suggested another lunar flight had been attempted, but was not successful in leaving Earth orbit. The relation of this flight to phases of the Moon was not like Zond 7, but did resemble Luna 16 and 17. Thus, it is reasonable to assume that this was another in the series begun by Luna 15.

Kosmos 305

On October 22, 1969, 1 lunar month after the Kosmos 300 failure, Kosmos 305 was launched. This may have been even less successful than its immediate forerunner, because no orbital period was announced suggesting that the payload decayed before the end of the first revolution. Some debris remained in orbit about 2 days.

1970 LUNAR FLIGHTS—LUNA 16 AND 17

Luna 16—First automated sample return

Luna 16 was launched on September 12, 1970, and it landed on the Moon at 0818 Moscow time on September 20 in the Sea of Fertility at 0°41′ S., 56°18′ E. The announced landing weight was 1,880 kilograms.[39]

The spacecraft had an extendable arm which could reach out beyond the immediate blast area of touchdown. At the end of the arm was an elaborate drilling rig which could take a sample of the lunar soil, and insert it into a special container for return to Earth. The drill cut to a depth of about 35 centimeters, at which point the Soviets were not certain whether bed rock or an isolated hard stone had been hit. Rather than risk damage to the equipment, drilling ceased. After 26 hours and 25 minutes on the surface, the ascent stage ignited at 1043 Moscow time.

The spacecraft made a ballistic return to Earth, landing on September 24, after a total mission duration of 11 days, 16 hours. The sample returned by Luna 16 weighed only 101 grams, but this nevertheless afforded an important opportunity for scientists in the Soviet Union. Descriptions of the material were very similar to those for the samples returned by the U.S. crews. Small samples were made available to scientists in other countries including a direct exchange with the United States.

The many articles by Soviet scientists which discussed Luna 16 put heavy emphasis on the eventual use of the Luna 16 techniques for exploration of Mars, Venus, and the planetoids. While Luna 16 was extolled as cheaper for exploring the Moon than the manned Apollo flights, the Soviets also stated that their exploration of the

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[39] Tass, Oct 3, 1970 1035 GMT

Mo. ould use several techniques in the future, including both automated devices and manned expeditions.

Luna 17 and Lunokhod 1

About 2 lunar months after the launch of Luna 16, Luna 17 was launched at 1744 Moscow time on November 10, 1970, landing in the Sea of Rains at 0647 Moscow time on November 17. The landing stage was essentially the same as used for Luna 16, except that in place of the drilling arm, it had a flat platform on top with dual ramps on opposite ends (see figure 22). Instead of the Luna 16 payload and its ascent rocket assembly, Luna 17 carried a mobile vehicle, Lunokhod 1.

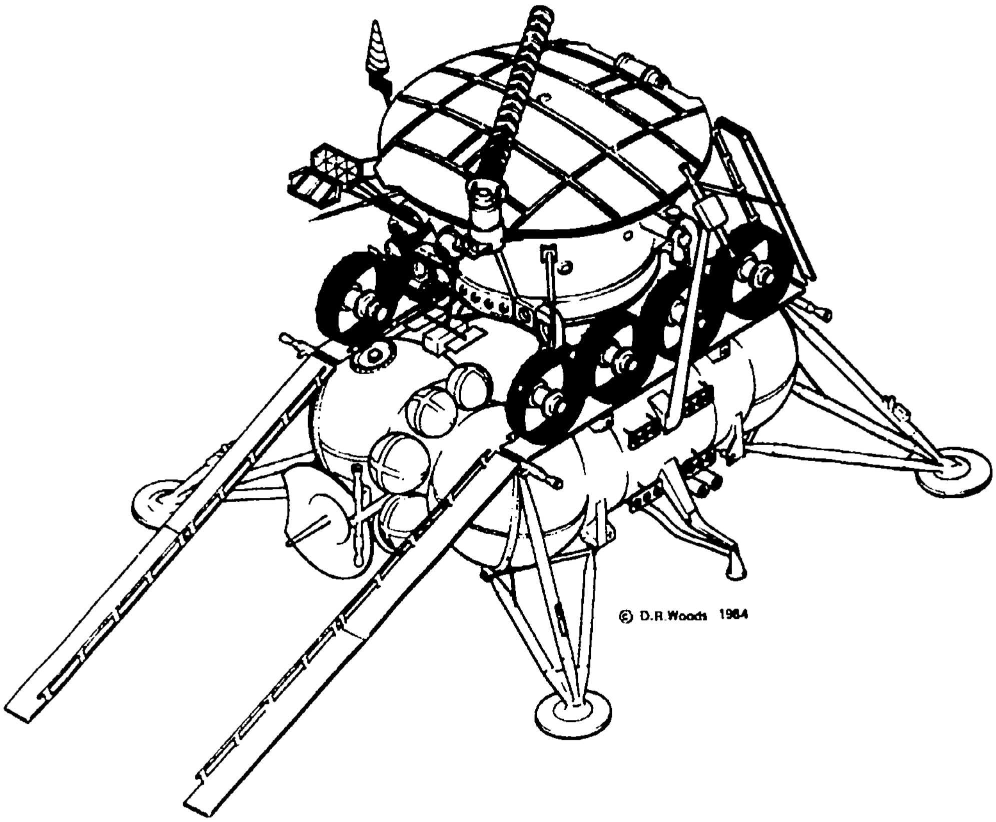

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FIGURE 22.—Luna 17 delivered the Lunokhod 1 rover to the surface of the Moon. Ramps at either side of the descent stage allowed the rover to roll to the surface to begin its studies.

Lunokhod 1 was shaped like an old-fashioned bath tub, with eight wheels (four to a side), and a large convex lid over the tublike compartment. The lid was hinged on one edge so it could lift up to expose the solar cells on its underside. The vehicle carried a cone-shaped antenna, a highly directional helical antenna, four television cameras, and special extendable devices to impact the lunar soil for testing density and mechanical properties.

The Lunokhod 1 was undeniably a remarkable vehicle. It was built of unspecified lightweight materials designed to withstand the stresses of flight from Earth and the great extremes of temperatures on the Moon. Plastic materials could not be use because they would deteriorate in the radiation environment of space. The eight wheels were independently powered, and a special suspension system was designed to overcome any unevenness of the lunar surface.

As noted earlier, the electric motors for the wheels were tested on Luna 12 and Luna 14. Lunokhod 1 was controlled by a four-man crew on Earth, and had the ability to move at two speeds, either continually or in short increments, forward or backward, and by applying power in opposite directions to the wheels on each side, could turn in its tracks. Automatic sensors and safety devices would stop the vehicle if the grade became too steep, or if it tilted too much to one side.

The four television cameras permitted observations in all directions, stereo views, and both closeup and panoramic views. Soil properties could be measured both by the impact devices and by optical studies of the vehicle tracks. An x ray spectrometer permitted analysis of soil constituents. Cosmic ray detectors were used to analyze the intensity and energy levels of protons, electrons, and alpha particles. Solar flares were also studied. A French laser reflector was used to reflect laser signals generated by French and Soviet scientists on Earth. A radioisotope heat source maintained sufficient internal heat to permit the equipment and chemical batteries to survive the lunar night.

On November 17, the first television pictures were returned. At 0928, Lunokhod 1 descended the steep ramp to reach the surface of the Moon, and began its travels in low gear. Its mass was 756 kilograms. Designed to operate for 3 lunar days, it continued to function, at least partially, for 11 or 12 lunar days (almost 1 Earth year), making an impressive record by any standards. Table 17 summarizes the results of this mission.

TABLE 17.—SUMMARY RECORD OF THE PERFORMANCE OF LUNOKHOD 1

Lunar day	Vehicle activated	Vehicle shutdown	Lunar night contacts	Travel distance (meters)	TV pictures	TV panoramas	Soil tests		Astronomy test
							Mechanical	Chemical	
1	Nov 17	Nov 22	2 radio, 1 laser	197	14	12	Some	1	Some
2	Dec 10	Dec 22	3 radio	1,522	Some	21	Some	3	[1] 33
3	Jan 8	Jan 20	2 radio	1,936	Some	20	[1] 200	10	30
4	Feb 8	Feb 19	2 radio	1,573	Some	10	Some	3	Some
5	Mar 9	Mar 20	2 radio	2,004	Some	Some	Some	2	Some
6	Apr 6	Apr 20	1 radio, 1 laser	1,029	Some	Some	Some	1	Some
7	May 7	May 20	1 radio	197	Some	Some	Some	2	.....
8	June 5	June 18	1 radio	1,559	Some	Some	Some	2	.....
9	July 4	July 17	1 radio	220	Some	Some	Some	1	Some
10	Aug 3	Aug 16		215	Some	.....	.....	.....	.....
11	Aug 31	Sept 15		88	Some	Some	.....	.....	.....
12	Sept 30	Oct 4		.....	.....	.....	.....	.....	.....
Total				10,540	20,000	206	500	25	(?)

[1] Cumulative

Notes: 1 The table shows what portion of each lunar day the Lunokhod 1 was activated. During lunar nights while the solar panel was generally closed and no movement occurred, some radio contacts were made to monitor that the vehicle was still operable though quiescent. The listed number of laser reflection tests probably understates what was done, considering both the Russians and the French were interested in testing the reflection.

2 The statistics for each day were compiled by a review of individual Tass bulletins numbering in the scores over a period of 10.5 months. Data became more sparse over time, either because of less news value or as experiments became inoperable.

Sources: Mostly from many individual Soviet Tass bulletins. The summary figures on total performance were carried in Aviatsiya i Kosmonavtika, No. 1, 1973, pp. 33-35.

Lunokhod 1's experiments officially ended on October 4, 1971, the 24th anniversary of Sputnik 1, when the radioisotope supply was depleted.

1971 LUNAR FLIGHTS—LUNA 18 AND 19

Luna 18

The next Soviet lunar flight was Luna 18, launched September 2, 1971. It carried the same basic third generation bus that had been used since Luna 15, and on September 11, it braked to a soft landing on the Moon. The Soviets announced that the surface had been too rough and signals ceased at touchdown.

Luna 19

Luna 19 was launched on September 28, 1971, and entered lunar orbit on October 3 (see figure 23). Nineteen experiments were conducted, involving studies of magnetic fields, cosmic radiation, solar data, and meteoroids. Findings from radio wave propagation experiments suggested a plasma existed around the Moon, and studies or orbital perturbations assisted in mapping mascons. On 10 occasions, surges of solar activity were studied, and the results were combined with data from Venera 7 and 8, Mars 2 and 3, and Prognoz 1 and 2.

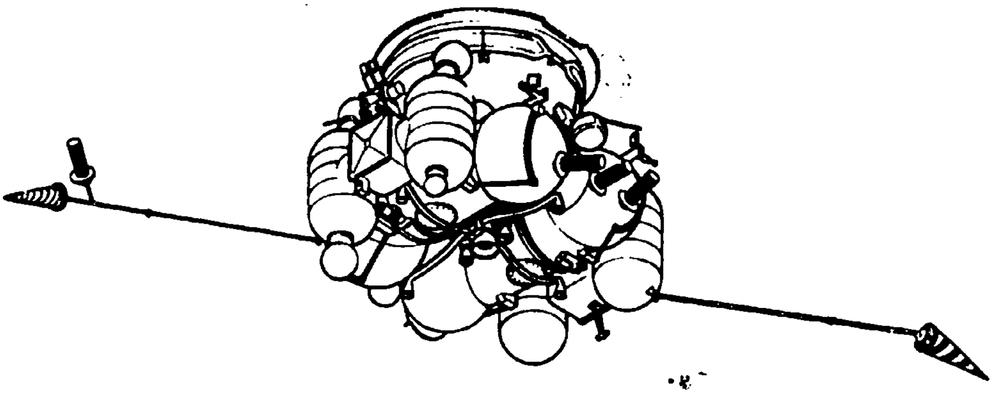
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FIGURE 23.—Two heavy Luna spacecraft were used for lunar orbit missions: Luna-19 and 22. The payload module appears to be based upon a rover vehicle, without wheels. Tracking of their orbits helped map the lunar gravitational field.

1972 LUNAR FLIGHT—LUNA 20: SECOND SAMPLE RETURN

Luna 20 was launched on February 14, 1972, and landed on February 21 near the Sea of Fertility, close to the Luna 18 landing site.

The mission was a repeat of the Luna 16 flight, and the return capsule with samples of lunar material was launched from the Moon on February 23. After a ballistic return to Earth, the sample was recovered and studied by Soviet scientists, who found it to be lighter in color than that returned by Luna 16. A total of 50 grams was returned this time, and samples were again exchanged with United States and French scientists.

Soviet analysis of the sample found traces of 70 chemical elements. The highlands sample, as indicated, was lighter and had more large particles. Their density was described at 1.1 and 1.2 grams/cubic centimeter compactable to 1.7 to 1.8 grams/cubic centimeter.

1973 LUNAR FLIGHT—LUNA 21 AND LUNOKHOD 2

Luna 21 was launched on January 8, 1973, and on January 16, it braked to a soft landing at the eastern edge of the Sea of Serenity in Le Monnier crater. The spacecraft carried the Lunokhod 2 vehicle (see figures 24 and 25), which had a mass of 840 kilograms and was improved over Lunokhod 1. Radioactive Polonium 210 was used as a heat source to keep it alive during the lunar nights. Table 18 summarizes these activities.

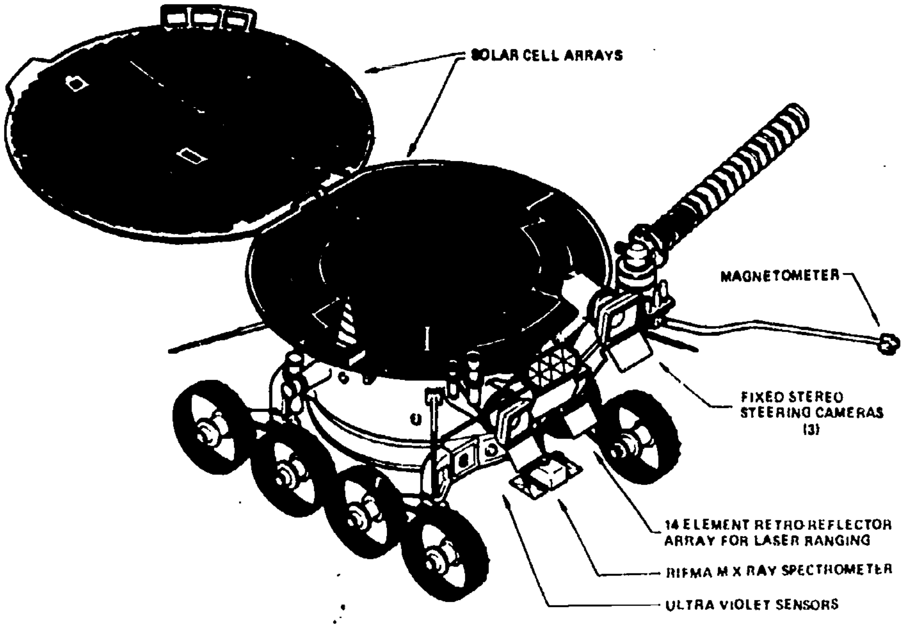

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FIGURE 24.—Lunokhod-2 (top view) was delivered to the Moon's surface by the Luna 21 spacecraft. A large circular cover on the 840 kg rover opened to expose two solar cell arrays to sunlight to power the vehicle. Three TV cameras provided stereo viewing to gauge distances.

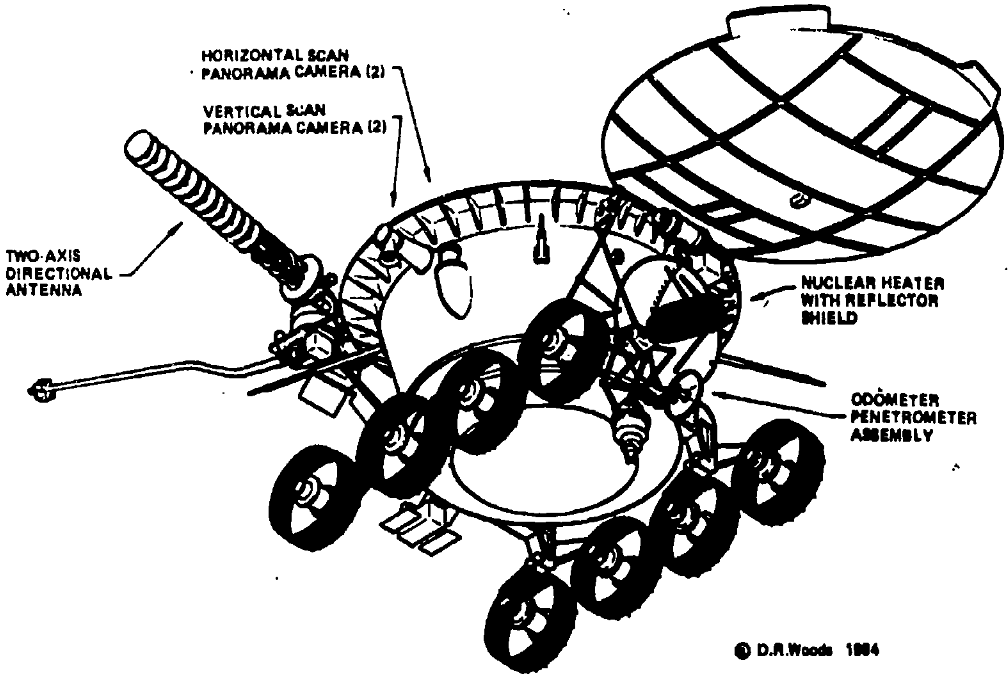

FIGURE 25.—Lunokhod-2 (bottom view) was fitted with a Po^{210} nuclear heater to keep it warm during the two-week-long lunar night. Each of the eight chassis wheels had its own electrical motor for added reliability. Lunokhod-2 traveled 37 km during its 4-month life.

TABLE 18.—SUMMARY RECORD OF THE PERFORMANCE OF LUNOKHOD 2

Lunar day	Vehicle activated	Vehicle shut down	Lunar night contacts—		Travel distance (meters)	TV pictures	TV panoramas	Soil tests		Astronomy tests
			Radio	Laser				Mechanical	Chemical	
1	Jan 16	Jan. 24			1,260					
2	Feb 8	Feb. 23			9,806					
3	Mar 11	Mar 23			16,533					
4	Apr 9	Apr. 22			8,600					
5	May 8	(June 3)			800					
	Total		(?)	4,000	37,000	80,000	86	740	(?)	(?)

Notes

1 The table shows what portion of each lunar day the Lunokhod 2 was activated. During the lunar nights while the solar panel generally was closed and no movement occurred, there were both radio contacts to monitor quiescent systems and laser reflection tests to measure vehicle location and lunar or Earth celestial mechanics data

2 The statistics on this operation were not reported in quantitative form except for the distance traveled. The numbers shown were constructed by compiling data from scores of individual Tass bulletins over a period of 4.5 months.

3 While the experiment was reported as concluded on June 3, 1973, this time is suspect since it was in the middle of the lunar night when the vehicle would be inactive anyway Normally, shutdown would come at the end of a lunar day, like May 20 or 21, with the failure discovered at time of revival around June 6 or 7 Since the travel reported for the fifth lunar day was so small, failure may have come as early as the second week in May

Sources Mostly from many individual Soviet Tass bulletin The summary figures on total performance were carried as a Tass announcement in Pravda, Moscow, June 4, 1973, p 1

Lunokhod 2 covered a distance three to four times greater than Lunokhod 1, and had twice the speed. As a result, a five-man ground crew was used instead of four. In addition, there were four times as many television pictures, and 50 percent more soil mechanical tests. The Soviets noted that Lunokhod 2 landed only 180 kilometers north of the landing site of Apollo 17, and it covered the area from the Sea of Serenity to the Taurus Mountains.

An extra television camera was added at a higher point on the spacecraft so that the Earth driver could see farther ahead and direct the vehicle with more confidence. Another new instrument was an astrophotometer which was used to determine the night skyglow on the Moon, and looked for zodiacal light in the plane of the ecliptic. This instrument previously had been tested on Kosmos 51 and Kosmos 213 in Earth orbit. Another new device was a magnetometer mounted on a pole projected ahead of the vehicle 2.5 meters.

Experiments using the French laser went very well on this flight, and it was possible to gauge distances from Earth to Moon with an accuracy of 20 to 30 centimeters, and to measure shifts of the Earth's pole of as little as 10 centimeters.

In general, the Soviets praised their design approach as preferable for longer studies than could be conducted by human crews. They forecast the use of roving automated vehicles on Mars and Venus, as well.

The Soviets announced that Lunokhod 2's mission had come to an end on June 3.

1974 LUNA FLIGHTS—LUNA 22 AND 23

Luna 22

Luna 22 was launched on May 29, 1974, and entered lunar orbit on June 2 to continue the work of Luna 19. Studies included taking pictures of large areas of the lunar surface, and taking measurements of the Moon's magnetic field, cosmic radiation, and gravitational data. Other orbital activities include measuring meteorite density and the spectrum of solar cosmic rays and concentration of circumlunar plasma and magnetic fields.

The spacecraft was placed in an orbit 255 by 24 km to permit high resolution picture taking. After that part of the mission was completed on June 13, the orbit was raised to 299 by 181 kilometers.

The spacecraft exhausted its supply of maneuvering fuel on September 2, 1975,[40] after 15 months of lunar studies. During its lifetime, there were 1,500 trajectory measurements made during 2,400 radio sessions with Earth; radio controllers sent 30,000 radio commands to Luna 22.

Luna 23—Attempted sample return

Luna 23 was launched on October 28, 1974, with the announced mission of performing further research into the Moon and space around the Moon. On November 2, the braking rocket was fired to place it into lunar orbit, and on November 6, it landed in the south part of the Sea of Crises.

The landing was successful, but the terrain was unfavorable and the drill was damaged and could not perform its mission of obtaining a sample from a depth of 2.5 meters. Communications with

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[40] Sotsialisticheskaya Industriya. Moscow. Oct 15, 1975, p 3

Luna 23 were terminated on November 9, after a reduced research program.

1976 LUNAR FLIGHT—LUNA 24: THIRD SAMPLE RETURN

Luna 24 was launched on August 9, 1976, almost 2 years after the Luna 23 failure. As of the end of 1980, no further Soviet lunar flights have been made.

On August 18, 1976, Luna 24 landed on the Moon in the southeastern part of the Sea of Crises at 12°45′ N., 62°12′ E., a position very close to the unsuccessful Luna 23.[41] The drill was designed to take a sample at a depth of approximately 2 meters (see figure 26). Previous samples taken by Luna 16 and 20 had reached only 30 centimeters. This time, a special drill rig was designed. The walls of the drill pipe were lined with flexible ribbons that were drawn from the outside of the pipe, into the pipe, and around the sample column, as the drill rotated deeper. More ribbon was rolled up around each portion of the lunar sample to keep the pipe from clogging, and to prevent fine sand from falling through. An impact-rotating mechanism was used to penetrate any rock that might be encountered; the motion of the drill changed depending on the resistance. A drum rotated to pull in the ribbon and to move the sample into the return vehicle ampule. A lock was then triggered and the drum moved inside the return vehicle. The beam and drill folded away from the rocket to prepare for launch.[42]

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[41] Izvestiya. Aug 20, 1976, p 2.
[42] Izvestiya. Aug. 20, 1976, p.2.

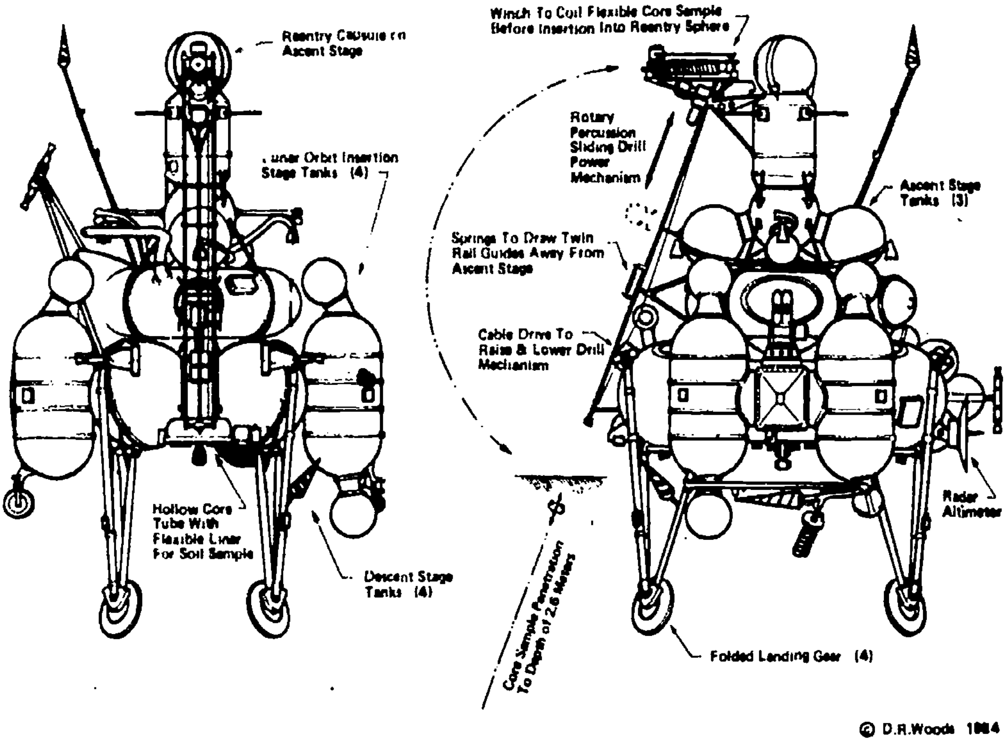

FIGURE 26.—Luna 24 collected a 2.6 meter core sample using a plastic, sausage-like tube, coiled with a winch and placed inside the reentry capsule for return to Earth.

On August 19, the Luna 24 return vehicle was launched from the Moon. The capsule made a ballistic return to Earth, landing 200 kilometers southeast of the city of Surgut. A total of 170 grams of material was returned, and the color was described as brownish or dark grey, depending on illumination. The layers were found to contain different size and color particles. Sixty elements were found using x ray microanalysis and mass spectroscopy.[43]

THE SOVIET MARS PROGRAM

Since the beginning of the space program, the Soviet Union has attempted to send probes to only two of the other eight planets in the solar system: Mars and Venus. Their success in studying the latter planet is discussed in section VI, but it has not been matched on Mars. Only seven probes officially named "Mars" have been launched, and from a mission standpoint, three were complete failures (Mars 1, 4, and 7) while three others were partial failures (Mars 2, 3, and 6) by Western standards. In addition, it would appear that there were several more Mars attempts which failed before leaving Earth orbit, and were given the generic Kosmos designation.

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[43] Pravda, Sept. 5, 1976, p. 3.

1960 MARS ATTEMPTS

The Soviet Union traditionally does not acknowledge spacecraft failures. In a number of instances, the United States has monitored failures which apparently would have sent spacecraft to Mars, but has disclosed this knowledge officially on only one occasion (September 5, 1962). On October 10 and October 14, 1960, the Soviet Union launched a new combination of rockets intended to send payloads to the vicinity of Mars, but neither was successful in reaching even Earth orbit.

A Soviet Mars attempt had been expected by Western observers at the appropriate astronomical "window" for the 1960 launch. Premier Khrushchev timed his arrival in New York at the United Nations accordingly, expecting to be able to announce the flights. A seaman defector told reporters that on board the Soviet ship *Baltika*, which had brought Khrushchev, was a replica of an advanced spacecraft which was to be put on display if a certain mission were successful. If true, the replica was carried back to the Soviet Union unseen.

1962 MARS ATTEMPT—MARS 1

The window for Mars flights comes about every 25 months, and Soviet launch attempts were made on October 24, November 1, and 4, 1962. All three reached Earth orbit; the first and third were never acknowledged by the Soviet Union because they never left that orbit. The November 1 launch was the only success, and was named Mars 1. Communications were received from the probe until March 21, 1963, after which signals ceased. The ship passed Mars at a distance of about 193,000 kilometers in June 1963.

This payload had been improved over Venera 1 (see p. 872). Its weight was raised to 893.5 kilograms, and it had a greatly improved "bus" for the instrumentation and more elaborate experiments. The basic design of this craft became standard for planetary missions.

1964 MARS ATTEMPTS—ZOND 2 AND 3

The Soviet Union launched Zond 2 toward Mars on November 30, 1964, and this time acknowledged its mission. Communications failed some time in April 1965, but it made a close pass by Mars at about 1,500 kilometers on August 6 of that year. There was a strong likelihood that another Mars attempt was planned for the 1964 window because multiple launch attempts were made for every other window to Mars and Venus beginning in 1960.

Not until July 18, 1965, however, was another Mars spacecraft launched. Zond 3 was placed on a trajectory toward the orbit of Mars, but the launch was made without reference to a suitable launch window for Mars, and the planet was nowhere near the Zond when it achieved that distance. However, as a diagnostic test, Zond 3 also made a flyby of the Moon, passing it at a distance of about 9,200 kilometers. It took 25 pictures of the far side, of a quality superior to those of Luna 3, which were returned to Earth by facsimile a number of times at ever-greater distances, proving the capabilities of the communications system. Some signals were still being received when Zond 3 reached the orbital path of Mars.

1971 MARS FLIGHTS—KOSMOS 419, MARS 2 AND 3

There were rumors in the summer of 1968 that there would be new major Mars attempts late in 1969, but there were no successful launches announced and no recognizable failures hidden under the Kosmos designation.[44] There were multiple rumors of launch failures at the appropriate window, however, so it is possible that the spacecraft never attained orbit.

The Soviets did take advantage of the 1971 opportunity. On May 10, Kosmos 419 was launched, and although the Soviets named the launch, they did not add the usual statements about everything going well. The spacecraft attained Earth orbit, but did not fire the rocket which would have launched it toward Mars and given it a Mars name.

The successful launch of Mars 2 on May 19 was announced by the Soviets as soon as it was clear that its rocket had placed it on the correct trajectory. Mars 3 was launched on May 28. Both spacecraft were combination orbiters and landers which carried geophysical experiments (no biological experiments were included). Figure 27 illustrates Mars 2 and 3.

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[44] Flight International, London, Mar. 27, 1971, p. 793

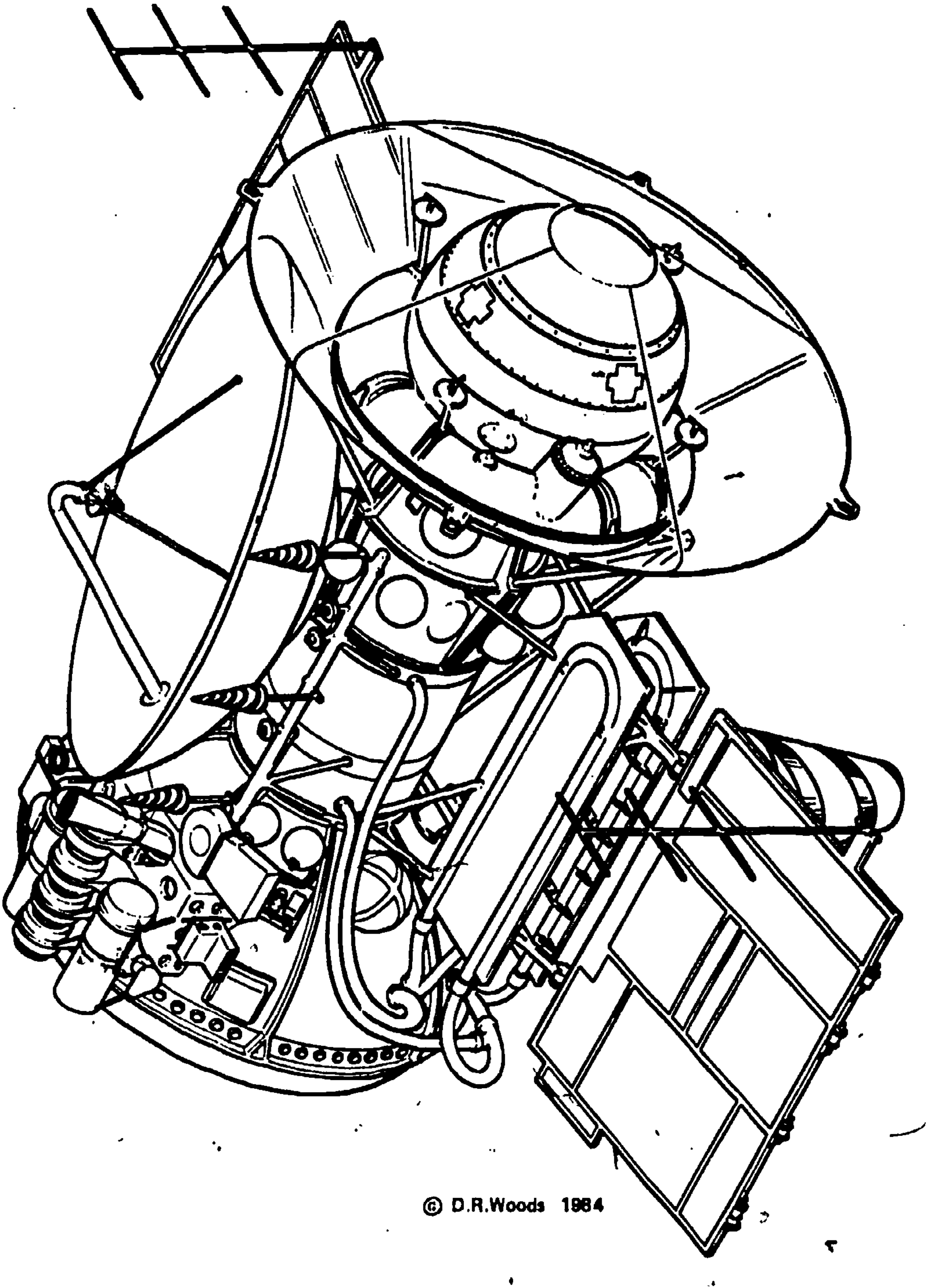

FIGURE 27.—Mars 2 and 3 were orbiter/lander combinations launched in 1971. The orbiters successfully entered orbit, but the Mars 2 lander apparently failed before touchdown, and the Mars 3 lander failed after transmitting only 20 seconds of data from the surface.

On November 30, 1971, the Soviets announced that Mars 2 had entered Martian orbit on September 27, 1971. The Soviets announced that the lander reached the surface of Mars, landing at 45° S., 58° E., but no date was given for this event, and no further mention of the Mars 2 lander was made. The Mars 2 orbiter continued its research from its 25,000 by 1,380 km orbit, inclined at 48°54', with a period of 18 hours.

The Mars 3 lander reached the surface on December 2, at 45° S., 158° E. Signals were transmitted from the Mars 3 lander by a weak omnidirectional system to the orbiter, where they were recorded and later played at a slower data rate via the orbiter's high gain antenna. The lander transmitted signals for only 20 seconds; why they ceased is unknown, but most observers suggest that dust storm conditions on the surface overwhelmed the lander.

Some details were released on Mars 3, and it can be assumed that Mars 2 was very similar. The lander carried atmospheric temperature and pressure sensors, a mass spectrometer to determine atmospheric components, a wind velocity meter, devices to measure the chemical and mechanical properties of the soil, and a television system to supply panoramic views of the surroundings. The mass of the lander was later revealed to have been 635 kilograms.[45]

The Mars 3 orbiter carried the French "Stereo" experiment, but otherwise the Mars 2 and 3 orbiter instrumentation was identical. There was a camera system with a wide-angle lens with a 52 mm focal length and a 4° narrow angle lens. Twelve frames were exposed and automatically developed on board, then scanned with 1,000 lines of 1,000 elements each, for transmission to Earth where they were recorded both on magnetic tape and on electrochemical paper. Photography was hampered by dust storms. Other equipment included:

An infrared radiometer to construct a Mars surface temperature distribution chart (8–40 microns);

An instrument to determine water vapor concentrations by spectral analysis of absorption in the 1.38 micron line;

An instrument to study surface relief by measuring the amount of carbon dioxide along a sighting line, according to the intensity of the 2.06 micron absorption band (an infrared spectrometer);

An instrument to study the reflectivity of the surface and atmosphere in the visible spectrum of 0.3 to 0.6 centimeter range, and for determining the dielectric permeability of the surface and temperature to a depth of 35–50 centimeters; and

An instrument to determine the density of the upper atomsphere and the concentration of atomic oxygen, hydrogen, and argon—an ultraviolet photometer.

In general the two orbiters performed about as planned. The Soviets announced the discovery of atomic hydrogen and atomic oxygen in the upper atmosphere. The main work program ended in March and the program was formally completed by August 22, 1972, by which time Mars 2 had completed 362 orbits and Mars 3, 20 orbits of the planet.

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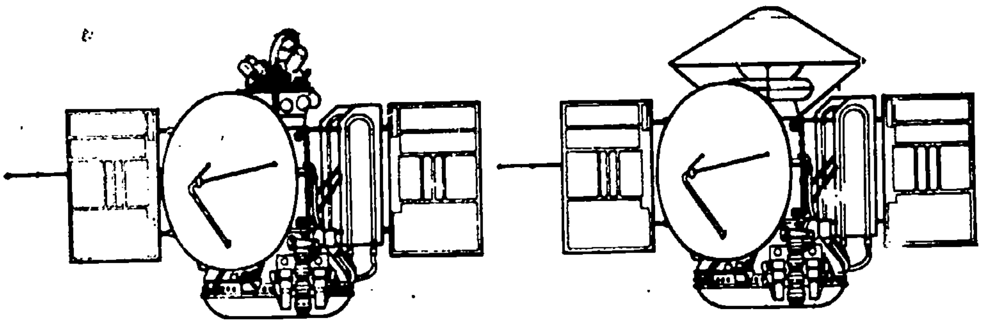
[45] Oja, Heikki, in Spaceflight, London, July 1975, p. 279, quoting a Soviet scientist.

The temperature range was found to be between 13° and −93° C, except at the North Pole where it was −110° C. Mountains as high as 3 kilometers high were found, and depressions as deep as 1 kilometer. The maximum water vapor reading was 5 microns (1/2,000 of Earth). The atmosphere was mostly carbon dioxide, but at high altitudes, separated into carbon monoxide and atomic oxygen, while water also broke into atomic hydrogen and atomic oxygen. The ionosphere was about one tenth as dense as the that of Earth, with its maximum strength at 140 kilometers. The magnetic field was about eight times as strong as the inter-planetary medium.

1973 MARS FLIGHTS—MARS 4, 5, 6, AND 7

Because of the changing positions of Earth and Mars relative to each other, by 1973 more energy was required to send probes to Mars. Thus, four launches instead of two were required to send the orbiter/lander pairs to Mars. Mars 4 and 5 were orbiters, while Mars 6 and 7 were landers, and they were launched respectively on July 21, July 25, August 5, and August 9, 1973 (see figure 28).

Mars 4 reached Mars on February 10, 1974, but its retrorocket failed to fire, so it did not enter orbit around the planet, instead making a close pass at 2,200 kilometers. It took photographs which were transmitted to Earth by facsimile scan. Mars 5 reached the planet on February 12 and entered an orbit 32,500 by 1,760 km, inclined at 35°, with a period of 25 hours.



Mars 4, 5
Relay Orbiter

Mars 6, 7
Reentry Capsule, Fly-By Bus

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FIGURE 28.—The 1973 Mars launch window was not as favorable as the 1971 window, so the total spacecraft weight had to be reduced to an average of 3945 kg each. They could carry propellant to achieve Mars orbit, or a lander probe, but not both. The Mars-5 spacecraft achieved Mars-orbit and Mars-6 made a successful reentry into the atmosphere. Unfortunately, it fell silent after transmitting 150 seconds of data during descent.

Mars 6 reached the vicinity of Mars on March 12, 1974, and the lander proceeded to the surface, landing at 24° S., 25° W. The Soviets disclosed that contact with Mars 6 had been lost 148 seconds after the parachute opened, just before it touched down. Mars 7 had reached the vicinity of Mars on March 9, and its descent module separated as planned, but a malfunction in an onboard system caused it to miss the planet by 1,300 kilometers. The landers had a mass of 635 kilograms each.[46]

Thus, only one of the four spacecraft, Mars 5, successfully accomplished its mission objectives. Some data were returned by Mars 4, and the two orbiters took a total of 60 photographs, some of high quality. Mars 6, although it did not survive landing, did provide direct readings of pressure, temperature and chemical composition of the atmosphere.

Mars 5 returned a wide variety of data. Among the instruments carried was a radio probe operating in the 8-32 centimeter range; a radio telescope operating at 3.5 centimeters; and infrared radiometer for the 8-26 micrometer range; a spectrometer with an interference filter for the 2-5 micrometer range; three photometers with interference filters operating at 1.38, 2, and 0.3-0.8 micrometers respectively; a photometer for studying the ozone band at 2,600 angstroms; a photometer for measuring the intensity of scattered solar light in the Lyman alpha range (1,215 angstroms); a gamma photometer; two polarimeters for nine narrow bands in the range 0.35-0.8 micrometers; and a phototelevision complex of instruments to take pictures for facsimile transmission to Earth. There were two cameras. The one called Vega had a focal length of 52 mm, was f/2.8, providing a 23 by 22.5 mm frame and its look angle was 35°42′. The other camera, Zufar, had a focal length of 350 mm, was f/2.5 with a 23 by 22.5 mm frame and its look angle was 5°40′.[47] Mars 4 used a red filter, while Mars 5 had red, blue, green and orange filters. Rectified maps were produced from these pictures which provided control points and links with the pictures taken 2 years earlier by the U.S. Mariner 9 probe.

Mars 5 made a study of the chemical composition of the atmosphere measuring the amount of water vapor and ozone. Mars 3, after the dust storm 2 years earlier, had found only 10-20 micrometers of water vapor, but Mars 5 made readings of up to 80 micrometers of water vapor, with variations of two to three fold even within short distances of a few hundred kilometers. Mars 5 found that the amount of ozone by volume was 0.00001 percent, with the layer at 30 kilometers.[48]

Several experiments were duplicated among the four main vehicles. Magnetometers were carried on Mars 4 and 7, as were plasma traps. Multichannel electrostatic instruments were carried by Mars 4 and 5. Mars 6 and 7 carried micrometeorite sensors, cosmic ray sensors, and the French solar radio emission experiments, Stereo, which had also flown on Mars 3. Another French experiment, Zhemo, was carried for studying the distribution and intensity of fluxes of protons and electrons en route to Mars.

THE SOVIET VENUS PROGRAM

In its planetary explorations, the Soviet Union has been most successful at Venus. By the end of 1980, a total of 12 Venera probes

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[46] Oja, Heikki In Spaceflight, London, July 1975, p. 279.

[47] Tekhnika Kinoi Televideniya, Moscow, no 9, 174, pp 57-60.

[48] Space Research Conducted in the U S S.R. in 1974, COSPAR Report, 18th Plenary Session. Translated into English and republished as JPRS 65778, Sept-29, 1975, by the Joint Publications Research Service Pp 2-21

had been launched, and five had made successful soft landings on the planet's surface, although the imaging system on two did not operate. Two Venera probes did send back the first pictures of the surface of Venus in 1975, however.

1961 VENUS LAUNCHES—VENERA 1

On February 4, 1961, the Soviets announced the launch of a "Tyazhaliy Sputnik" from which an interplanetary probe could be launched. The fact that this launch occurred at the correct hour for a Venus probe indicated the mission, while an Earth orbital success, was a Venus probe failure. Another launch was announced on February 12, 1961—Tyazheliy Sputnik 5—and from this Venera 1 was launched (see figures 29 and 30). The payload weighed 643.5 kilograms, and was by far the most elaborate payload combination unveiled by that time. For some weeks the mission went well, but when it was about 7.25 million kilometers from Earth, communications ceased. The payload is estimated to have passed Venus at a distance of about 100,000 kilometers on May 19, 1961.

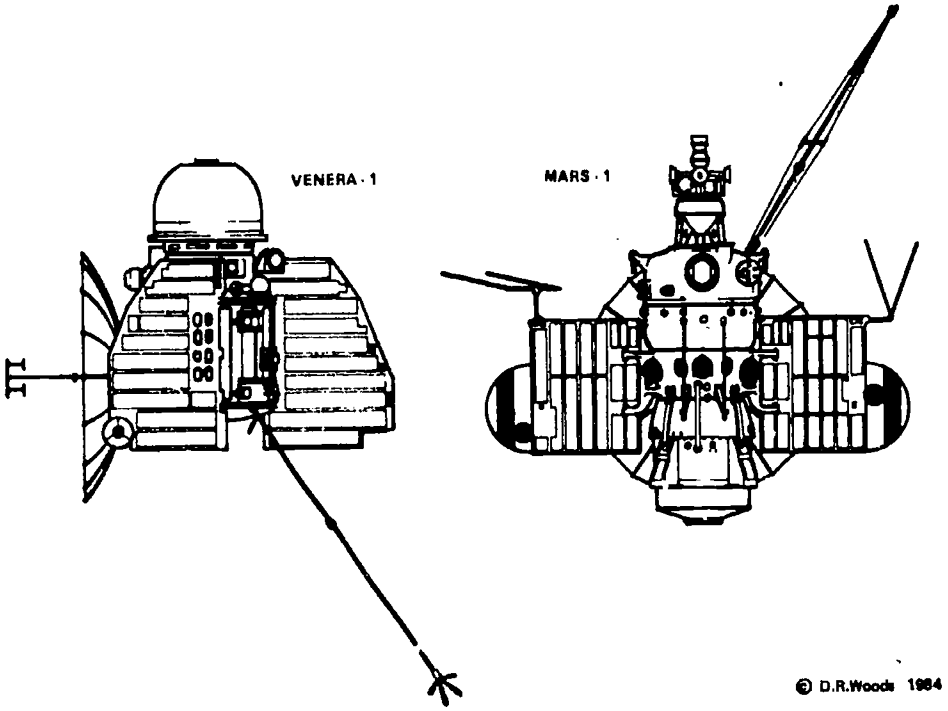

FIGURE 29.—Venera-1 (1961) and Mars-1 (1962) were the first planetary mission probes successfully ejected out of Earth orbit by the A-2-e booster. Each transmitted data from deep space but ceased operation before a flyby of their destination.

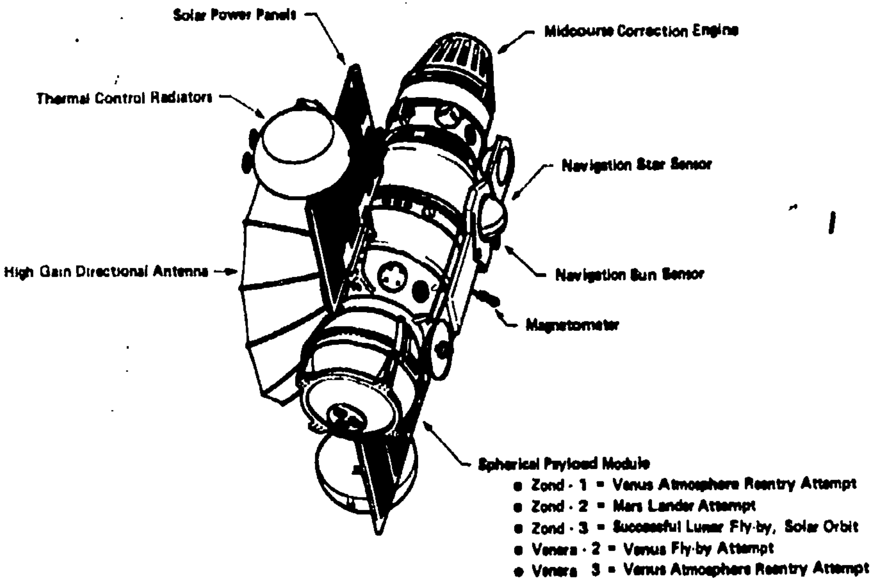

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FIGURE 30.—Several planetary probes were injected into solar orbit with destinations of Mars or Venus. Their missions, when unannounced, can be implied from their trajectories: minimum launch energy (maximum payload) missions were flyby attempts, while minimal arrival energy (slowest destination arrival) missions were lander attempts.

1962 VENUS ATTEMPTS

Venus launch windows come about every 19 months, and the Soviets made multiple launch attempts on August 25, September 1 and September 12, 1962, all carrying Venera spacecraft. All of these reached Earth orbit, but failed to launch their payloads successfully toward Venus. No Soviet acknowledgement of these launches has been made.

1964 VENUS ATTEMPTS—KOSMOS 21 AND 27 AND ZOND 1

By 1964, 10 planetary attempts had succeeded in launching only 2 spacecraft toward their planetary destination. The Soviets apparently launched a diagnostic flight on November 11, 1963, which was designated Kosmos 21, but it was not able to send a deep space probe beyond Earth orbit.

Nevertheless, on March 27, 1964, when the Venus window opened, another launch attempt was made, and when the spacecraft failed to leave Earth orbit, it was designated Kosmos 27.

On April 2, 1964, another Venus probe was launched. The Soviets designated it Zond 1, but the details announced on its course made clear that it was bound for Venus. Communications failed soon after May 14, and it passed Venus on July 19, 1964, at an estimated distance of 100,000 kilometers.

1965 VENUS FLIGHTS—VENERA 2 AND 3 AND KOSMOS 96

On November 12, 1965, Venera 2 was launched, followed 4 days later by Venera 3. On November 23, another Venus launch apparently was attempted, but it was designated Kosmos 96 when the planetary probe failed to leave Earth orbit.

Venera 2 passed Venus at a distance of about 24,000 kilometers on February 27, 1966. Venera 3 struck Venus on March 1, 1966, about 450 kilometers from the center of the visible disk. The Soviets were congratulated for these twin successes, which included sending the first manmade object to the surface of another planet, but a few days later, the Soviets revealed that communications had failed in both spacecraft at an unspecified time shortly before they reached Venus, so no planetary data was returned.

1967 VENUS FLIGHTS—VENERA 4 AND KOSMOS 167

Venera 4 was launched on June 12, 1967, and 2 days before its arrival at Venus, the Soviets revealed that its mission was to make direct atmospheric measurements (see figure 31). On October 18, 1967, a capsule separated from the bus, and after aerodynamic braking, the capsule deployed a parachute, and measurements were made for about 1.5 Earth hours while the probe descended toward the surface. Its successful return of planetary data was an important first in the Soviet program. Initially, the Soviets thought they had data readings all the way to the surface, but unless the landing occurred on a very high mountain peak, it is more likely that signals ceased at an altitude of 25 kilometers.

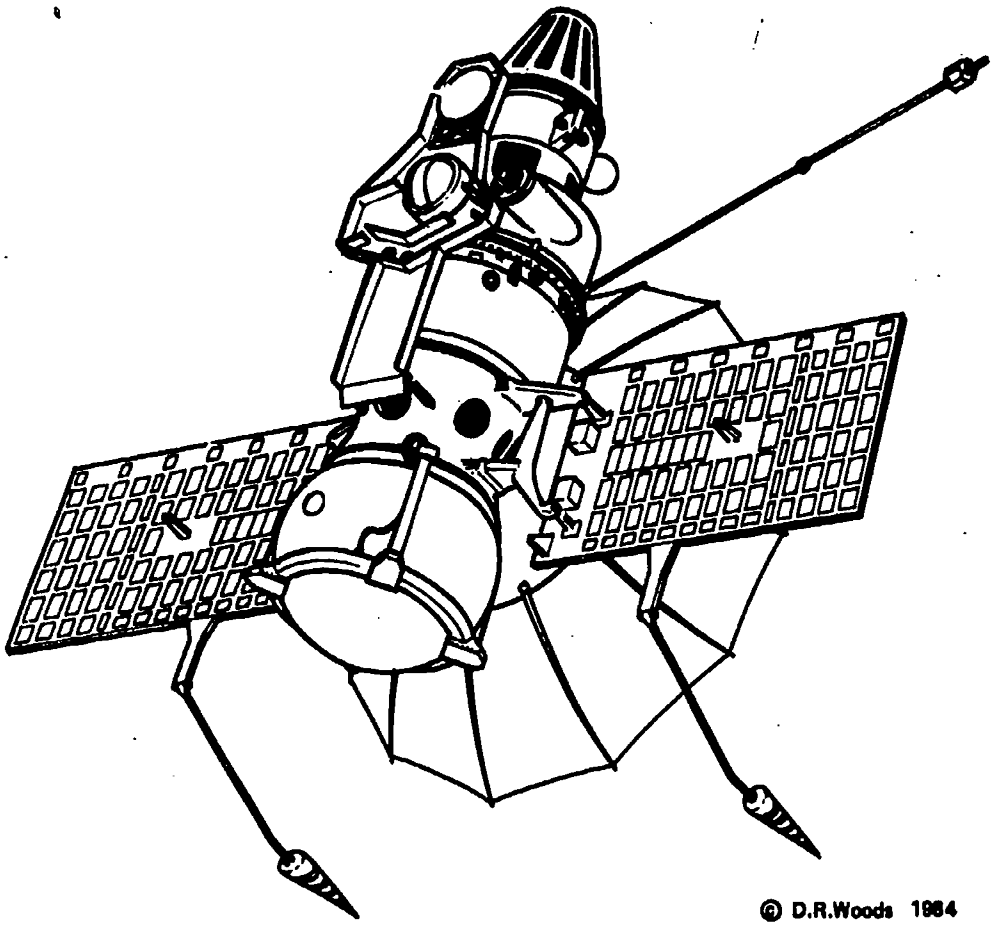

FIGURE 31.—Venera 4, 5 and 6 returned data about the atmosphere of Venus, but were not designed to survive on the surface. Venera 7 and 8 returned data from the atmosphere and the surface in the regions of night and day respectively.

The main bus of Venera 4 carried a magnetometer, cosmic ray counters, hydrogen and oxygen indicators, and charged particle traps. It discovered a weak hydrogen corona at 10,000 kilometers above the surface on the night side of Venus and a magnetic field only 0.001 the strength of that around Earth, and no radiation belts. The sterilized landing capsule was an egg-shaped package about 1 meter in diameter, weighing 383 kilograms and protected by ablative material against the high heat of entry friction. The parachute, deployed after the speed was slowed sufficiently, was made of heat resistant material. The capsule carried two thermometers, a barometer, a radio altimeter, an atmospheric density gauge, and 11 gas analyzers.

Signals from the capsule were received for 96 minutes both in the Soviet Union and at Britain's Jodrell Bank. The readings showed an initial temperature of 39° C with the final reading between 263 and 277° C. Atmospheric constituents were measured as 90 to 95 percent carbon dioxide, 0.4 to 0.8 percent oxygen, and between 0.1 and 0.7 percent (but not more than 1.6 percent) water vapor. The remainder might have been argon or other inert gases, and if nitrogen was present, it was not identified. The final pressure reading obtained was 15 to 22 times that of Earth. Later study by both American and Soviet scientists of the Soviet data suggested the Celsius temperature at the true surface was probably about double the reading from the spacecraft, and the atmospheric pressure was about 90 Earth atmospheres.

One midcourse correction was executed on July 29 to place Venera 4 on a proper trajectory to impact the visible center of the planet. During its entry, it is believed the capsule withstood temperatures in the range of 10,000 to 11,000° C. The capsule had been designed to withstand pressures up to 100 atmospheres and loads up to 300 G.

Five days after the launch of Venera 4, Kosmos 167 was sent to Earth orbit, and from its timing and behavior, it can be assumed that it would have been the second Venera of the 1967 window, but the planetary spacecraft did not leave Earth orbit.

1969 Venus Flights—Venera 5 and 6

On January 5, 1969, Venera 5 was launched toward Venus with a payload mass of 1,130 kilograms. Most of the details of the flight were the same as Venera 4. Data were returned for 53 minutes while the spacecraft descended through Venus' atmosphere, and it finally landed on the night side of the planet.

Venera 6 was launched 5 days after Venera 5, on January 10, 1969, and was a close duplicate of its immediate predecessor. Venera 6 reached Venus on May 17, a day after Venera 5, providing an opportunity for the cross calibration of results. As with Venera 5, Venera 6 deployed its parachute after slowing down aerodynamically, and data were returned for 51 minutes.

These spacecraft were somewhat improved over the earlier model, and could withstand 450 G's, compared to 300 on the earlier model. Instruments in the probe bus were designed to function between 0 and 40° C, but in actual fact were held between 10° and 25°. Because of the more rugged construction and better protection, the parachute size was cut to one third that of Venera 4 to permit a more rapid descent through the atmosphere to enhance the chance of survival closer to the surface.

1970 Venus Flights—Venera 7 and Kosmos 359

Venera 7 was launched on August 17, 1970, with a payload mass of 1,180 kilograms, the heaviest Soviet payload sent to the planets at that time. On December 15, only 14 seconds later than estimated, Venera 7 entered the atmosphere of Venus at 7:58:44 Moscow time. This signal reached the Soviet Union at 8:02:06. The initial speed was 11,600 meters per second, and after aerodynamical braking slowed the capsule to 250 meters per second, the parachute system was deployed, the antenna was extended, and signal transmissions to Earth commenced. Strong signals were received for 35 minutes, after which the Soviets continued to tune in the hiss of electronic "noise" from space. Using advanced computer techniques, they were able to separate out an additional 23 minutes of coded telemetry from the capsule after it landed, with only about 1 percent of the earlier signal strength. This was the first data transmission from the surface of another planet.

This capsule was made even sturdier than its predecessors, and was shaped as a perfect sphere for greater strength, with no holes drilled through its shell which might prove weak points during entry. Only after the top hatch blew off to deploy the parachute and antenna were the sensors exposed.

Surface temperatures were found to be 475° C, plus or minus 20° C. The pressure was about 90 times that on Earth's surface, plus or minus 15 atmospheres.

Five days after the launch of Venera 7, Kosmos 359 was placed in a low Earth orbit at the correct time for a Venus launch. A payload was separated from the Tyazheliy Sputnik, and the rocket motor fired, but placed the spacecraft into a slightly more elliptical Earth orbit, rather than sending it to Venus.

1972 VENUS FLIGHTS—VENERA 8 AND KOSMOS 482

Venera 8 was launched on March 27, 1972, with a payload mass of 1,180 kilograms like Venera 7. In contrast to all the previous nightside landing attempts at Venus, this capsule was separated to land on the day side, near the rim of the visible disk of the planet. Experiments were carried to measure brightness, temperature, atmospheric pressure, and for the first time, a device to study the nature of surface soil.

Signals continued for 50 minutes after landing. The temperature was found to be 465° C and the pressure 93 Earth atmospheres. Brightness equalled that on the Earth just before sunrise. Chemical analysis of the soil suggested a soil density of 1.5 grams per cubic centimeter. The soil was 4 percent potassium, 0.0002 percent uranium, and 0.00065 percent thorium, similar to granite.

On March 31, Kosmos 482 was launched at the correct time to be a Venera flight, and as with Kosmos 359, the payload separated but the rocket misfired.

1975 VENUS FLIGHTS—VENERA 9 AND 10

In 1975, the Soviets upgraded their Venus exploration program by initiating use of the larger D class launch vehicle for Venus missions instead of the A-2-e.

Venera 9 was launched on June 8, 1975, and was described as a new type of Venus spacecraft. On June 14, Venera 10 was launched, and the Soviets announced that it was similar in design and mission to Venera 9. Both spacecraft were orbiter/lander combinations (see figure 32). Soviet sources noted that while earlier Venera probes had required many commands from Earth to control their course, this time there were onboard digital computers which made many of the necessary calculations, adding flexibility to the operations.

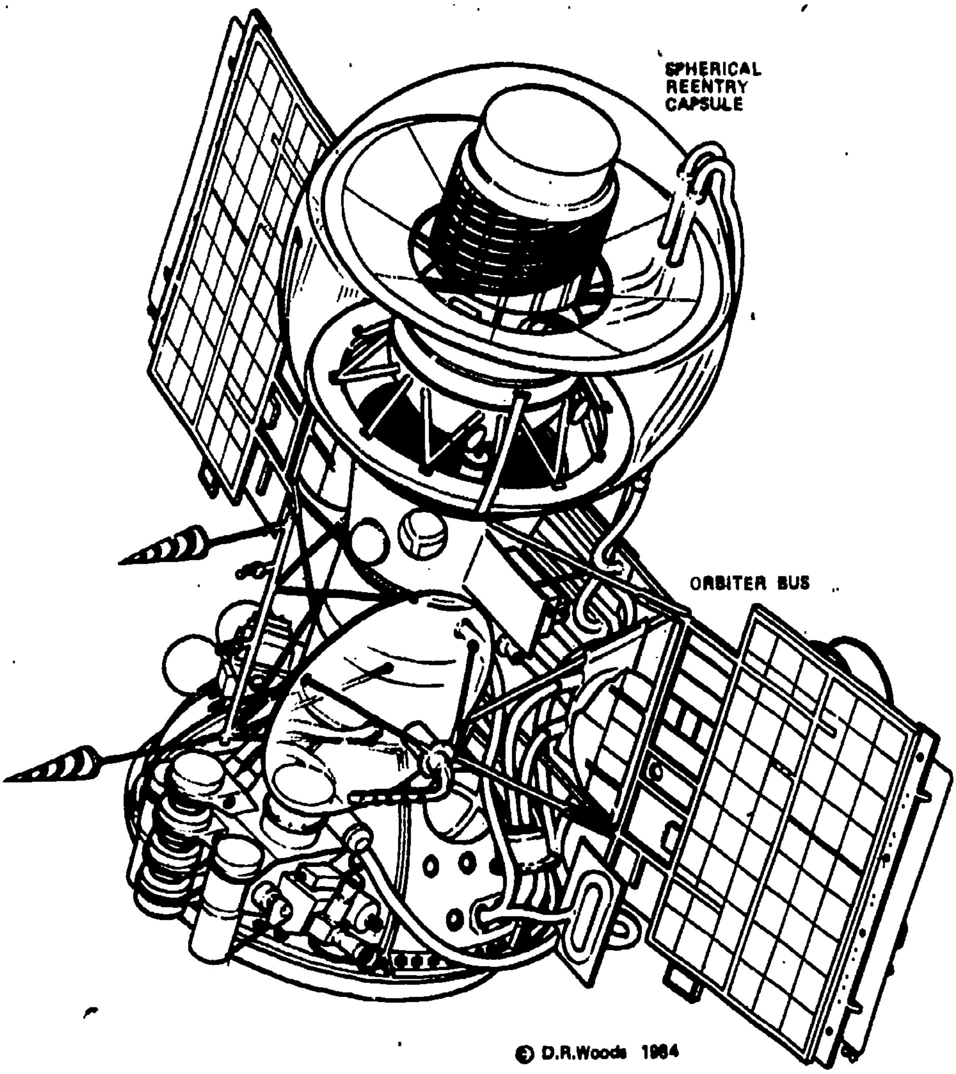

FIGURE 32.—The heavy Venera spacecraft consist of a spherical capsule which contains a lander, plus a bus which either orbits the planet (as in the case of Venera 9 and 10) or is placed on a fly-by trajectory (as in the case of Venera 11 and 12). Venera 9 and 10 returned the first pictures from the surface of Venus.

THE LANDERS

On October 20, the Venera 9 lander and orbiter separated, and on October 22, the lander entered the atmosphere of Venus at a speed of 10.7 km/sec. Following aerodynamic braking and parachute deployment, the Venera 9 lander touched down at 0813 Moscow time, and operated for 53 minutes on the surface.

The Venera 10 spacecraft separated into its two parts on October 23, and the lander reached the surface on October 25 at 0817 Moscow time. It landed 2,200 kilometers from Venera 9, and operated for 65 minutes on the surface.

The lander stood about 2 meters high, and the experiments were protected within a two-hemisphere shell able to withstand temperatures up to 2,000° C and 300 tons pressure. Lander instrumentation was precooled to −10° C and its exterior equipment to −100° C before entry, to lengthen the amount of time it could function on the surface. A special system of circulating fluids distributed the heat load.

Results from the experiments produced many surprises. First, it was discovered that the lighting was as bright as Moscow on a cloudy June day, so that the floodlights which had been carried on the spacecraft were not required.

Fifteen minutes after Venera 9 landed, a television panoramic picture began to emerge on Earth. There was no noticeable dust, and the picture was quite clear even without further processing. Details were good to a distance of 50-100 meters. A scattering of rocks 30-40 centimeters across, and a large stone on the apparent horizon, were observed. The panorama extended out to 160 meters, and the horizon may have been 200-300 meters away, but this is unclear. There was a defined curvature between surface and air at this horizon. The fact that rocks cast shadows suggested that direct sunlight was reaching the surface, in contrast to the expected solid cloud cover. Surprisingly, also, the rocks were not eroded, but showed sharp cleavages as if relatively young. Until this time, scientists had assumed that Venus was an old, geologically "dead" planet, but the existence of rocks with sharp edges strongly suggested that instead it is young and geologically active. These observations have been supported by subsequent United States and Soviet missions to Venus.

Pictures returned from Venera 10 showed that it had landed in an area with large pancake rocks, possibly with cooled lava or other weathered rocks in between.

Four Soviet scientists provided more details on the equipment carried on the Venera 9 and Venera 10 landers in a February 21, 1976, Pravda article.[49] The descent module carried the following instruments: a panoramic telephotometer; a photometer to measure light fluxes in the green, yellow, red, and two near-infrared spectra; a photometer to measure atmospheric brightness in three wavelength bands near 8 microns and to determine the chemical composition of the atmosphere; optical entry instrumentation to measure the radiation intensity of the atmosphere and clouds in two phases from 63 to 34 kilometers and from 63 to 18 kilometers; temperature and pressure sensors used from 63 kilometers to the surface; accelerometers to measure G forces during the deceleration phase; a mass spectrometer to determine the chemical composition of the atmosphere between 63 and 34 kilometers altitude; an anemometer to measure surface wind velocity; a gamma ray spectometer to detect any radioactive elements in surface rocks; and a radiation densitometer.

The article also outlines some of the data received from the landers. The temperature at the Venera 9 landing site was 460° C,

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[49] Avduyevskiy, V. (Corresponding member, Academy of Sciences, U.S.S.R.), V. Ishevskiy (Doctor of Technical Sciences), M. Marov and V. Moroz (Doctors of Physics-Mathematical Sciences), Pravda, Feb. 21, 1976, pp. 3-4.

and the pressure was 90 atmospheres. The surface illumination was about 10,000 lux. Local wind velocity was 0.4 to 0.7 meters per second. At 35-40 kilometers altitude, the ratio of carbon dioxide to water vapor was 1000 to 1. At the Venera 10 landing site, wind velocity was 0.8 to 1.3 meters per second.

Examination of surface rock for radioactive elements found 0.3 percent potassium, 0.0002 percent thorium, and 0.0001 percent uranium. Rock density was 2.7 to 2.9 grams per cubic centimeter.

THE ORBITERS

Both orbiters were put into their respective orbits the same day as their landers went to the surface of Venus. In addition to carrying experiments for orbital research, each served as a relay station between Earth and each lander.

The Venera 9 orbiter was placed in an orbit 112,000 by 1,300 kilometers, with a period of 48 hours, 18 minutes. Venera 10's orbit was 114,000 by 1,400 kilometers, with a period of 49 hours, 23 minutes.

The orbiters studied the structure, temperature, and radiation of the planet's cloud layers using spectrometers, radiometers, and photopolarimeters. By using radio sounding, they also measured the density of ions and electrons, and at high altitudes, the energy spectra directly with ion traps. Weak magnetic fields and particles in the solar wind stream were also measured.

The Pravda article cited earlier described the orbiter research in three categories: studies of the Venus cloud layer, studies of the upper atmosphere by radiophysical and optical means, and studies of solar wind interaction. Instruments used in cloud layer research included: a panoramic camera; an infrared spectrometer to measure the absorption band intensity of atmospheric gases and the reflecting capability in the 1.5 to 3.0 micron range; an infrared radiometer in the 8-30 micron range to measure cloud layer temperature; a photometer supplied by France to measure brightness of the ultraviolet light at 0.35 microns; a photopolarimeter to measure brightness and polarization of solar radiation reflected by the cloud layer in the 0.4 to 7.0 micron range; and a spectrometer in the 0.24 to 0.70 micron range to study the above-cloud layer. The upper atmosphere experiments included a photometer to measure solar radiation scattered by hydrogen atoms in the outer layers of the atmosphere and a spectrometer to measure the Venusian atmospheric glow in the 0.3 to 0.8 micron range. Solar wind studies used a magnetometer, a plasma electrostatic spectrometer and charged particle traps.

The orbiters measured the temperature of Venus' clouds at the upper boundary at −35° C and found that the cloud temperature on the nocturnal side was about 10° C higher. The brightness in ultraviolet rays varied within 20 percent. Other data indicated that the atmospheric temperature decreases with altitude, but at the 66-55 kilometer level, local temperature elevations are observed. The electron concentration on the daytime side of Venus was found to be significantly higher than on the nocturnal side, but was 10 times higher than in the terrestrial ionosphere.

1978 Venus Flights—Venera 11 and 12

Venera 11 was launched on September 9, 1978, and Venera 12 5 days later. As with Venera 9 and 10, these were combination spacecraft, but instead of an orbiter and a lander, these were a flyby bus and a lander. Each had a mass of 3,940 kilograms, less than Venera 9 and Venera 10, because the 1978 launch window had much greater energy requirements to reach Venus. The flyby bus also permitted longer contact time with the lander.

On September 25, the Soviet Union reported that corrections had been made to the Venera 11 and Venera 12 flight trajectories. There had been 37 radio communications to measure the trajectory, check onboard systems operations, and transmit scientific and telemetric data.[50] TASS announced on October 18 that Venera 11 and Venera 12 were continuing on their paths as planned, and studies were being conducted on physical processes in space.

RESEARCH CONDUCTED EN ROUTE TO VENUS

The Venera flights continued joint Soviet-French research on cosmic gamma ray flares which had begun on Prognoz 6, Prognoz 7 and Sneg 3,[51] and the Sneg-2MZ instrument, an omnidirectional gamma radiation detector, was used to locate the source and characteristics of gamma ray bursts.

Another experiment, called "Konus," was used for cosmic gamma ray studies while the spacecraft were en route to Venus. Konus took periodic measurements of the intensity and spectrum of the cosmic background with six scintillation counters forming the detector system. The source of the gamma ray burst was located by means of a triaxial stabilization of the space vehicle. From September to December 1978, Konus registered 27 gamma bursts and 120 solar flares. An experiment designated "KV-77" measured high-energy particles while Venera 11 and 12 were en route to Venus. A powerful flareup on the Sun occurred on September 23 and a stream of charged particles was observed for more than 2 days. At the same time, a dramatic increase in the intensity of protons and alpha particles of solar origin were recorded in all measured energy ranges in interplanetary space.[52]

Venera 11 and Venera 12 also conducted studies on interplanetary plasmas, and both vehicles carried identical plasma spectrometers. A Soviet scientific journal described the scientific objectives of the solar wind and geomagnetospheric research as: obtaining information on the heating and acceleration of solar wind ion components by measuring the parameters of proton and alpha components; investigation of the velocity of propagation of interplanetary shockwaves; study of the structure of the interactive region between the solar wind and the Earth's magnetosphere; analysis of the dissipation of ion energy in circumterrestrial and interplanetary shockwaves by measuring the proton and alpha components of the solar wind; and measurement of the solar wind as the American Pioneer-Venus passed through. Some Venera 11 and Venera

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[50] Tass, 1700 GMT, Sept. 25, 1978.

[51] Moscow World Service in English, 1630 GMT, Oct 13, 1978

[52] Kosmicheskiye Issledovaniya, vol. 17, No. 5, September-October 1979. Pp. 820-829.

12 instruments, including the plasma spectrometers, were used to make observations on December 4 and 9 in cooperation with the U.S. Pioneer-Venus spacecraft.[53]

By October 13, Venera 11 was 11.5 million kilometers from Earth and Venera 12 was 10.6 million kilometers from Earth. By November 4, Venera 11 and Venera 12 were more than 20 million kilometers from Earth. The French-Soviet gamma ray experiment had registered new outbursts of gamma rays of different energies and more than 20 weak x ray eruptions on the Sun.[54]

On November 24. 1978, TASS announced that more than 72 radio communications has been held with Venera 11 and Venera 12 during which some preliminary data processing had been conducted.

SURFACE EXPERIMENTS.

Venera 12 was first to reach Venus after a 98-day flight, and the descent module entered the atmosphere at 11.2 kilometers per second on December 21, 1978. The flyby bus continued its flight about 35,000 km past Venus. The temperature on the Venusian surface was 460° C and the pressure was 88 atmospheres. The module transmitted data for 110 minutes; communications ceased at 0800 when the Venera 12 module was in the shadow of Venus.[55]

Venera 11 reached Venus on December 25, 1978, and the descent module made a soft landing at 0624 Moscow time approximately 800 kilometers from Venera 12. The temperature on the surface was 446° C and the pressure was 88 atmospheres. The Venera 11 lander transmitted data for 95 minutes. The Venera 11 station was put in a flyby trajectory 35,000 km from Venus.[56]

No pictures were transmitted from the landers this time, and Soviet scientists have unofficially acknowledged that the imaging systems on both spacecraft failed.

RESEARCH DURING DESCENT

During the descent, the Venera 12 lander conducted experiments to determine the chemical composition of the clouds and atmosphere, and a study of electric charges in the planet's atmosphere from an altitude of 62 km to the surface.[57]

The entire September-October 1979 issue of Kosmicheskiye Issledovaniya (Cosmic Research) was devoted to technical discussions of the Venera 11 and Venera 12 flights. The majority of these articles were written on those experiments which were conducted during descent of the landers to the Venusian surface.

The Venera 11 descent module carried a backscattering nephelometer which was designed to measure the aerosol component of the atmosphere. Measurements were taken from an altitude of 51 kilometers to the surface. The greatest signal intensity was registered at 51 to 48 kilometers altitude. Increased levels were also measured in the 17-13 and 12-8 kilometer altitude ranges. In the

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[53] Kosmicheskiye Issledovaniya. vol. 17, No 5, 1979 Pp 780-792.

[54] Tass in Russian. 1528 GMT, Dec. 21, 1978

[55] Tass in English. 1242 GMT. Nov 4, 1978

[56] Tass in Russian. 1146 GMT. Dec 25, 1978

[57] Moscow World Service in English. 0930 GMT. Dec 21, 1978

remaining regions, the signal registered below the instruments response capability.[58]

Venera 11 and Venera 12 studied low-frequency electromagnetic radiation in the Venusian atmosphere. The discharges of energy resembled terrestrial lightning. The study of electric charges was begun at 62 kilometers and continued to the surface. One thunderstorm region was observed to occupy an area 150 kilometers horizontally and 2 kilometers vertically. The mean frequency of occurrence of discharges was far greater than during terrestrial thunderstorms.[59]

The two spacecraft carried spectrophotometric experiments, called IOAV scanning spectrophotometers. This equipment was used to study the spectral composition and spatial distribution of scattered solar radiation from 65 kilometers to the surface of Venus. The IOAV scanned continuously in the visible and near-infrared spectrum and also made circular scans in space. The objectives of the experiment were: to examine the spectral composition of scattered solar radiation in order to estimate the atmospheric content of substances with large absorption bands; to study the vertical structure of the atmosphere and horizontal homogeneity of the cloud layer; and to determine the energy balance of the atmosphere of Venus.[60] The experiment registered the spectra of the Venus daytime sky in the range of 4,500 to 12,000 angstroms and an angular distribution of brightness of scattered radiation in four filters. Absorption bands of carbon dioxide, water and gaseous sulfur were found in the spectra. It was found that about 6 percent of the total solar flux reached the planetary surface.[61]

Venera 11 and Venera 12 carried the Sigma gas chromatograph to investigate the chemical composition of the atmosphere. It weighed 10 kilograms and used a highly sensitive ionization detector. Nine samples were collected during descent between 42 kilometers and the surface. Mass spectrometers on the two spacecraft took 11 gas samples of the Venusian atmosphere from 23 kilometers altitude to the surface, 176 mass spectra were transmitted to Earth. The mass spectrometers revealed that the ratio of argon 36 to argon 40 on Venus was 200 to 300 times higher than on Earth.

NON SOVIET-BLOC COOPERATION IN SOVIET SPACE SCIENCE

Part 1, chapter 3 of this study discusses overall international cooperation in the Soviet space program. Included in these joint activities are a number of spacecraft, instruments and experiments provided by France, Sweden, India, and the United States. A brief review of these cooperative space science missions is provided below.

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[58] Kosmicheskiye Issledovaniya. vol 17. No. 5. 1979. pp. 743-747.
[59] Pis'ma v Astronomicheskiy Zhurnal. vol. 5. No. 5. 1979. pp. 229-236.
[60] Kosmicheskiye Issledovaniya. vol. 17. No. 5. 1979. pp. 714-726.
[61] Pis'ma. op. cit. pp. 229-236.

FRANCE

Oreol 1 and 2 (Aureole 1 and 2)

On December 27, 1971, the Soviets launched a French payload, Oreol 1 (Aureole 1), which was a follow-on to the Soviet auroral and ionospheric studies conducted on Kosmos 261 and 348. Coordinated ground observations were made in Bulgaria, Hungary, East Germany, Poland, Romania, Czechoslovakia, and the Soviet Union. The French experiments used a three component magnetometer to measure low energy ranges of electronic and protons and were supplemented by Soviet studies on the high energy ranges.

Oreol 2 (Aureole 2) was launched on December 26, 1973, and carried essentially the same equipment. Oreol 2's orbit permitted extensive probing of the regions where auroral lights occur. Research was conducted to determine whether the heat of the upper atmosphere would be sufficient to initiate an Earth controlled thermonuclear reaction for power purposes.

MAS 1 and 2 (SRET 1 and 2)

MAS 1 (SRET 1) was a 15 kilogram French payload carried into orbit along with Molniya 1-20, which was launched on April 4, 1972. The payload was an engineering test for different kinds of solar cells to be used in space.

MAS 2 (SRET 2) was launched on June 5, 1975, with Molniya 1-30. The payload had a mass of 29.6 kilograms and was an engineering test for thermal protection of space payloads. It had different radiation systems and thermally insulated coatings of teflon, kenton, and other materials.

Sneg 3 (Signe)

The French satellite Sneg 3 (Signe) was launched on June 17, 1977, from Kapustin Yar using a C-1 launch vehicle. The payload had a mass of 102 kilograms, of which 28 kilograms was scientific apparatus. The equipment included: a gamma ray spectrometer, a device to study discrete sources of x ray and gamma ray radiation, and a device to detect ultraviolet radiation in the solar wind.[62]

A direct digital communication line was established between the Computation Center of the Soviet Academy of Sciences' Space Research Institute and the French Space Research Institute using telephone lines.

Other Cooperative Activities

France has participated in several Soviet biological research satellites in the Kosmos series. French President Georges Pompidou was present at the launch of the first of these, Kosmos 368, on October 8, 1970. France provided instruments for Kosmos 782, 936, and 1129, all of which were biological research satellites, and are discussed in part 2, chapter 4, p. 667, of this study.

As discussed earlier in this chapter, France provided instruments to study the solar wind, the magnetosphere, and solar gamma ray and neutron emissions on Prognoz 2 in 1972, and Prognoz 6 and 7

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[62] Yezhegodnik Bolshoy Sovetskoy Entsiklopedii, 1978, Moscow P 490

carried the French experiments Galaktika 1 and 2 to study galactic ultraviolet rays.

Lunokhod 1 and 2 carried French laser reflectors. Soviet scientists at the Crimean Astrophysical Observatory and French scientists at the Pic du Midi d'Ossau Observatory bounced laser pulses off the reflectors to make exact measurements of the distance between the Earth and the Moon.

The Venera 9 and 10 orbiters were equipped with French-built ultraviolet photometers, and Venera 11 and 12 carried French hardware to detect gamma ray bursts in space. The Centre Nationale d'Etudes Spatiales participated in analyzing the data from these spacecraft. Increased French participation is planned for the Soviet Venera 84 (VEGA) project, which will release two French-designed balloons into Venus' atmosphere, as well as send two Soviet landers to the surface and then continue on to a rendezvous with Halley's comet.

The Mars 3 spacecraft carried the French experiment Stereo for monitoring solar radiation. This was also carried on Mars 6 and 7, along with another French experiment called "Zhemo" for studying solar proton and electron fluxes.

INDIA

In August 1971, an agreement between India and the Soviet Union was negotiated for joint development and launch of a satellite. The agreement was signed on May 10, 1972, and on April 19, 1975, the Indian satellite Aryabhata (Ariabat) was launched from Kapustin Yar. Fifty Indian specialists were allowed at the site to witness the launch.

The satellite had a mass of 360 kilograms, and was tracked by the Soviets until its orbit was well defined, after which both the Soviets and the Indians tracked it. Experiments covered the fields of x ray astronomy, solar gamma and neutron radiation, and particle flows and radiation in the ionosphere. While most of the equipment had been built in India, the solar cells and memory units were provided by the Soviets.

After 5 days of flight (60 orbits), the experiments were turned off because of power supply problems.

Another Indian satellite, Bhaskar, was launched by the Soviets in 1979 but this was for applications rather than space science.

SWEDEN

Swedish experiments were carried on three Soviet flights: Interkosmos 16, Prognoz 6 and Prognoz 7. During the 1979 SAMBO project, Sweden launched balloons from its Kiruna range in the far northern region of the country for magnetospheric studies, and the research was coordinated with the Soviet program, International Investigations of the Magnetosphere.

UNITED STATES

By the end of 1980, the United States had directly participated in three biosatellite missions with the Soviets (Kosmos 782, 936, and 1129). These are discussed in part 2, chapter 4, p. 667, of this report. In addition, the two countries have cooperated in the exchange of data from their planetary probes.

TABLE 19.—SUMMARY OF LUNAR DISTANCE FLIGHT ATTEMPTS, 1958–80

Launch date	Spacecraft name	Nationality	Weight (kg)	Mission	Results
1958					
Aug. 17	Pioneer 0	United States	38	Orbit Moon	Fail—exploded 16 km up.
Oct 11	Pioneer 1	do	38	do	Fail—climbed 113,830 km, fell back over South Pacific.
Nov 8	Pioneer 2	do	39	do	Fail—climbed 1,550 km, fell near Africa.
Dec 6	Pioneer 3	do	6	Fly by Moon	Fail—climbed 102,320 km, fell over Africa.
1959					
Jan 2	Luna 1	U.S.S.R	361	Strike Moon	Partial—missed Moon by 5–6,000 km, entered solar orbit.
Mar 3	Pioneer 4	United States	6	Fly by Moon	Success—passed Moon at 60,500 km, entering solar orbit.
Sept 12	Luna 2	U.S.S.R	390	Strike Moon	Success—struck 335 km from visible center.
Sept 24	Pioneer P-1	United States	170	Orbit Moon	Fail—exploded in static test before launch.
Oct 4	Luna 3	U.S.S.R	435	Photo far side	Success—returned pictures of 70 percent of far side of Moon.
Nov 26	Pioneer	United States	169	Orbit Moon	Fail-shroud tore away in launch, payload impacted near Africa.
1960					
Sept 25	Pioneer	do	176	do	Fail—impacted in Africa.
Dec 15	Pioneer P-31	do	176	do	Fail—climbed 13 km and exploded.
1961					
Aug 23	Ranger 1	do	306	Vehicle test	Fail—intended to climb to 1,102,850 km, but stayed in low Earth orbit.
Nov 18	Ranger 2	do	306	do	Fail—intended to climb to 1.102,850 km, but stayed in low Earth orbit.
1962					
Jan 26	Ranger 3	do	330	TV, hard land	Partial—missed Moon by 36,808 km, no TV pictures or landed instruments.
Apr 23	Ranger	do	331	do	Partial—timer failed, fell [illegible] far side of Moon, no pictures.
Oct 18	Ranger 5	do	342	do	Partial—power failure, so missed Moon by 725 km, entered solar orbit.
1963					
Jan 4	Unannounced	U.S.S.R	1,400?	Moon soft land	Fail—Earth orbit only.
Apr 2	Luna 4	U.S.S.R	1,422	do	Partial—missed Moon by 8,500 km, barycentric or solar orbit.
1964					
Jan 30	Ranger 6	United States	365	TV before strike	Partial—on target, but no pictures taken.
July 28	Ranger 7	do	366	do	Success—returned 4,308 pictures of Moon to impact.
Dec 11	Centaur 2	do	952	Vehicle test	Fail—did not restart and soon fell in Australia.

TABLE 19.—SUMMARY OF LUNAR DISTANCE FLIGHT ATTEMPTS, 1958–80—Continued

Launch date	Spacecraft name	Nationality	Weight (kg)	Mission	Results
1965					
Feb. 17	Ranger 8	do	367	TV before strike	Success—returned 7,137 pictures of Moon to impact.
Mar 2	Centaur AC 5	do	635	Vehicle test	Fail—exploded at pad.
Mar 12	Kosmos 60	U.S.S.R.	1,470?	Moon soft land	Fail—Earth orbit only.
Mar 21	Ranger 9	United States	366	TV before strike	Success—returned 5,814 pictures of Moon to impact.
May 9	Luna 5	U.S.S.R.	1,476	Moon soft land	Partial—retrofire failed, impacted Moon.
June 8	Luna 6	U.S.S.R.	1,442	do	Partial—missed Moon by 160,000 km, entered solar or barycentric orbit.
July 18	Zond 3	U.S.S.R.	890	Photo far side	Success—returned 25 pictures entered solar orbit.
Aug 11	Centaur 3	United States	952	Vehicle test	Success—reached 820–824 km out with Surveyor dynamic model in barycentric orbit.
Oct 4	Luna 7	U.S.S.R.	1,506	Moon soft land	Partial—retrofired early, fell on Moon.
Dec 3	Luna 8	U.S.S.R.	1,552	do	Partial—retrofired late, fell on Moon.
1966					
Jan 31	Luna 9	U.S.S.R.	13,583	do	Success—returned 27 pictures from lunar surface.
Feb 26	Apollo-Saturn 201	United States	15.331	Vehicle test	Success—flew suborbitally to land in the Pacific.
Mar 1	Kosmos 111	U.S.S.R.	1,600?	Moon orbit	Fail—Earth orbit only.
Mar 31	Luna 10	U.S.S.R.	1.600	do	Success—returned physical measurements from lunar orbit.
Apr 8	Centaur 4	United States	771	Vehicle test	Fail—low Earth orbit only.
May 30	Surveyor 1	do	995	Moon soft land	Success—returned 11,237 from lunar surface.
July 1	Explorer 33	do	93	Moon orbit	Partial—failed to approach Moon at right speed, so in barycentric orbit.
July 5	Apollo-Saturn 203	do	26.535	Vehicle test	Success—simulated in Earth orbit a Saturn V flight.
Aug 10	Lunar Orbiter 1	do	387	Moon orbit	Success—returned 414 pictures of potential landing sites on Moon.
Aug 24	Luna 11	U.S.S.R.	1,604?	do	Success—but failed to return pictures from lunar orbit.
Aug 25	Apollo-Saturn 202	United States	20,275	Vehicle test	Success—simulated reentry in suborbital flight.
Sept 20	Surveyor 2	do	1,000	Moon soft land	Partial—stabilization failed, struck Moon.
Oct 22	Luna 12	U.S.S.R.	1,625?	Moon orbit	Success—returned pictures of Moon.
Oct 26	Centaur 5	United States	726	Vehicle test	Success—mass model of surveyor carried to 465,032 km.
Nov 6	Lunar Orbiter 2	do	390	Moon orbit	Success—returned 422 pictures of Apollo sites, far side.
Dec 21	Luna 13	U.S.S.R.	1.595?	Moon soft land	Success—returned pictures and soil density measures.
1967					
Jan 27	Apollo-Saturn 204	United States	20.412	Capsule test	Fail—burned on pad in exercise.
Feb 5	Lunar Orbiter 3	do	385	Moon orbit	Success—returned 307 pictures of Apollo sites.
Apr 17	Surveyor 3	do	1.035	Moon soft land	Success—returned 6,315 pictures, dug soil with shovel.
May 4	Lunar Orbiter 4	do	390	Moon orbit	Success—returned 326 pictures of large areas of the Moon.
[illegible]	Surveyor 4	do	1,039	Moon soft land	Partial—signals ceased at touchdown on Moon.

July 19	Explorer 35	do	104	Moon orbit	Success—returned data from lunar orbit.
Aug. 1	Lunar Orbiter 5	do	390	do	Success—returned 424 pictures including much of far side.
Sept. 8	Surveyor 5	do	1,005	Moon soft land	Success—returned 18,006 pictures, chemical analysis of soil.
Nov. 7	Surveyor 6	do	1,008	Moon soft land	Success—returned 30,065 pictures, chemical and mechanical soil study.
Nov. 9	Apollo 6	do	42,506	Vehicle test	Success—simulated full lunar return reentry in Earth orbit.
1968:					
Jan. 7	Surveyor 7	do	1,040	Moon soft land	Success—returned 21,274 pictures, chemical analysis of soil from trench it dug.
Jan. 22	Apollo 5	do	14,379	Vehicle test	Success—tested lunar module in Earth orbit.
Mar. 2	Zond 4	U.S.S.R	5,375?	do	Partial—flew to lunar distance but recovery in doubt.
Apr. 4	Apollo 6	United States	42,577	Vehicle test	Partial—did not go to lunar distance, but recovered payload.
Apr. 7	Luna 14	U.S.S.R	1,615?	Moon orbit	Success—returned data on lunar mass distribution.
Sept. 14	Zond 5	U.S.S.R	5,375	Circumlunar	Success—ballistic reentry with biological subjects and pictures.
Oct. 11	Apollo 7	United States	20,577	Manned test	Success—flex in Earth orbit.
Nov. 10	Zond 6	U.S.S.R	5,375?	Circumulunar	Success—lifting reentry with biological specimens and pictures.
Dec. 21	Apollo 8	United States	43,654	Moon orbit	Success—men in lunar orbit and recovered.
1969:					
Mar 3	Apollo 9	do	47,167	Manned test	Success—tested lunar module rendezvous, crew recovered.
May 18	Apollo 10	do	48,638	Moon orbit	Success—tested lunar module rendezvous at Moon, crew recovered.
July 13	Luna 15	U.S.S.R	5,600?	Moon soft land	Partial—lunar orbit success, but landing failed.
July 16	Apollo 11	United States	49,698	do	Success—first manned landing on Moon and return.
Aug. 7	Zond 7	U.S.S.R	5,375?	Circumlunar	Success—lifting reentry; color and b/w photographs.
Sept. 23	Kosmos 300	U.S.S.R	5,600?	Moon soft land	Fail—Earth orbit only.
Oct. 22	Kosmos 305	U.S.S.R	5,600?	do	Do.
Nov. 14	Apollo 12	United States	49,804	do	Success—manned lunar-landing and return with part of Surveyor 3.
1970:					
Apr 11	Apollo 13	do	49,990	do	Partial—explosion in service module limited flight to circumlunar; crew saved.
Sept. 12	Luna 16	U.S.S.R	5,600?	do	Success—made automated sample collection, returned it to Earth.
Oct. 20	Zond 8	U.S.S.R	5,375	Circumlunar	Success—ballistic reentry with photographs.
Nov. 10	Luna 17	U.S.S.R	5,600?	Moon soft land	Success—landed automated roving vehicle for long-term exploration.
1971					
Jan 31	Apollo 14	United States	46,346	do	Success—manned lunar landing and return.
July 26	Apollo 15	do	52,759	do	Success—manned lunar landing, roving vehicle, safe return.
Sept. 2	Luna 18	U.S.S.R	5,600?	do	Partial—lunar orbit success, but crashed on landing.
Sept. 28	Luna 19	U.S.S.R	5,600?	Moon orbit	Success—returned photographs and other data.
1972:					
Feb. 14	Luna 20	U.S.S.R	5,600?	Moon soft land	Success—made automated sample collection, returned it to Earth.
Apr. 16	Apollo 16	United States	48,606	do	Success—manned lunar landing, roving vehicle, safe return.
Dec. 7	Apollo 17	do	46,825	do	Do.

TABLE 19.—SUMMARY OF LUNAR DISTANCE FLIGHT ATTEMPTS, 1958-80—Continued

Launch date	Spacecraft name	Nationality	Weight (kg)	Mission	Results
1973:					
Jan. 8	Luna 21	U.S.S.R	5,600?	do	Success—landed automated roving vehicle for long-term exploration.
June 10	Explorer 49	United States	328	Moon orbit	Success—radio astronomy from far side of Moon.
1974					
May 29	Luna 22	U.S.S.R	5,600?	do	Success—returned pictures and data.
Oct. 28	Luna 23	U.S.S.R	5,600?	Moon soft land	Partial—landed safely, but drill damaged so no sample returned to Earth.
1976:					
Aug. 9	Luna 24	U.S.S.R	5,600?	do	Success—made automated sample collection, returned to Earth.

Notes

1. The table includes all known attempts to send payloads to the Moon or to distances from Earth equal to the distance of the Moon from Earth, together with test flights in Earth orbit of lunar-associated hardware. It cannot include Soviet flight failures which did not reach Earth orbit because these are not in the public domain. Hence, the cumulative weight of Soviet payloads almost certainly understates reality.

2. Weights listed are in kilograms

3. In a very few instances, the mission has been assigned by inference, in terms of the context of the time in which it took place.

4. The test of success or failure is somewhat arbitrary. Any flight staying in relatively low Earth orbit as well as not achieving Earth orbit is counted as a failure. Flights which at least approached the Moon, although not achieving the estimated goal received the rating of partial success.

5. The Soviet label Luna was applied after the fact to the first flights which at the time were simply called Cosmic Rockets, with the third one called an Automatic Interplanetary Station (AIS 1). Luna 1 was also called Mechta (Dream).

Sources: Soviet data are from Soviet Tass Bulletins for the most part, supplemented by inferential judgments that some Earth orbital flights were almost certainly lunar attempts which failed, based upon the timing of the launch, the nature of the debris in Earth orbit, the launch vehicle used, and the orbital path chosen. U.S. data are based mostly on NASA press releases, although the first lunar attempt was sponsored and reported on by the Advanced Research Projects Agency (ARPA) of the Department of Defense before the creation of NASA. Estimated weights of Luna 11, 12, 13, and 14 by D.R. Woods. Weights of Luna 15 through Luna 24 and Zond 4-8 were estimated by the Royal Aircraft Establishment.

TABLE 20.—CLASSIFICATION OF SOVIET LUNAR RELATED PAYLOADS BY FLIGHT PERFORMANCE

Year	Intended to be suborbital only	Intended for Earth orbit but failed	Intended for Earth orbit and succeeded	Intended for lunar distance but failed	Intended for lunar distance but Earth orbit only	Intended for lunar distance and succeeded	Total lunar related	Subtotal landed on Moon	Subtotal orbited Moon	Subtotal returned from Moon to Earth
1957										
1958						3A	3A	1A		
1959										
1960										
1961										
1962										
1963					1A	1A	2A			

1964								
1965			1A	4A	5A	3A		
1966			1A	5A	6A	2A	3A	
1967	1R		2R		3R			
1968				1A3R	1A3R		1A	2R
1969			2A	1A1R	3A1R	1A	1A	1R
1970	2R			3A1R	3A3R	2A	2A	1A1R
1971	2R			3A	3A2R	1A	2A	
1972				2A	2A	1A	1A	1A
1973				1A	1A	1A	1A	
1974				3A	3A	1A	2A	
1975								
1976				2A	2A	1A	1A	1A
1977								
1978								
1979								
1980								
Total	5R		5A2R	29A5R	34A12R	14A	14A	3A4R

Notes.

1 Suffixes: A Automated payloads; R Man-related payloads; M Manned payloads.

2 For the purposes of this table, Kosmos 159 in 1967, Kosmos 379 in 1970, and Kosmos 398 and 434 in 1971 are counted as man-related lunar-related flights although this is not provable in an absolute sense. This accounts for the difference of 4 between the counts of lunar man-related in table 10 of part 1 p. 32 and this table.

3 This table explains the difference in numbers between lunar flights and flights which traveled as far away as the Moon.

4 Almost certainly there have been lunar failures which did not attain even Earth orbit, and therefore the listing is incomplete.

5 The table does not include Zond 3 of 1965, a Mars diagnostic flight which also returned lunar pictures.

6 The payload count exceeds the launch count by 5 because of sample returners, 3 of which returned to Earth.

TABLE 21.—CLASSIFICATION OF U.S. LUNAR RELATED PAYLOADS BY FLIGHT PERFORMANCE

Year	Intended to be suborbital only	Intended for Earth orbit but failed	Intended for Earth orbit and succeeded	Intended for lunar distance but failed	Intended for lunar distance but Earth orbit only	Intended for lunar distance and succeeded	Total lunar related	Subtotal landed on Moon	Subtotal orbited Moon	Subtotal returned from Moon to Earth
1957										
1958				4A						
1959				2A			4A			
1960				2A		1A	3A			
1961	1R				2A		2A			
1962	1A2R					3A	2A1R			

TABLE 21.—CLASSIFICATION OF U.S. LUNAR RELATED PAYLOADS BY FLIGHT PERFORMANCE—Continued

Year	Intended to be suborbital only	Intended for Earth orbit but failed	Intended for Earth orbit and succeeded	Intended for lunar distance but failed	Intended for lunar distance but Earth orbit only	Intended for lunar distance and succeeded	Total lunar related	Subtotal landed on Moon	Subtotal orbited Moon	Subtotal returned from Moon to Earth
1963	3R		1A				4A2R	1A		
1964	2R	1A	1A3R			2A	1A3R			
1965	2R		3R	1A		3A	4A5R	2A		
1966	3R	(1M)	1R		1A	6A	4A5R	2A	2A	
1967			1R			8A	7A4R(1M)	2A	4A	
1968			3R1M			1A1M	8A1R	4A	1M	1M
1969			2M			6M	1A3R2M	1A	3M	3M
1970						1R2M	8M	2M		1M
1971						3R4M	1R2M		2M	2M
1972						3R4M	3R4M	2M	2M	2M
1973						1A	1A	2M	1A	
1974										
1975										
1976										
1977										
1978										
1979										
1980										
Total	1A13R	1A(1M)	2A11R3M	9A	3A	25A7R17M	41A31R21M	12A6M	7A8M	9M

Notes

1. This table can be reconciled with table 11 in part 1 of the study, but only by noting a complex set of adjustments. Suffixes: A—Automated payloads; R—Man-rated payloads; M—Manned payloads.

TABLE 22.—WORLD SUMMARY OF PLANETARY DISTANCE FLIGHT ATTEMPTS, 1960–80

Launch date	Spacecraft name	Nationality	Weight (kg)	Mission	Results
1960:					
Mar. 11	Pioneer	United States	43	Interplanetary toward Sun	Success—returned data from 36.2 million kilometers.
Oct. 10	Unacknowledged	U.S.S.R	640?	Mars	Fail—did not reach Earth orbit.
[illegible]	do	U.S.S.R	640?	do	Do.

1961:					
Feb. 4	Tyazheliy Sputnik 4	U.S.S.R	640?	Venus	Fail—Earth orbit only.
Feb. 12	Venera 1	U.S.S.R	644	do	Partial—communications failed, passed Venus at 100,000 km.
1962:					
July 22	Mariner 1	United States	202	Venus flyby	Fail—destroyed at 160 km. altitude.
Aug 25	Unacknowledged	U.S.S.R	890?	Venus	Fail—Earth orbit only.
Aug. 27	Mariner 2	United States	203	Venus flyby	Success—passed Venus at 34,853 km.
Sept. 1	Unacknowledged	U.S.S.R	890?	Venus	Fail—Earth orbit only.
Sept. 12	do	U.S.S.R	890?	do	Do.
Oct. 24	do	U.S.S.R	890?	Mars	Do.
Nov. 1	Mars 1	U.S.S.R	894	do	Partial—communications failed, passed Mars at 191,000 km.
Nov 4	Unacknowledged	U.S.S.R	890?	do	Fail—Earth orbit only.
Nov 11	Kosmos 21	U.S.S.R	890?	Venus test	Do.
1964					
Mar 27	Kosmos 27	U.S.S.R	890?	Venus	Do.
Apr. 2	Zond 1	U.S.S.R	890?	do	Partial—communications failed, passed Venus at 100,000 km.
Nov 5	Mariner 3	United States	261	Mars flyby	Fail—shroud did not separate, thrown into wrong orbit.
Nov 28	Mariner 4	do	261	do	Success—returned 22 pictures.
Nov 30	Zond 2	U.S.S.R	890?	Mars	Partial—communications failed, passed Mars at 1,500 km.
1965					
July 18	Zond 3	U.S.S.R	890?	Mars test	Success—returned 25 pictures of Moon far side, retransmitted from increasing distances.
Nov 12	Venera 2	U.S.S.R	963	Venus flyby	Partial—communications failed.
Nov 16	Venera 3	U.S.S.R	960	Venus land	Partial—communications failed. Struck Venus 450 km. from visible center.
Nov 23	Kosmos 96	U.S.S.R	960?	Venus	Fail—Earth orbit only.
Dec. 16	Pioneer 6	United States	61	Interplanetary toward Sun	Success—returned data.
1966					
Aug. 17	Pioneer 7	do	61	Interplanetary away from Sun	Do.

TABLE 22.—WORLD SUMMARY OF PLANETARY DISTANCE FLIGHT ATTEMPTS, 1960-80—Continued

Launch date	Spacecraft name	Nationality	Weight (kg)	Mission	Results
1967:					
June 12	Venera 4	U.S.S.R	1,106	Venus land	Success—returned direct readings of atmosphere to 25 km. altitude.
June 14	Mariner 5	United States	245	Venus flyby	Success—returned data, passed Venus at 4,094 km.
June 17	Kosmos 167	U.S.S.R	1,100?	Venus	Fail—Earth orbit only.
Dec 13	Pioneer 8	United States	66	Interplanetary away from Sun	Success—returned data.
1968:					
Nov. 8	Pioneer 9	do	67	Interplanetary toward Sun	Do.
1969:					
Jan 5	Venera 5	U.S.S.R	1,130	Venus land	Success—returned direct readings of atmosphere to near surface.
Jan. 10	Venera 6	U.S.S.R	1,130	do	Do.
Feb. 25	Mariner 6	United States	380	Mars flyby	Success—returned 24 pictures and other data.
Mar. 27	Mariner 7	do	380	do	Success—returned 31 pictures and other data.
Xxx XX	Unacknowledged	U.S.S.R	4,650?	Mars soft land	Fail—did not reach Earth orbit.
Xxx XX	Unacknowledged	U.S.S.R	4,650?	do	Do.
Aug 27	Pioneer E	U.S.S.R	66	Interplanetary at Earth orbit	Fail—destroyed by range safety.
1970:					
Aug. 17	Venera 7	U.S.S.R	1,180	Venus soft land	Success—sent back data from atmosphere and surface of Venus.
Aug 22	Kosmos 359	U.S.S.R.	1,180	do	Fail—Earth orbit only.
1971					
May 8	Mariner 8	United States	1,029	Mars orbit	Fail—fell in Atlantic Ocean.
May 10	Kosmos 419	U.S.S.R	4,650?	Mars soft land	Fail—Earth orbit only.
May 19	Mars 2	U.S.S.R	4,650	do	Partial—returned data from orbiter, but lander destroyed.
May 28	Mars 3	U.S.S.R	4,650	do	Success—returned orbital data and survived landing.
May 30	Mariner 9	United States	1,030	Mars orbit	Success—returned 6,786 pictures of Mars.

1972:					
Mar. 3	Pioneer 10	do	258	Jupiter flyby	Success—returned pictures and other data.
Mar 27	Venera 8	U.S.S.R	1,180?	Venus soft land	Success—atmospheric data and soil analysis returned.
Mar. 31	Kosmos 482	U.S.S.R	1,180?	do	Fail—Earth orbit only.
1973:					
Apr. 6	Pioneer 11	United States	259	Jupiter, Saturn flyby	Success—returned Jupiter and Saturn pictures and data.
July 21	Mars 4	U.S.S.R	4,150?	Mars orbit	Partial—returned data from flyby, but did not enter orbit.
July 25	Mars 5	U.S.S.R	4,150?	do	Success—returned data and pictures.
Aug. 5	Mars 6	U.S.S.R	4.150?	Mars soft land	Partial—returned data from flyby, but lander signals ceased.
Aug. 9	Mars 7	U.S.S.R	4,150?	do	Partial—returned data from flyby, but lander missed by 1,300 km.
Nov 3	Mariner 10	United States	504	Venus, Mercury flyby	Success—returned pictures from Venus and pictures from Mercury three times.
1974 Dec. 10	Helios 1	G.F.R/U.S	370	Sun approach	Success—returned data.
1975:					
June 8	Venera 9	U.S.S.R	4,936	Venus soft land	Success—returned pictures and other data.
June 14	Venera 10	U.S.S.R	5,033	do	Do.
Aug 20	Viking 1	United States	3,400	Mars soft land	Do.
Sept 9	Viking 2	do	3,400	do	Do.
1976					
Jan. 15	Helios 2	G.F.R./U.S	376	Sun approach	Success—returned data.
1977					
Aug. 20	Voyager 2	United States	700	ter, Saturn, Uranus flybys	Success—returned pictures and data from Jupiter and Saturn en route to Uranus.
Sept. 5	Voyager 1	do	700	Jupiter, Saturn flybys	Success—returned pictures and data from Jupiter and Saturn.
1978					
May 20	Pioneer Venus 1	do	549	Venus	Success—returned data and pictures.
Aug 8	Pioneer Venus 2	do	904	Venus probe	Success—five vehicles returned direct data from atmosphere.

TABLE 22.—WORLD SUMMARY OF PLANETARY DISTANCE FLIGHT ATTEMPTS, 1960–80—Continued

Launch date	Spacecraft name	Nationality	Weight (kg)	Mission	Results
Sept. 9	Venera 11	U.S.S.R	3,940?	Venus soft land	Success—returned data from surface.
Sept. 14	Venera 12	U.S.S.R	3,940?	do	Do.

Notes

1 The table includes all known attempts to send payloads to the planets or into solar orbit, not including those intended to go to the Moon which only incidentally may have escaped barycentric orbit to enter heliocentric orbit. The only year in which there had been persistent reports of Soviet intentions to launch planetary flights for which there is no public record of failure dates is 1969 This could mean that Mars flights using the D-1-e vehicle began in that year, but failed to reach Earth orbit

2 Weights listed are in kilograms

3 In a few instances, the mission has been assigned by inference, in terms of the context of the time in which it took place Some of the Soviet flights to the planets may have been orbiters or landers, but no attempt has been made to guess the mission other than that of the planet name

4 The test of success or failure is somewhat arbitrary. Any flight staying in relatively low Earth orbit as well as those not achieving Earth orbit are counted as failures. Flights at least approaching interplanetary distances although not achieving their estimated goal received the rating of partial success

Sources Soviet data are from Soviet Tass Bulletins for the most part, supplemented by inferential judgments that some Earth orbital flights were almost certainly planetary attempts which failed, based on the timing of the launch, the nature of the debris in Earth orbit, the launch vehicle used, and the orbital path chosen. U.S data are based mostly on NASA press releases. Weight estimates for the more recent Mars and Venus flights by the Russians have been varied from the weight of Mars 2 and 3 at the suggestion of D R Woods and C P Vick, to reflect approximate requirement effects on payloads.

TABLE 23.—CLASSIFICATION OF SOVIET INTERPLANETARY RELATED PAYLOADS BY FLIGHT PERFORMANCE

Year	Intended to escape but failed	Intended to escape but Earth orbit only	Intended to escape and succeeded	Total interplanetary missions	Subtotal interplanetary inward	Subtotal interplanetary outward	Subtotal to Mercury	Subtotal to Venus	Subtotal to Mars	Subtotal to Jupiter	Subtotal to Saturn
1957											
1958											
1959											
1960	2M			2M							
1961		1V	1V	2V				1F			
1962		3V2M	1M	3V3M					1F		
1963		1V		1V							
1964		1V	1V1M	2V1M				1F	1F		
1965		1V	2V1M	3V1M				1F1L			
1966											
1967		1V	1V	2V				1L			
1968											
1969	(2M)		2V	2V(2M)				2L			

1970		1V	1V	2V				1L			
1971		1M	4M	5M					2L2O		
1972		1V	1V	2V				1L			
1973			6M	6M					1L2F1O		
1974											
1975			4V	4V				2L2O			
1976											
1977											
1978			4V	4V				2L2F			
1979											
1980											
Total	4M	10V3M	17V13M	27V20M				5F10120	4F3L3O		

Notes:

1. Suffixes: M-Mars, V-Venus, F-Flyby of planet, L-Landing on planet, O-Orbit of planet.
2. The totals in this table are consistent with table 10 of part 1 of the study, if one notes the 2 positive 2 probable Mars failures.
3. Venus related launchings were 23, including 2 diagnostic flights in 1963 and 1964; the added 4 payloads in the table resulted from double payload flights on single launches.
4. Mars related launchings were 16, including 4 failures and 1 diagnostic flight in 1965; the added payloads in the table resulted from double payload flights on single launches. Note the diagnostic flight, Zond 3 escaped, but did not fly near Mars, one orbiter executed a flyby instead, and one lander also executed a flyby instead.
5. It is possible that there have been other planetary launch failures not reflected in the table.

TABLE 24.—CLASSIFICATION OF U.S. INTERPLANETARY RELATED PAYLOADS BY FLIGHT PERFORMANCE

Year	Intended to escape but failed	Intended to escape but Earth orbit only	Intended to escape and succeeded	Total interplanetary missions	Subtotal interplanetary inward	Subtotal interplanetary outward	Subtotal to Mercury	Subtotal to Venus	Subtotal to Mars	Subtotal to Jupiter	Subtotal to Saturn
1957											
1958											
1959											
1960			1H	1H	1						
1961											
1962	1V		1V	2V		1		1F			
1963											
1964			2M	2M					1F		
1965			1H	1H	1						
1966			1A	1A		1					
1967			1V1A	1V1A		1		1F			
1968			1H	1H	1						
1969	1H		2M	1H2M					2F		

TABLE 24 —CLASSIFICATION OF U.S. INTERPLANETARY RELATED PAYLOADS BY FLIGHT PERFORMANCE¹—Continued

Year	Intended to escape but failed	Intended to escape but Earth orbit only	Intended to escape and succeeded	Total interplanetary missions	Subtotal interplanetary inward	Subtotal interplanetary outward	Subtotal to Mercury	Subtotal to Venus	Subtotal to Mars	Subtotal to Jupiter	Subtotal to Saturn
1970											
1971	1M		1M	2M					10		
1972			1J	1J						1F	
1973			1MeV1JS	1MeV1JS						1F	1F
1974			1H	1H	1		1Fx3	1F			
1975			4M	4M					202L		
1976			1H	1H							
1977			2JS	2JS						2F	2F
1978			6V1H	6V1H	1			105L			
1979											
1980											
Totals	1V1H1M		6H8V2A9M	7H9C2A10M	5	3	1Fx3	3F105L	3F302L	4F	3F

Notes

1 Suffixes H-Inward toward Sun A-Away from Sun Me-Mercury V-Venus M-Mars J-Jupiter S-Saturn F-Flyby O-Orbiter L-Lander
2 The totals in this table are consistent with the count in table 11 of part 1 of this study
3 Venus related launches totaled 6 including 1 which continued to Mercury for three visits to that planet The landing mission included 5 payloads—4 landers and a bus
4 Mars related launches totaled 8, including 1 which escaped Earth but went nowhere near the planet, and 2 which carried both orbiters and landers.
5 Three of the 4 Jupiter payloads have continued or will continue to Saturn at least 1 will later visit Uranus.

Sources See Appendix F of U S Civilian Space Programs published by the House Science and Technology Committee in 1981

TABLE 25.—SUMMARY OF PLANETARY WINDOWS

Year	Venus		Mars	
	Soviet Union	United States	Soviet Union	United States
1960			F,F	None.
1961	F, Venera 1	None		
1962	F,F,F	Mariner 1, Mariner 2	F, Mars 1, F	None.
1963				
1964	F, Zond 1	None	Zond 2 (Zond 3)	Mariner 3, Mariner 4.
1965	Venera 2, Venera 3, F	None		
1966				
1967	Venera 4, F	Mariner 5	None	None.
1968				
1969	Venera 5, Venera 6	None	F,F	Mariner 6, Mariner 7.
1970	Venera 7, F	None		
1971			F, Mars 2, Mars 3	Mariner 8, Mariner 9.
1972	Venera 8, F	None		
1973	None	Mariner 10	Mars 4, Mars 5, Mars 6, Mars 7.	None.
1974				
1975	Venera 9, Venera 10	None	None	Viking 1, Viking 2.
1976				
1977	None	None	None	None.
1978	Venera 11, Venera 12	Pioneer Venus 1, Pioneer Venus 2.		
1979			None	None.
1980	None	None		

Notes:

1. The table reflects launches (including unacknowledged failures (F) to Mars and to Venus by the Soviet Union and the United States) at each most favorable (minimum energy) launch opportunity.
2. Venus opportunities come every 19 months and a fraction; Mars opportunities come every 25 months and a fraction; exact intervals depend upon the year because of slight eccentricities in the orbits of the planets.
3. The Soviet pattern was to use every opportunity, skipping a first time in the case of each planet when they were making the transition from the standard launch vehicle to the Proton size of launch vehicle (A-2-e to D-1-e). Since that first non-use of the opportunity, additional blanks appear for reasons of expense and technological discouragement. The U.S. pattern has included a much larger number of skipped opportunities, mostly for budgetary reasons.

Sources: Summarized from other tables accompanying this chapter.

Chapter 4

Applications of Space to the Soviet Economy

EARLY RECOGNITION OF POTENTIAL USES OF APPLICATIONS SATELLITES

Although Soviet writers early recognized the potential applications of satellites to a wide variety of practical uses, including communications relay,[1] direct broadcast, weather observation,[2] navigation[3] and traffic control, study of Earth resources, and development of permanent manned stations in orbit which would perform many tasks,[4] the Russians were initially slow to exploit space. Whereas the first civil applications satellites appeared in the U.S. program in 1958, the year of the first successful American flight, equivalent Soviet flights were delayed until 1965. Thus, despite seemingly advanced space exploitation technology, the Russians did not move as rapidly from first flights to operational systems as did the Americans.

COMMUNICATIONS SATELLITES

With its vast underdeveloped areas, the Soviet Union benefits greatly from communications satellites. Regions which are remote and difficult to reach are interconnected by satellite without the expense of laying cable through difficult terrain to operate under harsh weather conditions. Through the use of satellites, reliable telephone and television service can be brought inexpensively to all parts of the Soviet Union. In view of such geographic and economic advantages, it is not surprising that the first satellite domestic distribution system in the world was the Soviet Orbita system.

EARLY EXPERIMENTS

At the International Astronautics Federation annual meeting in Stockholm, in August 1961, Arnold W. Frutkin, Director of NASA's International Programs, suggested to Academician Anatoliy A. Blagonravov, of the Soviet Academy of Sciences, that the two nations communicate with each other by means of the balloon satellite, Echo 1, as a gesture of friendliness and a step toward cooperation.

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[1] Shmakov, P.V. Tekhnika Kino i Televideniya No. 4, 1960, pp. 3-7.

[2] Kondrat'yev, K Ya. Uspekhi Fizicheskikh Nauk, vol. 74, No. 2, 1961, pp. 193-222.

[3] Siforov, V I. Priroda No. 6, 1966, pp. 2-3.

[4] Bubnov, I.N., and L.N. Kaminin "Manned Space Stations," Voyennoye Izdatel'stvo Ministerstva Oborony SSSR, Moscow 1964.

On discovering that the height of the orbit did not provide the mutual visibility necessary for a direct link, it was agreed that the Nuffield Radio Astronomical Observatory of the University of Manchester at Jodrell Bank, England, would be used as the U.S. terminal through the conventional transatlantic submarine cable.

Although such an aim was never achieved, an agreement reached on June 8, 1962, between Dr. Hugh L. Dryden, Deputy Administrator of NASA, and Academician Blagonravov to conduct experimental passive communications transmissions using Echo 2, was fulfilled in part during February and March 1962. The plan called for unmodulated and modulated carrier, teletype, slowed speech, facsimile, and telegraph (Morse code) two-way transmissions to be beamed via the satellite between Jodrell Bank and the radioastronomical facility of the Gorkiy State University at Zemenski. Only transmissions from Jodrell Bank were made.[5]

Although space communications in the form of command controls had been tested in many previous Soviet flights, and voice and television circuits were tested as early as 1960 in the Korabl Sputnik series, Kosmos 41 which was launched August 22, 1964, was the first clear precursor of the present Soviet operational communications satellite system.

At the time, Kosmos 41 was given no special description or publicity. It could not be judged from published sources whether this flight was designed only to test the mechanics of achieving a 12-hour semi-synchronous orbit, and to gather geophysical data and information on the durability of solar cells in exposure to the space environment at those altitudes, or whether the mission was intended as the first of the Molniya 1 flights, and the communications part of the payload suffered a catastrophic failure. However, as soon as the orbital elements were published, Western observers were able to identify its most likely mission as being associated with plans for a communications satellite. This was confirmed in 1969.[6]

THE MOLNIYA AND ORBITA SYSTEMS

The first Molniya 1 (Lighting) satellite was launched on April 23, 1965, in a flight nearly parallel to that performed by Kosmos 41 the previous year. Molniya 1 was described as having the main task of relaying television programs, long distance bilateral, multichannel telephone, radiophoto, and telegraph communications. Two days after the launch, the first television broadcast was relayed from Moscow to Vladivostok through Molniya 1. On the 27th of April, a return program was carried from Vladivostok to Moscow for further distribution by land line to all the Soviet bloc country members of the Intervision system.

Since the initial orbit attained was not precisely 12 hours, the satellite would not repeat the same ground trace. Hence, on May 4, 1965, it was announced that correction engines had been fired to perfect the orbit to that originally hoped for, so that it would not

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[5] Kalashnikov, N.V., I. Ya. Kantor and V.I. Bykov. Elektrosvyaz, vol. 19, No. 7, 1965, pp. 25-9.

[6] Pravda, Moscow, Sept. 21, 1969, p. 3.

gradually drift to a less desirable position in relation to Soviet ground stations.

Molniya 2 and Molniya 3 series satellites appeared as time went by and, at one time, all three types were operational simultaneously. The Molniya 2 satellites were phased out and currently eight Molniya 1 and four Molniya 3 satellites are operational at any one time. Molniya provided the first routine color relays and forms the basis of a Washington-Moscow "hotline".

From time to time there are reports of results obtained from scientific instruments carried onboard Molniya satellites. As described later in this chapter, the third and fourth Molniya-1s transmitted TV cloud-cover pictures back to Earth.[7] [8] Molniya satellites have also been used to study particle flows within the radiation belts surrounding the Earth. Two simultaneously operating Molniya 1 satellites were used in January and July, 1971, during magnetic storms of different intensities to investigate the dynamics or relativistic electrons in the outer belt inside and outside the plasmasphere,[9] and a Molniya-2 satellite gathered data on protons and alpha-particles on October 25, 1975.[10]

DESCRIPTION OF MOLNIYA 1

The Molniya 1 is a complex craft somewhat similar to the early lunar and planetary craft. The main body is a pressurized cylinder with conical ends and external cooling/heating coils, related to the temperature regulating system, which are wrapped around the main cylinder. There are also small correcting rockets to maintain the attitude of the spacecraft in the required position. Atop the main cylindrical body are the special correction motor system and Sun-seeking optical sensors. This subsystem is conical in shape and is surrounded by a ring of gas bottles containing fuel for the correction system.

At the opposite end of the main body are Earth-seeking optical sensors. Extending from either side of the main body are the structures for two high-gain antenna systems, steerable parabolic dishes used for the main communications tasks. Also, at the bottom of the main body are six fairly long panels which fold outward to radiate from the main body like petals on a daisy. These are covered with solar cells to power the craft. They generate 500–700 watts over a long period of time. Figure 33 shows this configuration.

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[7] Isvestiva, Moscow, May 20, 1966, p 6

[8] Krasnava Zvezda, Moscow, Oct 22, 1966, p 1

[9] Senchuro, I N and P I Sharin, Kosmicheskiye Issledovaniya, vol [illegible], No 5, 1982, pp. 712-717

[10] Panasyuk, M I and N A Vlasova, Kosmicheskiye Issledovaniya, vol 19, No 1, 1981, pp 76-81

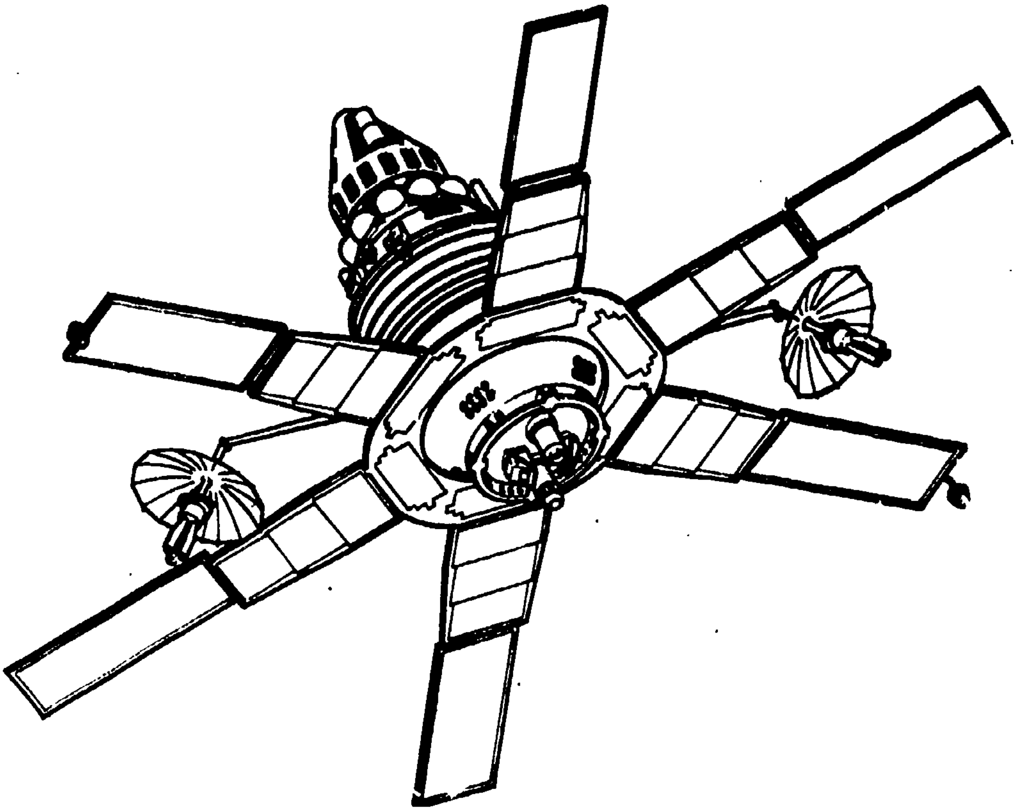

FIGURE 33.—Molniya 1 Satellite

Inside the craft are the main communications receivers and transmitters, the buffer batteries, various sensors and telemetry systems, an on-board computer, and other necessary equipment for housekeeping and control.

The directional parabolic antennas have a gain of approximately 18 db. According to a Soviet account, the Molniya 1 Sun sensor locks onto the Sun to maximize the power for the solar cell system, and there is a gyrostabilizer to maintain this attitude. The Earth seekers then lock onto Earth and are used to point the parabolic antennas to maximize signal strength. The ground stations on Earth also track the satellite and point their own antennas directly at the satellite. The two antennas are not used simultaneously. The second antenna is supplied for redundancy to extend useful life.[11]

In 1976, Maarten Houtman of the Netherlands noticed that the Molniya 1 displayed in the State Tsiolkovskiy Museum of the History of Kosmonautics at Kaluga had a four-helix array surrounding the horn. A photograph of this was published in The Royal Air Forces Quarterly.[12]

The communications equipment of the satellite includes three complete transceiver systems, one active, and two as standby in the

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[11] Aviatsiya i Kosmonavtika, No. 7, 1968, pp. 17-20.

[12] Perry, G.E. R.A.F. Qy., London, vol. 17, No. 2, summer 1977, p. 157.

interest of redundancy to extend operational life. Most of the equipment is solid state except for metal-ceramic triodes, klystrons, magnetrons and traveling wave tubes. The useful life of the tubes is 40-50 thousand hours. Although in the first models the input noise level was 2,000-3,000 °K, tunnel diodes were soon to reduce this by a factor of 2 to 3. There are four traveling wave tubes, used, three active, and one as a spare. Television service is provided in a frequency range from 3,400 to 4,100 MHz, and other telecommunications in a frequency range from 800 to 1,000 MHz. Television is transmitted at a power level of 40 watts, and data and telephony at 20 watts.

The capability of the payload includes a complete television channel with additional capability for television audio, multichannel telephony, VHF telegraphy (by multiplexing some of the telephone channels), and photofacsimile.[13]

DESCRIPTION OF MOLNIYA 2

On November 24, 1971, the U.S.S.R. launched its first Molniya 2 communications satellite. The same launch vehicle was used for the Molniya 1 launch so it may be presumed that there was no great increase in the size and weight of the satellite and that the main improvement lay in the electronics. Solar panels were increased, adding about 50 percent to the power. With the change to the higher four and six gigahertz (GHz) frequencies, the earlier umbrella-like antennas with their clusters of three horns were replaced by arrays of five horns each. This configuration is shown in figure 34.

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[13] Aviatsiya i Kosmonavtika. No. 7, 1968, pp. 17-20.

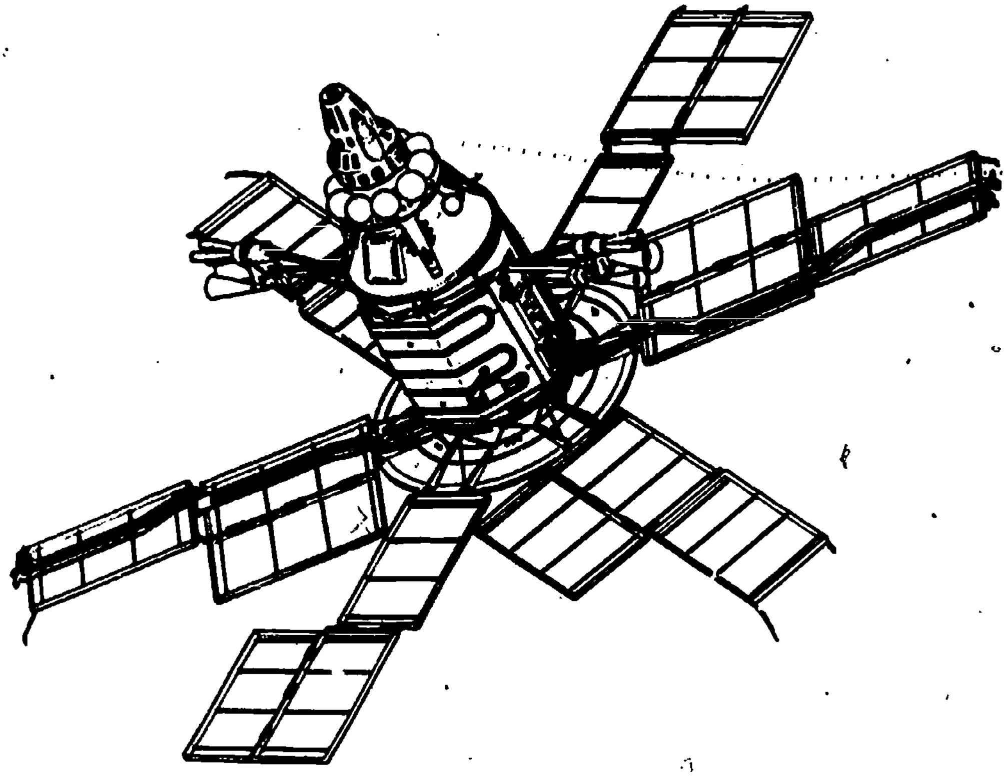

FIGURE 34.—Molniya 2 Satellite

The Molniya 2 announcements mentioned "international cooperation," a phrase absent from standard Molniya 1 announcements. It had been suggested that this, along with the use of higher frequencies, may have suggested a move toward compatibility with the Intelsat system,[14] but this now looks less probable

DESCRIPTION OF MOLNIYA 3

The first Molniya 3 was launched on November 2, 1974. To date, no model of the spacecraft has been put on public display. The principal difference between Molniya 3 and Molniya 2 satellites seems to be its color television relay and higher communications frequencies. Earlier Molniyas broadcast mainly black and white television and numerous experimental color programs.

THE ORBITA SYSTEM

Orbita is the name used to describe the total complex of ground stations used in conjunction with dedicated communications satellites. Each can receive television transmissions relayed through geosynchronous and Molniya satellites, with further relay to the surrounding area. Additionally, the Orbita stations can receive and

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[14] Flight International. Feb. 8, 1973. p. 206a.

transmit telephone, telegraph, facsimile, and weather data via the Molniya satellites.

The first year of operations was limited to tests between Moscow and Vladivostok of the several types of service possible through the system. By 1966, the first phase of installation of Orbita stations was completed to make service more widespread. Each later year has brought an additional increment of ground stations. A special effort was made to have the Orbita system operational over much of the country by the fall of 1967 the celebrations of the 50th anniversary of the U.S.S.R. On November 2, 1967, operations opened to 23 points for regular service to 100 million persons.[15] Another concentrated effort to add stations in more remote regions of the Arctic and eastern Siberia was made before the celebration of the centenary of Lenin's birth in 1970.

The number of ground stations increased as time went by and, by the end of 1981 some 90 stations were installed in many political-administrative centers and large cities of the Soviet Union. The introduction of the Moskva system see p. 933) and the addition of satellites in geosynchronous orbits has not diminished the importance of the Orbita network.[16]

Television signals are transmitted from television studios in Moscow through ground communications channels to one of the ground transmitting stations for communicating with a satellite. They are then emitted through the ground station's antenna to the satellite where, after reception, they are relayed immediately to all receiving stations of the Orbita network located at the time in question in the zone of mutual radio contact from satellites and set aside for working with each specific type of satellite.

Television signals received by the Orbita ground station from the satellite are sent to the local television center through wideband cable lines and over considerable distances by a radio relay link. Finally, the local television center by means of its transmitter and television antenna transmits and relays the television program received through the Orbita network to ordinary collective- or individual-use station antennas.

Selection of the positions of Orbita ground stations, in addition to consideration of the convenience of placement of a direct connection by cable or microwave link to the local television center, takes into account the influence of industrial interference and avoidance, whenever possible, of intersection of the ground-satellite-ground lines of sight with air routes.[17]

Many of the ground stations are "transceiver" stations. This means that they can be used not only to receive television programs from Moscow, but also to transmit locally produced programs to the capital.[18]

A great number of telephone conversations or relays of radio broadcasts can also be carried via the Orbita transceiver stations using a frequency-division-multiplex system. Each telephone channel of 3 kHz bandwidth can accommodate up to 20 telegraph tele-

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[15] Moscow Radio, Oct. 26, 1967, 1900 G m t

[16] Agadzhanov, P A., A.A. Bol'shoy and V.I Galkin. Communications Satellites. Izdatel'stvo Znaniye. 1981, p 64

[17] Idem

[18] Svoren, R Nauka i Zhizn. December 1981

printer signals, each of which requires only a 50-60 Hz bandwidth. The Orbita system is also used to send pages of the central newspapers, such as Pravda and Izvestiya, to remote regions so that local printers can make up the printing matrices at virtually the same time as in Moscow, whereas previously they had to be delivered by aircraft.

The space segment currently consists of one Molniya 3 satellite in its highly elliptical orbit with Raduga satellites at Statsionar 2 (35 °E) and Statsionar 3 (85 °E).[19]

Description of a typical Orbita ground station

Orbita stations are circular and constructed of reinforced concrete. The roof of each station serves as a foundation for the installation of a high-efficiency, fully rotatable, parabolic antenna 12 m in diameter. The antenna design allows for operation of a temperature range from −50 to +50 °C and at wind speeds up to 36 m/s. A shaped feed horn contributes to the utilization factor for the surface of the antenna of approximately 0.7 in the 4/6 GHz band. The gain/temperature specification for stations with these antennas is 31 dB/K. For several links 25-meter antennas are employed.

Antenna pointing is effected by the use of electric motor drives. The tracking system controlling these drives can operate in either the programmable or autotracking mode.

The antenna-pointing apparatus, receiving equipment, and the switchboard which transfers the signal to and from local land lines together with the associated conversion equipment is housed in a central hall beneath the antenna.

Separate compartments and rooms located around the outside of the central hall contain the air conditioning and cooling for the entire apparatus and the control system for the antenna-pointing equipment. An additional block is necessary for equipment to separate the audio and video signal components.[20]

Figure 35 is a drawing of a typical Orbita ground station.

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[19] Idem.

[20] Pravda. Moscow, Oct. 29, 1967, p. 3; Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, National Paper: U.S.S.R., A/CONF. 101/NP/30. Sept. 2, 1981; Agadzhanov, P.A., et al., idem.

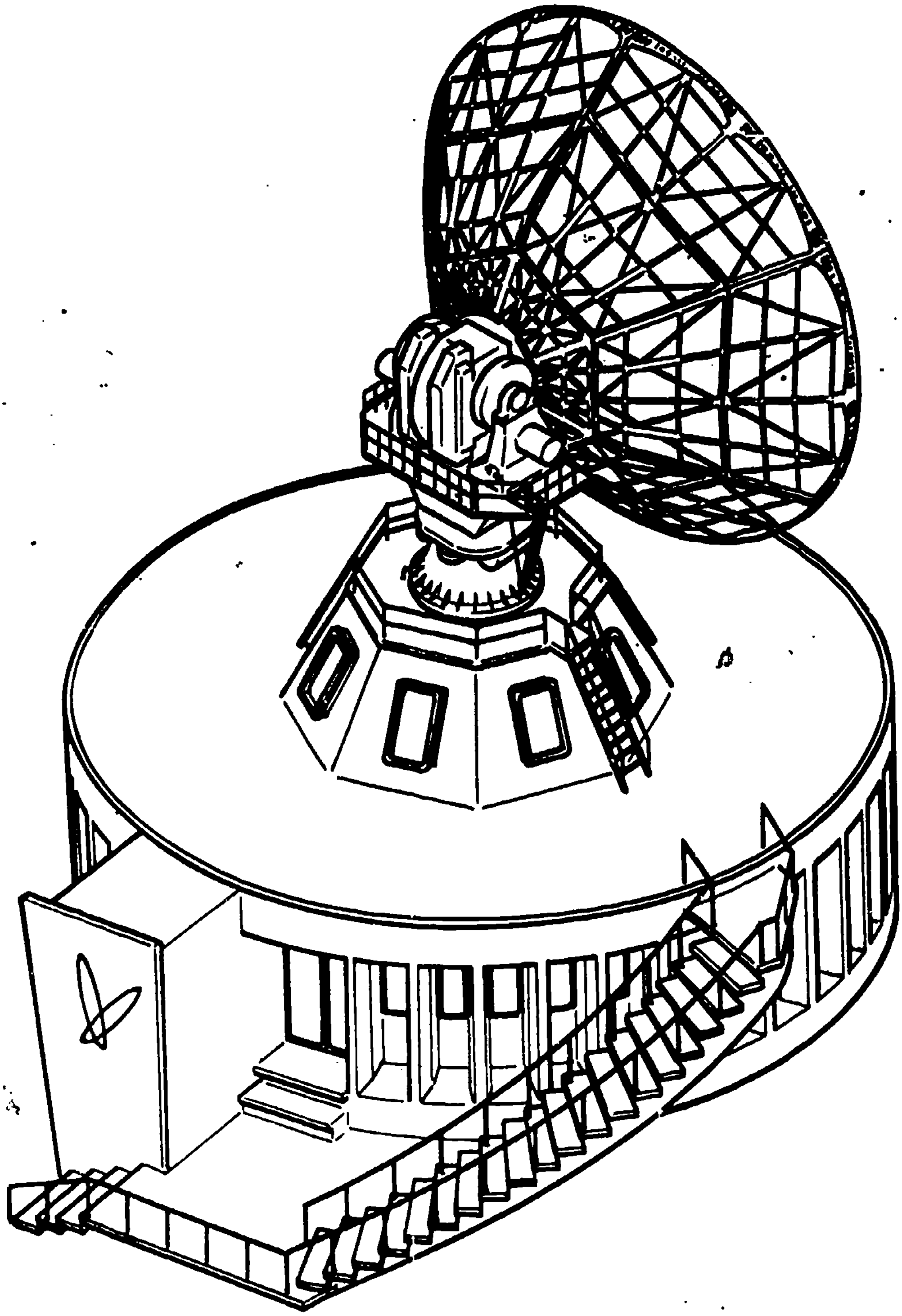

FIGURE 35.—Orbita Ground Station

The operation of each of the Orbita stations is similar. The signals from the antenna are fed through the wave-guide to the band-pass filter, through two low-noise parametric amplifiers, which increase signal strength 100 million times, and then on to the rest of the receiving terminal equipment. The first parametric amplifier is cooled by liquid nitrogen and operates without frequency conversion. The second parametric amplifier is not cooled and operates with a double frequency conversion. For operating convenience, even at the cost of some noise, all the receiving equipment is located in the same chamber. The equipment is mounted on a standard bay with an IF filter and preamplifier, as well as quartz crystal heterodyne oscillator with a frequency multiplier and an additional IF filter which prevents overload of the amplifiers by locally generated noise. A tunable beat frequency oscillator is included to provide for manual tuning of the signal in addition to automatic tuning provided by the quartz crystal heterodyne oscillator with a frequency multiplier.[21]

The quality of the television picture output from the ground stations is, in most respects, fully adequate by international standards. The scanning standard is 625 lines/frame, 25 frames/second with audio integral to the video band on a PCM basis. The signal is transmitted from the Orbita ground station to the local broadcast television station by a single hop, point-to-point microwave or coaxial cable link. Further improvements in the Orbita stations have been adding the capability of sending and receiving radio telephone and facsimile signals between the station and six Molniya satellites. Still other equipment being added to Orbita stations will greatly expand their capacity to provide the complete range of telecommunications activity, including computer data relay.[22]

Location of ground stations

When the first phase of Orbita station location was complete in November 1967, there were two-way transmission stations at Moscow and Vladivostok as well as receiving stations at Murmansk, Arkhangelsk, Skytyvkar, Ashkabad, Frunze, Alma-Ata, Novosibirsk, Surgut, Vorkuta, Kemerovo, Norilsk, Krasnoyarsk, Bratsk, Irkutsk, Ulan-Ude, Chita, Yakutsk, Magadan, Komsomolsk, Yuzhno-Sakhalinsk, Khabarovsk, and Petropavlovsk-Kamchatka. By 1975 stations which were either completed or under construction included those at Gur'yev, Abakan, Kyzyl, Dzhezkazgan, Bilibino, Nikolayevsk-na-Amure, Aldan, Pevek, Sangar, Tazovskiy, Anadyr, Nar'yan-Mar, Skovorodino, Kadym, Ust'Ilimsk, Dushanbe, Khorog, Yuzhno-Kuril'sk, and the television center located in Tadzhikistan in the Pamir mountains. Plans for new stations included Aleksandrovsk and Poronaysk. The general target was to add six to eight stations a year so that by 1980, virtually all of the Soviet Union would have television service.[23]

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[21] Pravda, Moscow, Oct 29, 1967, p 3; Radio Moscow, No 10, Oct 1967, pp. 16-17; Elektrosvyaz', No 11, 1967

[22] Radio Moscow, No 10, Oct 1967, pp 15-16 This source discusses more technical aspects of the circuits than are presented here See also Elektrosvyaz', No 11, 1967, pp. 4-8.

[23] Aviatsiya i Kosmonavtika, No 5, 1970, pp 12-13; Vestnik Suyzai, No 4, April 1970, p. 29.

The Soviet plan called for 60 operating stations by the end of 1975.[24] At the end of 1981 this total had risen to approximately 90 and by the beginning of 1983 the number was stated variously to be 100 or so, just 100, or nearly 100.[25]

Table 26 is a listing of ground stations served by Soviet communications satellites derived from a recent publication of the International Frequency Registration Board of the International Telecommunications Union. It will be noted that not all of the stations mentioned above are included in the listing. Neither is the Orbita station which has been reported at Ulan Bator in the Mongolian People's Republic.

TABLE 26.—LOCATIONS OF PRINCIPAL GROUND STATIONS

Location	Long E	Lat N	Associated satellites
USSR			
Arkhangelsk	40 31	64 32	Molniya 2.[1]
Dudinka	86 10	69 20	Do.
Frunze	74 37	42 54	Statsionar[1]
Guskhrustalnyi	40 50	55 45	Do[1]
Irkutsk	129 46	62 02	Statsionar T
Irkutsk	104 02	52 26	Statsionar 1[1]
Kemerovo	86 04	55 21	Do.
Komsomolskamur	136 58	50 34	Molniya 1 Nos. 1/2
Magadan	151 50	59 40	Molniya 2
Moskva	37 18	55 45	Intelsat 4 Atl 1, Molniya 1 Nos 1/2, Molniya 2, Statsionar 1
Murmansk		...	Molniya 2
Novosibirsk	82 55	55 00	Molniya 2, Statsionar 1.
Petropavlo Kam	158 40	53 00	Molniya 2.[1]
Salekhard	66 45	66 14	Do
Surgut	73 30	61 17	Do.
Syktyvkar	50 31	61 41	Do
Tchita	113 30	52 02	Statsionar 1.[1]
Ulan Ude	107 38	51 05	Do[1]
Zalarsk	102 38	56 12	Molniya 2[1]
Bulgaria Sofia	23 27	42 30	Molniya 3
Cuba Caribe	82 05	23 02	Do.
Czechoslovakia Praha	14 32	49 36	Molniya 2.
German Democratic Republic Fuerstenwalde	14 05	52 19	Do
Hungary Taliandorogd	17 36	46 59	Molniya 3[1]
Poland Kielce	20 55	50 55	Molniya 2

[1] Uplink frequencies only are provided for these stations.

Note:

1. Information derived from "List of Space Radiocommunication Stations and Radio Astronomy Stations," IFRB, ITU, Geneva Apr. 1, 1980.
2. Murmansk is listed in sec. 2 as a ground station served by Molniya 2 but does not appear in sec. 1 in its own right.

THE MOLNIYA ORBIT

The Molniya communications satellites are placed in highly elliptical orbits with an eccentricity of approximately 0.74. The orbital period of around 717.75 minutes is chosen so that, despite the very small precession of the orbital plane about the Earth's axis (approximately 0.148 degrees/day) and the motion of the Earth around the Sun, the ground-track repeats itself, albeit some 4.5

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[24] Moscow Radio, May 7, 1975, 0100 GMT, An Audience of Millions, Izvestiya. Moscow. May 7, 1974, p. 6.

[25] Soviet Weekly, Feb. 12, 1983, pp. 8-9.

minutes earlier each day. Such an orbit, with repetitive ground-tracks, may be said to be stabilized.

This combination of eccentricity and orbital period produces apogee and perigee heights (maximum and minimum heights above the Earth's surface) of 39,743 km and 609 km respectively. The apogee is placed to give maximum communications coverage in the Northern Hemisphere across the vast expanse of the Soviet Union with perigee near 60°, northbound (argument of perigee close to 280°). The orbit also precesses in its own plane at a rate of $4.98a^{-3.5}(1-e^2)^{-2}(5\cos^2 i-1)$ degrees/day, where a is the semi-major axis of the ellipse measured in Earth-radii, e is the eccentricity and i is the inclination of the orbit. When $i=63.4°$, the final term in the expression becomes zero. All Molniya inclinations have had inclinations lying between 62.8° and 65.4° which have kept precession-rates to between 0.007 and −0.022 degrees/day. This has the effect of keeping perigee deep in the Southern Hemisphere throughout the active life of the satellite.

Dr. R.R. Allan, of the R.A.E., showed that these stabilized ground-tracks could only occur in certain positions due to perturbations caused by the departure of the Earth's surface from a true sphere.[26] Fortunately for the Russians, one of these positions takes the ground-track right across the centre of the Soviet Union. Figure 36 shows the stabilized ground-track of a Molniya satellite, with ticks placed at hourly intervals from apogee.

The major reason for the choice of the highly elliptical orbit is the long dwell-time over the Northern Hemisphere parts of the ground-track due to the extremely low velocity near apogee (approx. 1.5 km/s). The combination of low velocity and an apogee height exceeding six Earth-radii gives periods of up to 8 hours mutual visibility between Vladivostok in the east and Moscow in the west while on the Asian loop. Moreover, during this time, the satellite is visible from most parts of the U.S.S.R.

A considerable part of the North American loop, near apogee, is also visible from the U.S.S.R. across the North Pole and this is by no means a "wasted opportunity." In the first annex to this chapter it is reported that this loop is the one employed for internal TV distribution from Moscow.

Figure 37 is an orthographic projection of the stabilized ground-track of a Molniya satellite relative to a stationary Earth with times measured from the ascending node (northbound equator crossing) after Hooper et al.[27] Figures 38 and 39 are polar stereographic projections of the Northern Hemisphere showing the ground-track of the North American loop. Locations lying outside the shaded areas have the satellite in view at an elevation in excess of 10°. Figure 38 shows the satellite at 60° N, northbound, 114 minutes after the Equator and some 3 hours before apogee. By this time it is in view of the Orbita ground-station at Moscow, and although at less than 10° elevation as seen from the Vladivostok ground station, it is above the horizon. Figure 39 shows the satel-

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[26] Allan, R.R. "The Operation of Molniya Communications Satellites." Technical Report 69266, R.A.E. November 1969.

[27] Hooper, W.P., Rogers and Whitman. "The U.S.A.-U.S.S.R. Direct Communications Link Terminal." AIAA 5th Communications Satellite Systems Conference, Los Angeles, CA, 1974.

lite at 50° N, southbound, some 5½ hours later. Although the satellite is no longer above the Vladivostok horizon, Moscow still has it above 10° elevation.

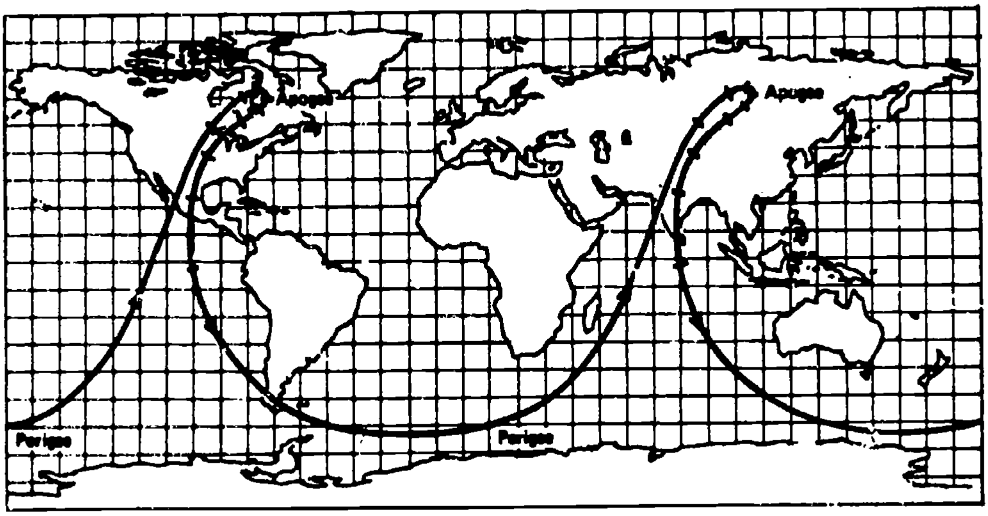

FIGURE 36.—Stabilized Ground Track of Molniya 1-45

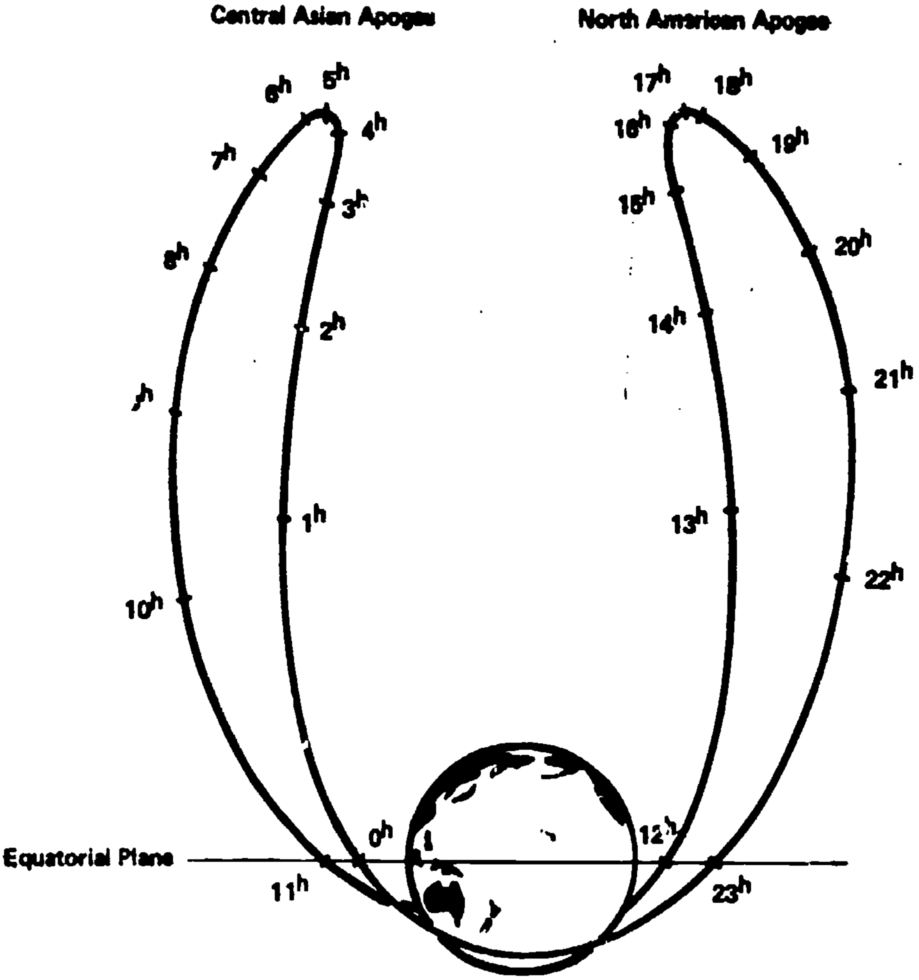

FIGURE 37.—Orthographic Projection of the Stabilized Ground Track of a Molniya Satellite Relative to a Stationary Earth

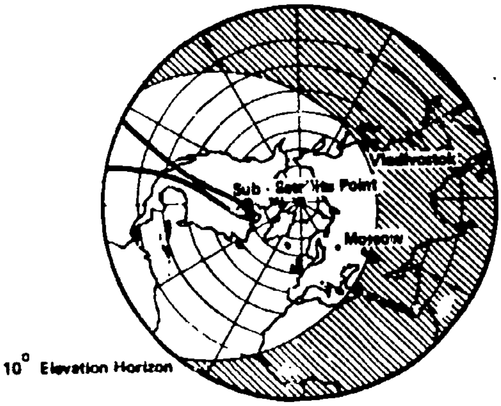

FIGURE 38.—Stabilized Ground Track of a Molniya 1-45, Upleg, Polar Projection

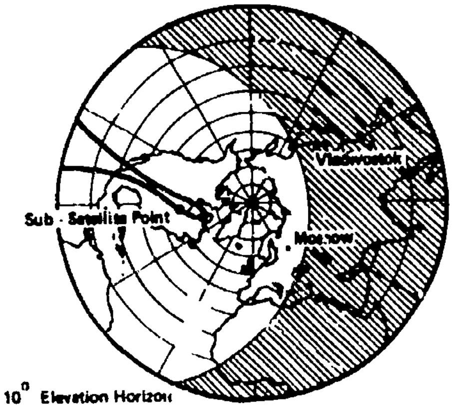

FIGURE 39. Stabilized Ground Track of a Molniya 1-45, Downleg, Polar Projection

METHODS OF ESTABLISHING THE STABILIZED GROUND TRACK

Initially, all Molniya satellites were launched from Tyuratam into orbits inclined at 65° to the Equator. Allan[28] has shown that the fourth Molniya 1 was the first to use a stabilized ground-track. The fifth Molniya 1 was not stabilized and the sixth and seventh only partly stabilized. Thereafter, the correction engine has been used to achieve some degree of stabilization of all Molniya ground-tracks.

The initial method of achieving a stabilized ground-track was to place the satellite into an intermediate orbit with period of the order of 700 to 710 minutes. This resulted in an eastward drift of ground-track of between 3° and 8° per day. When the ground-track had drifted to the desired position, a firing of the correction engine at perigee raised apogee to produce the stabilized orbit. The times elapsing between launch and stabilization ranged from 8 to 20 days.

The launch of the 13th Molniya 1 signalled a move to the Plesetsk launch site and orbital inclinations of 65.4°. A similar stabilization technique was employed. The change of site was a transfer of routine launches from Tyuratam rather than to reduce the time-delay between launch and stabilization of the ground-track. The 15th Molniya 1 was not ground-track-stabilized until the 60th revolution, 30 days after launch.

All Molniya 2 and Molniya 3 satellites have been launched from Plesetsk, and only eight Molniya 1's have been launched from Tyuratam since the shift to Plesetsk with the 15th Molniya 1 early in 1970. The first four of these flew at the old inclination of 65° but the remainder have had inclinations of 62.9°. Most of these eight launches have been made in mid-winter but the last two were launched in mid-summer during 1976 and 1977.

The seventh Molniya 2 satellite and all subsequent Plesetsk-launched Molniyas have flown at the 62.9° inclination. The change in inclination resulted in a new stabilization pattern. The satellite is placed into an intermediate orbit with a period of between 730 and 740 minutes producing a westerly drift of ground-track of around 10 degrees/day. This has permitted stabilization by lowering apogee within 4 or 5 days of the launch.

RECORD OF MOLNIYA LAUNCHES

Table 27 lists the Molniya launches, together with a few Kosmos launches with the same characteristics, which represented either test flights, Molniya failures, or military communications satellites outside the Molniya program but using essentially the same hardware

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[28] Ibid.

TABLE 27.—MOLNIYA AND RELATED KOSMOS COMMUNICATIONS SATELLITES

Launch date	Molniya			Launch site		Apogee	Perigee	Inclination	Period	Decay date	Life in days	Remarks
	1	2	3	TT	PL							
1964												
Aug 22	X			X		39,855	394	64	715			Kosmos 41 Molniya.
1965												
Apr 23	1			X		39,380	497	65	708	May 8, 1979	5,128	
Oct 1	2			X		40,000	500	65	719	Mar. 17, 1967	518	
1966												
Apr 25	3			X		39,500	499	64.5	710	June 11, 1973	2,604	Also carried TV camera.
Oct 20	4			X		39,400	485	64.9	713	Sept 11, 1968	692	Do.
1967												
May 24	5			X		39,810	460	64	715	Nov 26, 1971	1,647	
Oct 3	6			X		39,600	465	65	712	Mar 4, 1969	519	
Oct 22	7			X		39,740	456	64.7	714	Dec. 31, 1969	801	
1968												
Apr 21	8			X		39,700	460	65	713	Jan. 29, 1974	2,109	
July 6	9			X		39,770	470	65	715	May 15, 1971	1,044	
Oct 5	10			X		39,600	490	65	712	July 16, 1976	2,841	
1969												
Apr 11	11			X		39,700	470	65	713	Apr. 17, 1974	1,832	
July 22	12			X		39,540	520	64.9	711	June 18, 1971	696	
1970												
Feb 19	13				X	39,175	487	65.3	703	Sept 29, 1975	2,048	
June 26	14				X	39,280	470	65	705	Feb 16, 1976	2,061	
Sept 29	15				X	39,300	480	65.5	706	Mar 20, 1976	1,999	
Nov 27	16				X	39,430	435	65.3	707	Nov 25, 1975	1,824	
Dec 25	17			X		39,600	480	65.0	712	Dec. 22, 1975	1,823	
1971												
July 28	18				X	39,300	470	65.4	705	July 19, 1977	2,183	
Nov 24		1			X	39,350	460	65.4	706	May 1976	1,63[illegible]	
Dec 19	19				X	39,200	490	65.4	703	Apr. 13, 1977	1,942	
1972												
Apr 4	20				X	39,260	480	65.6	695	Jan 30, 1974	666	
May 19		2			X	39,300	460	65.5	705	Mar 22, 1977	1,768	
Sept 30		3			X	39,200	480	65.3	703	Jan 12, 1978	1,930	
Oct 14	21				X	39,300	480	65.3	705	Nov 1, 1977	1,844	
Dec 2	22			X		39,100	500	65	703	Feb 11, 1976	1,166	
Dec 12		4			X	39,300	470	65.3	705	Jan. 22, 1975	771	
1973												
Feb 3	23			X		39,200	470	65	703	Oct 23, 1977	1,723	
Apr 5		5			X	39,100	500	65	702	Jan 6, 1979	2,102	

July 11		6			X	39,280	480	65.3	705	July 7, 1978	1,822	
Aug 30	24				X	37,970	480	65.3	679	Apr. 10, 1979	2,049	
Oct 19		7			X	40,600	630	62.8	736			
Nov 14	25			X		39,140	480	65	702	Aug. 16, 1979	2,101	
Nov 30	26				X	40,900	460	62.7	737			
Dec. 25		8			X	40,865	466	62.8	737			
1974												
Apr 20	27				X	40,713	646	62.9	738			
Apr 26		9			X	40,850	463	62.9	737			
July 23		10			X	40,900	460	62.8	737			
Oct 24	28				X	40,617	683	62.8	736			
Nov 21			1		X	40,690	650	62.8	732			
Dec 21		11			X	40,675	641	62.9	737			
1975												
Feb 6		12			X	40,685	640	62.8	737			
Apr 14			2		X	40,660	636	63	736			
Apr 29	29				X	40,848	468	63	737			
June 5	30				X	40,890	450	63	737			
July 8		13			X	40,864	465	62.8	737			
Sept 2	31				X	40,681	639	62.8	737			
Sept 9		14			X	40,836	470	62.8	736			
Nov 14			3		X	40,930	470	62.4	736			
Dec 17		15			X	40,836	451	62.8	736			
Dec 27			4		X	40,800	470	62.8	736			
1976												
Jan 22	32			X		38,934	491	62.5	698			
Mar 11	33				X	40,683	518	62.5	734			
Mar 19	34			X		38,984	494	63	699			
May 12			5		X	[illegible],660	652	62.8	736			
July 1		X			X	860	505	62.8	98.1			Probable Molniya 2 failure, Kosmos 837.
July 26	35			X		39,059	499	62.9	701			
Sept 1		X			X	98	243	62.8	91.7	Dec. 31, 1976	121	Probable Molniya 2 failure, Kosmos 853.
Dec 2		16			X	40,608	657	62.8	736			
Dec 28			6		X	40,630	640	62.8	736			
1977												
Feb 11		17			X	40,757	493	62.5	735			
Mar 24	36				X	40,816	484	62.8	736			
Apr 28			7		X	40,817	467	62.8	736			
June 24	37			X		39,016	480	62.9	700			
Aug 30	38				X	40,000	480	62.8	736			
Oct 28			8		X	40,764	478	62.8	735			
1978												
Jan 24			9		X	40,631	661	62.8	736			
Mar 2	39				X	40,733	632	62.8	738			
June 2	40				X	40,837	457	62.5	736			
July 14	41				X	40,660	650	62.8	737			

TABLE 27.—MOLNIYA AND RELATED KOSMOS COMMUNICATIONS SATELLITES—Continued

Launch date	Molniya 1	Molniya 2	Molniya 3	Launch site TT	Launch site PL	Apogee	Perigee	Inclination	Period	Decay date	Life in days	Remarks
Aug 22	42				X	40,788	480	62.8	736			
Oct 13			10		X	40,825	467	62.8	736			
1979												
Jan 18			11		X	40,806	474	62.8	736			
Apr 12	43				X	40,590	656	62.9	735			
June 5			12		X	40,769	473	62.5	735			
July 31	44				X	40,860	470	62.8	737			
Oct 20	45				X	40,640	640	62.8	736			
1980												
Jan 11	46				X	40,830	478	62.8	737			
Apr 18			X		X	485	317	62.5	92.3			Probable Molniya 3 failure, Kosmos 1175.
June 21	47				X	40,707	658	62.5	738			
July 18			13		X	40,815	467	62.8	736			
Nov 16	48				X	40,651	640	62.8	736			

Notes

1 The table lists by date each flight in the Molniya 1, 2, or 3 series. Where a precursor or a flight failure was involved which received a Kosmos number, that information is carried at the right-hand edge of the table, while an X is placed in the applicable Molniya column.

2 Launch sites are indicated as either Tyuratam (TT) or Plesetsk (PL).

3 The orbital elements are as announced by Tass. It should be recognized that the bulk of the flights were successfully maneuvered in the days or weeks after launch to stabilize the payload in the appropriate ground track required to support the total Orbita system. Apogee and perigee are in kilometers; inclination in degrees; and period in minutes.

4 The date of orbital decay and days of life are shown as derived from app. III of pt. 1, mostly originally drawn from the records of the Royal Aircraft Establishment.

5 The text explains the merits of an initial orbital period under 720 minutes, or over 720, with the kinds of maneuvers required in each case to establish the semisynchronous orbit with a relatively fixed ground track.

6 A few related Kosmos flights with orbits similar to Molniya could represent Molniya failures in some instances, because of approximate fits to the orbit planes within which these flights were lanuched. On net balance, it has been concluded these questionable flights are a better fit with the Soviet military early warning system. These flights most in question are: Kosmos 174—Aug. 31, 1967, TT, 39,750 km apogee; 500 km perigee; 64.5 inclination; 715 period; decayed Dec. 30, 1968. Kosmos 260—Dec 16, 1968, TT, 39,600 km apogee; 500 km perigee; 65 inclination, 712 period; decayed July 9, 1973.

Sources: App. III of pt. 1, Tass, and the Royal Aircraft Establishment.

DEVELOPMENT OF THE MOLNIYA SYSTEM

The early history of the Molniya satellites has been described by Allan[29] who pointed out that the 8th, 9th and 10th Molniya 1's constituted a three-satellite system with orbital planes spaced at approximately 120° intervals providing a complete 24-hour coverage of the U.S.S.R. Each satellite repeated the ground-track of its predecessor some 8 hours later in time. He also speculated that the 11th and 12th Molniya 1's might be the pioneers of a four-satellite system with orbital planes space 90° apart and satellites following each other at 6-hour intervals.

In 1974, Philip Perkins and Geoffrey Perry, of Kettering Grammar School, developed a simple graphical method for monitoring the operational status of Molniya satellites in the Orbita system. Using data supplied by the Goddard Space Flight Center, they plotted the values of right ascension of the ascending nodes against date and obtained a series of four straight lines spaced at 90° intervals, confirming Allan's hypothesis.[30] Later, Perry developed this technique to produce a simple calculator, consisting of three cardboard discs, to reveal the operational status at a glance.[31] This was first demonstrated in public at the meeting of the National Space Club in Washington, DC, on July 28, 1976. By these techniques they were able to trace the history of replacement of Molniya satellites as they reached the ends of their active lives. Labelling the four groups of satellites from A through D, the replacement history of the Molniya 1's is seen to be as shown in table 28.

It will be seen that the comfortable state of affairs which existed at the end of 1975 following the launch of the 31st Molniya 1 was rudely disturbed early in 1976 by the launch of the 32d Molniya 1 into an orbital plane midway between groups D and A. Three more launches in March and July of that year completed a set of four satellites with planes spaced midway between each of the four original groups. It was suggested that Molniya 1's had been transferred to a wholly military role with a subsequent relocation of positions.[32] No sooner had this been published than four more Molniya 1's were placed into the original groups. Currently it would appear that eight Molniya 1's are operational in planes spaced at 45° intervals. Birkill's observations from Sheffield, England, indicate that the Molniya 1's in the main groups still carry domestic traffic on both loops but that the four active inter-group spacecraft operate only on the Asian loop in what may be presumed to be a military mode.

The first Molniya 2 was positioned approximately midway between groups A and D of the Molniya 1's and, when the second Molniya 2 was positioned midway between groups A and B, the possibility arose that the Molniya 2's were a supplementary system to fill gaps in the existing system. However the third Molniya 2, between groups B and C, was spaced 120 away from the second, i.e., nearer to group C. Although these first three Molniya 2's did not join the Molniya 1 groups, the fourth Molniya 2 was placed in

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[29] Ibid

[30] Perkins, P.J. and G.E. Perry, Flight International, London, 107, Jan 16, 1975, p 79

[31] Perry, G.E. R.A.F. Qy., London, 17, summer 1977, p 162

[32] Ibid, p 1[illegible]

group D and, thereafter, all Molniya 2 launches added their payloads to the Molniya 1 groups. The last Molniya 2 launch was the 17th of the series, in February 1977. It must now be concluded that the Molniya 2's have been phased out. Table 29 shows the replacement sequence of the Molniya 2 satellites.

When the Molniya 3 satellites were introduced they joined groups C, D, A, and B in turn over a 13-month period between November 1974 and the end of 1975. At that time the system comprised four groups, each of three satellites, following each other at approximately 6-hour intervals, with a maximum time difference of 40 minutes between any member of each group.[33] Table 30 shows the replacement sequence of the Molniya 3 satellites.

Table 31, due to Andrew Ward, shows the operational status of Molniya satellites as of December 31, 1980. During January 1981, the 10th Molniya 3 and the 41st Molniya 1 were replaced by the next satellites in each series. Andrew Sims has shown that the Molniya 1 replacement was not ground-track stabilized until the third opportunity, 42 days after it was launched.

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[33] Soviet Space Programs, 1971–75, table 5-3, p. 373

TABLE 28.—REPLACEMENT SEQUENCE OF MOLNIYA 1 SATELLITES

A		B		C		D		(A)
11								
		12						
				13				
						14		
		15						
						16		
17								
				18				
		19						
20								
21								
						22		
				23				
		24						
25								
				26				
						27		
				28				
29								
		30						
				31				
							32	
					33			
			34					
	35							
						36		
				37				
38								
		39						
			40					
	41							
					42			
							43	
			44					
45								
				46				
						47		
							48	

TABLE 29.—REPLACEMENT SEQUENCE OF MOLNIYA 2 SATELLITES

A		B	C	D		(A)
					1	
	2					
			3			
				4		
		5				
6						
				7		
			8			
9						
		10				
				11		
			12			
13						
14						
		15				
			16			
				17		

TABLE 30.—REPLACEMENT SEQUENCE OF MOLNIYA 3 SATELLITES

A	B	C	D
		1	
			2
3			
	4		
		5	
	6		
			7
		8	
9			
	10		
		11	
			12
13			

REPLACEMENT PHILOSOPHY

Flying different types of Molniya in groups and the introduction of the four midgroup Molniya 1's are both forms of built-in system-redundancy similar to the West's in-orbit spares. Nevertheless, it is not unreasonable to suppose that replacement satellites are launched as soon as operational satellites fail or begin to fail. It is to be expected that this would also tend to occur when the particular group was carrying "peak-hour" traffic. Analysis reveals 39.3 percent of the first 35 Molniya 1's to be placed in the current groupings; the last 14 Molniya 2's and the first 12 Molniya 3's have been launched when their group's apogee-time occurred within ±3 hours of 1030 Moscow time. The remainder have been reasonably equally shared between the other 6-hour periods of the day; 21.3 percent in each of the periods from 1930 to 0130 and from 0130 to 0730, with the rest in the period between 1330 and 1930 M.T.

This being the case, one might expect a linear relationship between launch-date and group-designation with a gradient of the order of 320 days. The 717.75 minute orbital period implies that satellites are 4.5 minutes earlier each day and that in 320 days the whole cycle will have been completed. This hypothesis was tested for the aforementioned 61 satellites but no direct linear relationship could be discovered. However, by considering groups A and C together and groups B and D together and similarly pairing the midgroup satellites, Perry and Philip Hill found such a relationship with a gradient of 152 days, approximately one-half of that expected if groups are to be considered singly but within 5 percent of the half-cycle duration of approximately 160 days. This was taken as support for the hypothesis of across-the-pole usage on the North American pass, now confirmed by Birkill's observations.

An attempt to predict Molniya launches in the latter half of 1980 using this relationship met with moderate success, the 13th Molniya 3 and 48th Molniya 1 being launched 40 and 22 days "early" respectively. However, it must be realized that some of the predicted optimum dates might possibly coincide with prohibitive dates due to conditions that would lead to very short lifetimes. Specialists at the Royal Aircraft Establishment, Farnborough, England, have shown that the lifetime of a satellite in a highly eccentric orbit, which is strongly affected by luni-solar gravitational perturbations, is determined by the initial values of the orbital parameters and hence on the timing of the launch.[34] [35]

Tyuratam launches are made with initial ascending nodes some 3 hours after the group's ascending node with Plesetsk launches some 5 hours later still, due to the more westerly location of the launch site.

Reference to table 25 will enable the reader to form his own judgment of the active lifespans of these satellites. An explanation of the replacement of the 13th Molniya 2 by the 14th after only 2 months is that the orbit was never properly ground-track-stabilized. Presumably launched to ensure optimum communications during the Apollo-Soyuz mission in the following week, the orbit was lowered to a period of 718.6 minutes. One might speculate that the correction engine failed to make a sufficiently long burn. Whatever the reason, no further correction was made and although it remained in the same orbital plane as the other members of group A, it fell further and further behind in time and consequently drifted off station in a westerly direction.

TABLE 31.—OPERATIONAL STATUS OF MOLNIYA SATELLITES AS OF DEC. 31, 1980

Molniya	Int'l desig	Period (min)	Perigee (km)	Apogee (km)	Rev	Asc	Node time t	Longitude °W
3 13	80-63A	717 45	442	39.908	334	1	54 91	109.51
Group A								
1 45	79-91A	717 70	633	39.728	879	2	10 56	115.22
1 48	80-92A	717 76	588	39.776	91	5	19.48	116.70
3 12	79-48A	717 56	436	39.919	1,143	8	7.92	114.30
Group D								
1 47	80-53A	717 68	625	39 736	387	8	32 95	118 40
1 42	78-80A	717 84	1 343	39.026	1.729	11	43 43	116 72
1 46	80-02A	717 90	870	39.502	713	14	1 47	115.77
Group C								
3 11	79-04A	717 89	1 407	38.964	1.431	14	18 48	112.43
1 44	79-70A	717 63	1.145	39.213	1.042	17	2 42	115 33
3 10	78-95A	717 70	914	39.448	1.565	19	46 64	111 61
Group B								
1 39	78-24A	717 79	1.185	39.180	2.077	20	35 77	117 21
1 41	78-72A	717 78	801	39.564	1.809	23	19 90	118 81

Mean time [illegible] min and all satellites are within ± 30 minutes of this
Mean longitude 115.1[illegible]° W and all satellites are within ± 5.7° of this
Molniya 1-[illegible] was replaced by the 49th Molniya 1 on Jan 9, 1981
Molniya 3-1[illegible] was replaced by the 14th Molniya 3 on Jan 30, 1981

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[34] Cook, G E., and Diana W Scott Planet Space Science, 15, 1967, pp. 1549-1550

MOLNIYA FAILURES WITHIN THE KOSMOS PROGRAM

As has already been mentioned elsewhere in this report, certain satellites in the Kosmos series have flown in orbits similar to those of the Molniya satellites. With the exception of Kosmos 41, which was, most probably, an engineering test as part of the R&D leading to the establishment of the Orbita system, it was at one time tempting to regard such satellites as Molniya failures. While it would appear that, from orbital plane spacing considerations, the 6th Molniya 1 replaced Kosmos 174 within 33 days of its launch[36] and that Kosmos 260 could have been a replacement for the 8th Molniya 1, such an assumption is not valid in the cases of all Kosmos satellites with Molniya-type orbits. Perry pointed out that the orbital plane of Kosmos 706 does not coincide with any of the four groups.[37] In 1977, Perry pointed out that this satellite, and others which did not fit into the groups, had arguments of perigee close to 315° rather than close to the 280° of the successful Molniyas and Kosmos 837 and 853.[38] These two satellites, launched on July 11 and September 1, 1976, were really intended to replace one of the satellites in group D.[39] In the first instance the final stage of the launch vehicle did not fire long enough to achieve the desired highly elliptical orbit and on the second occasion did not fire at all to move from the intermediate parking orbit. The speculation that it was the 11th Molniya 2 that was to be replaced, since it had already been in orbit for 18 months, was strengthened when the next successful launch into group D was indeed a Molniya 2.

One can form the opinion that it takes 2 months to ready a replacement payload if there should be a launch failure. When a further attempt was not made around November 1, 1976, it seemed reasonable to assume that group D was not then placed in a "peak-hour" traffic position and that the next attempt would be delayed until the other loop of the ground-track reached this position. The 17th Molniya 2 was placed into group D on February 11, 1977, some 7 months after the launch of Kosmos 837.

Two more failures occurred in 1980. Kosmos 1164 and 1175, launched on February 12 and April 18, were in quite different orbital planes. Kosmos 1164 most probably falls into the early warning category. Four objects from the Kosmos 1175 launch were cataloged in low parking orbits.

As with Kosmos 1164, the TASS announcement of the launch omitted the usual closing statement to the effect that the onboard instrumentation of the satellite was functioning normally. Although in the same orbital plane as the group A satellites it was not clear until the 13th Molniya 3 launch that it was intended to replace the 9th Molniya 3 rather than the 45th Molniya 1.

THE SYNCHRONOUS COMMUNICATIONS SATELLITES

A satellite at a mean height of 35,787 km above the Earth's surface rotates in its orbit at the same rate at which the Earth rotates

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[36] King-Hele, D.G. Technical Report 75052, R.A.E., May 1975
Flight International, London, 92, Oct 12, 1967, p 628
[38] Perry, G.E., Flight International, London, 107, Apr 24, 1975, p 686
[39] Perry, G.E. R.A.F. Qy. London, 17, autumn 1977, p 277

in its orbit about the Sun. Such an orbit is said to be geosynchronous. When a geosynchronous orbit is established in the equatorial plane it becomes geostationary. A ground station antenna can remain fixed in elevation and azimuth since the satellite appears to be stationary in the sky. Because the motion of the Earth around the Sun provides 0.98° of rotation daily the true geostationary orbital period is only 1,436 minutes instead of 24 hours.

In 1945, Arthur C. Clarke showed that almost complete global coverage could be obtained with three such satellites spaced at 120° intervals around the Equator.[40] It was long felt that poor coverage of the northernmost parts of the Soviet Union from a geostationary orbit was an important reason for the adoption of the elliptical semi-synchronous Molniya orbit in addition to the Soviets' inadequate technology for placing satellites into geostationary orbits during the 1960's.

The first indication that a geostationary system was being contemplated came in February 1969 when the Soviets lodged information with the International Frequency Registration Board (I.F.R.B.) of the International Telecommunications Union (I.T.U.) in Geneva, relating to Molniya 2 and Statsionar satellites. The Statsionar satellite was to be placed over the Equator between 75° and 85° E. In the following year, the date given for Statsionar to become operational was December 1, 1970.

KOSMOS 637, MOLNIYA 1-S, AND KOSMOS 775

The first Soviet geostationary launch did not take place until March 1974. Kosmos 637 was probably an engineering test to check out the technique for launching into and stabilization of a geostationary orbit.

Four months later a spacecraft designated Molniya 1-S was placed into geostationary orbit. Its locaton was chosen to give coverage to Eurasia, Africa, and Australia. This could have been a normal Molniya 1 satellite used for testing communication and command links at geostationary distances.

The third geostationary launch, in October 1975, was designated Kosmos 775. This could also have been a precursor of the operational geostationary communications satellites or even a minor failure. One suggestion was that it had an early-warning mission.[41]

DESCRIPTION OF RADUGA

Late in December 1975, the Soviets launched "a new communications satellite" which they named Raduga (Rainbow). It carried equipment "to ensure uninterrupted round-the-clock telephone and telegraph radio communication in the centimetric waveband and simultaneous transmission of color and black-and-white Central Television programs to the network of Orbita stations." In addition to the improved multichannel communication and television relay equipment, the satellite carried "a three-axis system of fine orientation towards the Earth, a power supply system with Sun-seeking

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[41] Perry, G.E. R.A.F. Q., London 17, summer 1977, p. 161.

[40] Clarke, A.C. Extra-terrestrial Relays. Wireless World, vol. No. 10, October 1945, pp. 305-308.

guidance and tracking of solar cell batteries, an orbital correction system, a thermoregulation system, and a radio system for precision measurement of orbital parameters and satellite control."[42]

No model of a Raduga has been publicly displayed nor pictures published. The Royal Aircraft Establishment's Table of Artificial Earth Satellites does not list any probable mass, dimensions, or configuration. An estimate of mass between 2000 and 4000 kg for a cylindrical body, 5 m in length and 2 m diameter has been mentioned. The same report gives two solar panels and two antennas and specifies one TV channel and 10 telephony/data channels, each of which is capable of carrying 100 multiplexed telephone circuits.

The first Raduga was placed at the Statsionar 1 location, as were the second and fifth satellites of the series. The third, fourth, and sixth satellites were placed at the Statsionar 2 location, commencing in 1977. The 10th Raduga was placed at the Statsionar 3 location at the end of 1981. Some repositioning of these satellites was occasioned by coverage for the Moscow Olympic Games in 1980.

DESCRIPTION OF EKRAN

The Tass announcement of the first Ekran (Screen) satellite was strikingly similar to those for the first Raduga. Only the mission differed, being described as "for further development of telecasting systems." The relay equipment ensured telecasting of Central Televison's color and black-and-white programs to "the network of collective-using receiving devices situated in the inhabited localities of Siberia and the extreme North."[43]

A model of Ekran was displayed in the Soviet pavilion at the 1977 International Air Salon at Le Bourget, Paris. Figure 40 is a drawing of this model. An outstanding feature was the large 96-element cophased helical antenna array, measuring 5.7×2.1 m, deployed as 4-by-6 matrices on four panels and resembling a "bedspring mattress." This provides a gain of 28 dB on the axis of the radiation pattern. The familiar cylindrical body has been retained with the vernier correction engine but this was surrounded by an annular panel forming part of the thermoregulation system. Four solar cell panels were mounted in pairs at the ends of booms extending at right angles to the axis of the satellite, each consisting of sub-assemblies arranged in 6-by-3 matrices.

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[42] Tass in English, Dec. 23, 1975, 1811 Gmt

[43] Tass in English, Oct. 26, 1976, 0824 GMT

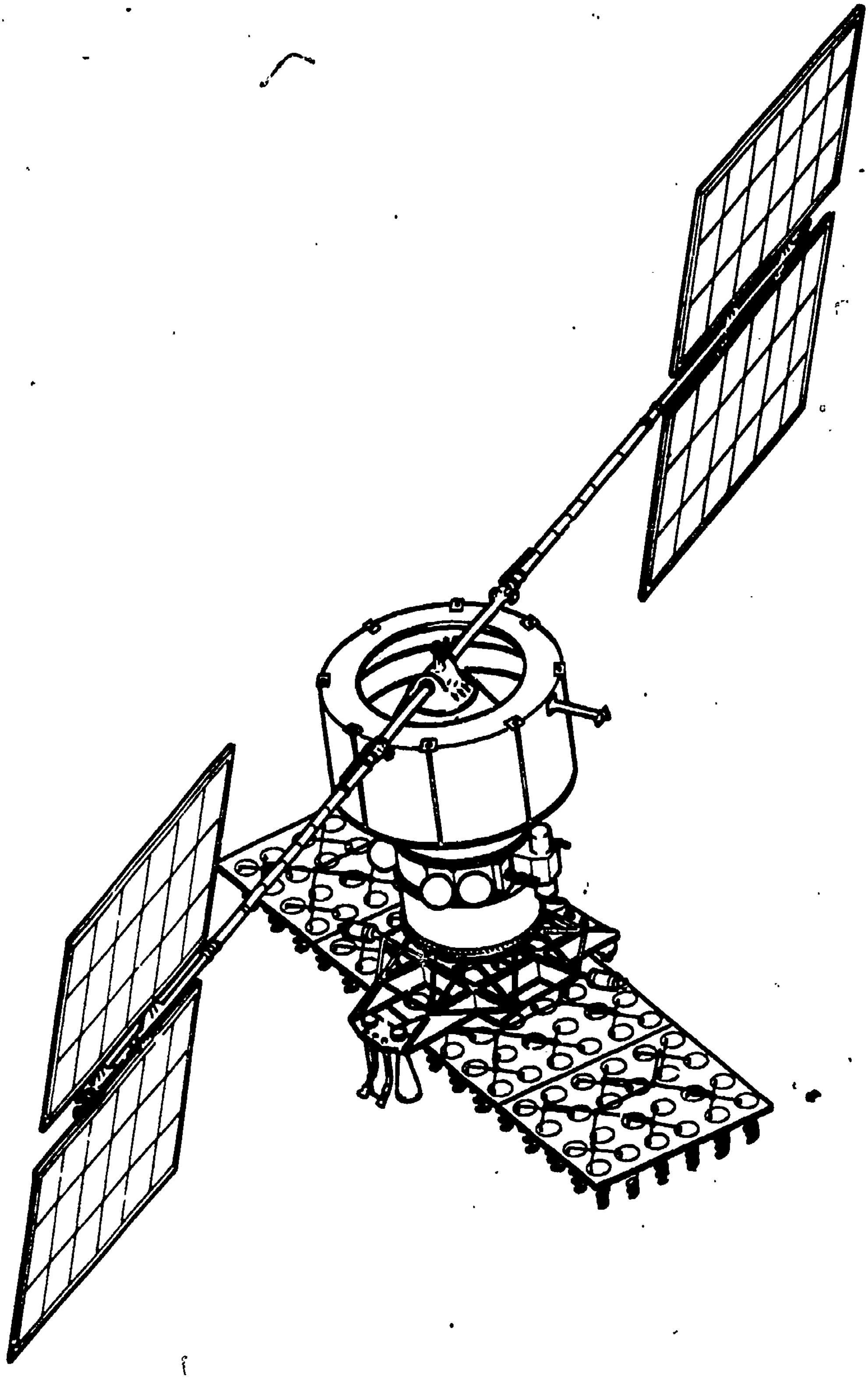

FIGURE 40.—Ekran Satellite

Ekran satellites have, with one exception, been given the Statsionar T designation. The seventh Ekran, in 1981, was designated Statsionar 1 in the Tass announcement but this might have been a typographical error.[44] Table 4 in the booklet Communication Satellites shows the registration as S-T.[45]

Two Ekran satellites are used at the Statsionar T location. Their successive operation ensures transmission of one color TV program and two radio broadcast programs for 12 to 16 hours within a 24-hour period.[46]

DESCRIPTION OF GORIZONT

The first Gorizont (Horizon) satellite to be launched at the end of 1978 posed something of a problem for Western analysts. The announced orbit, although nearly geosynchronous with a period of 1,420 minutes, was not geostationary due to an inclination of the orbit to the equator of 11.3°. Nor was the orbit, ranging from between 48,365 and 22,581 km, anywhere near circular. Its purpose was to "further improve and develop communications systems with the aid of artificial Earth satellites" and it was reported that it was "planned to use Gorizont satellites for relaying Soviet TV transmissions of the 22d Summer Olympics in 1980."[47]

There was some speculation that such an orbit was designed to give increased Northern Hemisphere coverage.[48] However, subsequent Gorizonts were placed in the conventional near-geostationary orbits and it must be assumed that this unique orbit was the result of some attitude or propulsion error. The R.A.E. table lists an object, 1978-118 D, and suggests that this was in the 47° intermediate orbit, but no such fragment is listed in the NASA Satellite Situation Report as having decayed or still remaining in orbit.

Models of the Gorizont satellites were displayed at Le Bourget in 1979 and 1981. Figure 41 is based on these models. The cylindrical body and annular thermoregulator are similar to those of Ekran. The arrangement of the solar cell arrays differs in configuration from that of Ekran and amounts to some 2.3 square meters with further cells located around the circumference of the upper part of the spacecraft. Three-axis body stabilization is employed and attitude is determined from readings of three infrared and one visible light horizon sensors. In addition to global coverage horn antennas there are spot-beam receiving and transmitting antennas. The large circular dish, slightly more than 1 meter in diameter, supplies the 4 GHz downlink, as does the larger of the three "orange-peel" shaped antennas. The two smaller antennas operate in the 6 GHz band used for uplink. These "orange-peel" antennas produce a beam that is wider in one direction than in the orthoganal and are adjusted prior to launch to change the coverage area from one satellite to another.[49]

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[44] Tass in English, June 26, 1981, 1400 G m.t

[45] Agadzhanov, P A., et al., Idem

[46] Idem

[47] Tass in Russian for Abroad, Dec. 20, 1978, 1020 G.m.t.

[48] Soviet Aerospace, Nov 5, 1979, p. 70

[49] Aviation Week & Space Technology, vol. 110, No. 24, June 11, 1979, p. 40; vol. 110, No. 26, June 25, 1979, p 43.

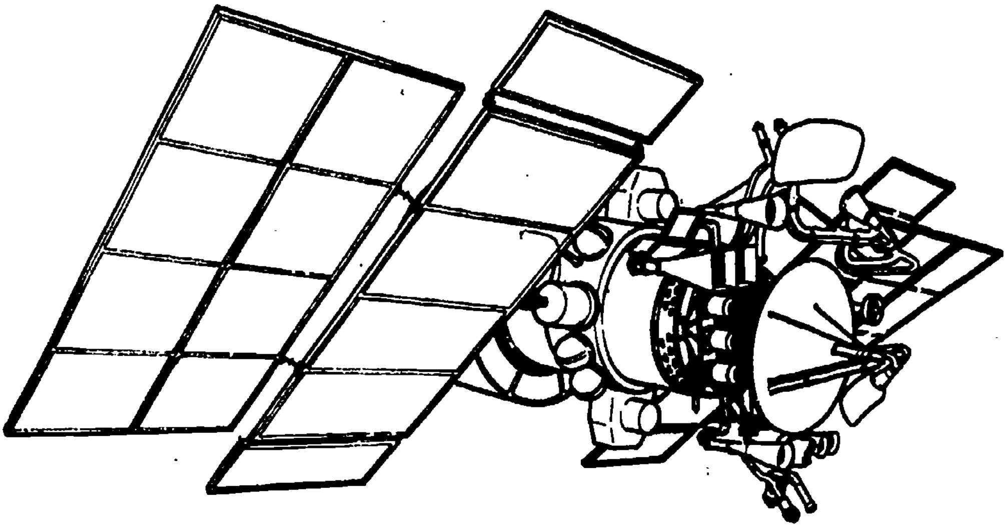

FIGURE 41.—Gorizont Satellite

Gorizont satellites are equipped with a single 40 W repeater and five 15 W repeaters.

The second and fourth Gorizonts were deployed at the Statsionar 4 location with the third going to the Statsioner 5 location. Table 4 in the booklet Communications Satellites gives the S–5 registration to the first Gorizont. Statsionar registrations did not appear in the TASS announcements for the fifth and sixth Gorizonts in 1982.

LOUTCH, GALS, AND VOLNA

Notifications to the IFRB give, from time to time, details of frequencies and locations planned for new satellites and systems. Details of Volna and Gals appeared in 1977.[50] The Loutch and Loutch-P systems were mentioned in 1979.[51] Common positions at Statsionar locations for members of each series caused speculation that payloads might be combined into single multipurpose satellites.[52] Such a theory gained support in 1982 when Pravda reported that additional relayers were installed on Gorizont 5, having Loutch and Volna registrations.[53]

Loutch and Loutch-P

Loutch (Beam) can also be found with the spellings Lutch or Luch. The Loutch and Loutch-P systems will both comprise four satellites each operating in the Ku-band with 14 GHz uplink and 11 GHz downlink for international and domestic communications

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[50] Aviation Week & Space Technology, vol. 107, No. 20, Nov. 14, 1977, p. 20.
[51] Soviet Aerospace, Nov. 5, 1979, pp. 69–70.
[52] Aviation Week & Space Technology, ibid.
[53] Pravda, Moscow, May 3, 1982, p. 3.

designed to compete with the Intelsat 5 system.[54] Planned for launch in 1978, these satellites had still to appear at the end of 1982.

Loutch 1 to 4 were to be located at the Statsionar 4, 5, 6, and 7 positions respectively although Statsionar 12 (40° E) has also been reported as the location for Loutch 4. The Loutch-P series were to be deployed at the Statsionar 8, 9, 1, and 4 locations respectively, specifically for Government telephone, telegraph, and television services.[55]

Gals

Gals (Tack) satellites were planned for launch in 1979 to establish a four-satellite global network for military communications. Uplink between 7.9 and 8.4 GHz and downlink between 7.25 and 7.75 GHz are in bands officially allocated for Government service but internationally accepted as military communications bands. Analysts calculated that Earth terminals would require dish antennas of diameter between 1.5 and 2 m.[56]

Locations for Gals 1 to 4 were given as Statsionar 8, 9, 3, and 10 respectively. Further locations at Statsionar 15 (130° E) and 3 have been seen for Gals 5 and 6.

Volna

Seven multipurpose Volna (Wave) satellites for mobile communications for maritime, aeronautical, and land use were due to be in operation by the end of 1980. Statsionar locations for Volnas 1 through 7 were given as Statsionar 8, 4, 9, 5, 3, 7, and 10 respectively.[57] Variations of these locations have been seen with Volna 5 at Statsionar 1 and a Volna 8 at Statsionar 6.[58]

Even numbered Volnas would operate in bands allocated by the ITU exclusively for the maritime mobile service, 1.636 to 1.644 GHz uplink and 1.535 to 1.542 GHz downlink, and the aeronautical mobile service, 1.645 to 1.660 GHz uplink and 1.543 to 1.558 GHz downlink.

Odd numbered Volnas would operate in these same bands and also in the 335 to 399 MHz uplink and 240 to 328 MHz downlink bands used by the U.S. Navy for its maritime service.[59] Analysts deduced that shipboard antennas a little more than 1 m in diameter, similar to those operating in the West with the Marisat system, would be required and that land-mobile antennas could be simple crossed rabbit-ears, or dipoles, less than 0.6 m across.

Volna notifications were designated for official or Government communications exclusively rather than for public communications. Volna has been said to be a national system and not for international use.

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[54] Aviation Week & Space Technology, vol. 112, No 9, Mar. 3, 1980, p. 83.

[55] Selected Communications Satellites, Comsat General Corp., Washington, DC., Sept. 1, 1981 (wallchart).

[56] Aviation Week & Space Technology, vol. 107, No. 20, Nov. 14, 1977, p. 20.

[57] Idem.

[58] Satellite Week, vol. 4, No. 17, Apr. 26, 1982, p. 4.

[59] Aviation Week & Space Technology, vol. 107, No. 20, Nov. 14, 1977, p. 20.

STATSIONAR DESIGNATIONS

When the S[illegible] notified the IFRB of the ITU, in 1970, of their intention to launch a Statsionar 1 satellite into a geosynchronous orbit between 75° and 85° E it was generally assumed by Western analysts that the satellite would be named Statsionar. Cosmos 637 and Molniya 1-S could both have been considered as candidates for this designation.[60] However, before a satellite received such a designation, notification for a Statsionar T was published on June 9, 1975, followed by the notifications for Statsionars 2 and 3 on September 9. Statsionar T was specifically for television broadcasting within the territory of the Soviet Union relaying transmissions from a station at Gus-Khrustalnyi, near Moscow, to a network of community-reception Earth terminals. Statsionars 2 and 3, designed for telephone, telegraph, and phototelegraph communications and for sound broadcasting and television program transmissions would serve Europe and the western part of the Soviet Union, and the whole of the Soviet Union with the exception of the Kamchatka peninsula respectively.

Before the end of 1975, the IFRB was notified on behalf of the U.S.S.R. Ministry of Posts and Telecommunications, of seven more Statsionars. Locations of these first Statsionars are given in table 32.

TABLF 32.—ANNOUNCED LOCATIONS FOR SOVIET GEOSYNCHRONOUS PAYLOADS

Location	°Longitude	Tolerance		Remarks
		°Longitude	°Inclination	
Statsionar 1	80E	1.0	3.0	Originally 75E-85E.
Statsionar 2	35E	.5	3.0	
Statsionar 3	85E	.5	3.0	
Statsionar 4	14W	.5	1.2	Volna 2 location also.
Statsionar 5	53E	.5	1.2	Volna 4 location also; originally 58° E.
Statsionar 6	90E	.5	1.2	Originally 85° E.
Statsionar 7	140E	.5	1.2	Volna 6 and Loutch 4 locations also.
Statsionar 8	25W	.5	1.2	
Statsionar 9	45E	.5	1.2	
Statsionar 10	170W	.5	1.2	
Statsionar T	99E	1.0	1.0	TV within the U.S.S.R. via Guskhrustalnyi; 714 MHz downlink.

Notes

1 Information derived from "List of Space Radiocommunication Stations and Radioastronomy Stations," I.F.R.B., I.T.U., Geneva, Apr. 1, 1980

2 Each longitude given in column 2 is the center of a service arc, 4° of longitude in extent

3 Loutch has 11 GHz downlink (uplink frequency not given) and Volna has 1.5 GHz uplink and downlink. 6 GHz uplink and 4 GHz downlink in all other cases except where noted

On December 22, 1975, the first satellite with a Statsionar 1 designation was launched and given the name, Raduga. When the second Raduga satellite was given the same Statsionar designation and was closely followed by the first Ekran, which was designated Statsionar T, it became clear that Statsionar was the name given to the location of the sub-satellite point on the Equator and that satellites with more than one name could occupy Statsionar locations.

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[60] Aviation Week & Space Technology, vol. 103, No. 12, Sept. 22, 1975, p. 17.

More recently Statsionar locations 11 throuugh 15 have been registered at 8.5° W, 40° E, 80° E (formerly used for Statsionar 1), 95° E, and 130° E.

Reportedly, from the U.S.S.R. notification on the Statsionar system, it was evident that there would be potential frequency interference problems with the Franco-German Symphonie satellite, then operating over the Atlantic, and the two satellites planned for the Indonesian domestic communications system.[61] In January 1976, a four-man delegation from the then 91-nation International Telecommunications Satellite Organization (INTELSAT) opened negotiations with its Soviet counterpart in Geneva to solve possible frequency interference problems.[62] In January 1980, it was reported that an Ekran satellite at Statsionar T was transmitting so strongly that interference was occurring with radio services in Peking and that an official complaint had been registered.[63]

THE EKRAN SYSTEM

A key feature of this televison broadcasting system is the comparatively high power of the Ekran satellite's transmitter: about 200 W as opposed to the 30–40 W of the other communications satellites. This has permitted the design of the antenna and receiving equipment of the ground receiving station to be simplified considerably. Yagi-arrays have replaced the large dish antennas required for the Orbita system. The receiver does not demand constant servicing, nor does the associated local relay station which distributes the received television program to the surrounding area using the normal television channels which can be received by standard television sets such as the "Rubin" or "Rekord". The ground equipment of the Ekran system needs so little attention that it can even be set up in isolated villages in the taiga where a low-power relay of only 1 W is all that is necessary. The Ekran receiving network had nearly 2,000 stations with its own relay equipment by the end of 1981 which brought territories inhabited by 20 million people into the U.S.S.R.'s main television network.[64]

The 714 MHz downlink chosen for the Ekran system made possible the use of the simple and inexpensive receivers and Yagi antennas. Two types of collective-use receiving stations have been developed which operate reliably under conditions of Siberia and the extreme North. The first class, or professional, type are equipped with 32 or 16 element antennas giving a signal-to-noise ratio of 55 dB which is relayed to local TV centers and high power TV repeaters. These receiving stations in combination with the repeater have been given the identifier STV–100. The second class, or set, type feed low power TV repeaters or cable distribution networks. They have four element antennas with a signal-to-noise ratio of not less than 48 dB and have the identifier STV–1.[65]

The series production of ground stations, antennas and repeaters is carried out by enterprises of the Ministry of the Communications

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[61] Johnsen, K., Aviation Week & Space Technology, vol. 103, No. 14, Dec. 15, 1975, pp. 14–16.
[62] Aviation Week & Space Technology, vol. 104, No. 5, Feb. 2, 1976, pp. 44–45.
[63] Television, vol. 30, No. 3, January 1980, p. 151.
[64] Svoren, R. Nauka i Zhizn, December 1981.
[65] Agadzhanov, P.A., et al., National Paper: U.S.S.R., Sept. 2, 1981, pp. 65–66. Idem.

Equipment Industry. Receiving stations are installed and commissioned by organizations of the U.S.S.R. Ministry of Communications. These stations have been installed in the Kazakh SSR, the Buryat, Tuva and Yakut ASSRs, in Altayskiy, Krasnoyarskiy and Khabarovskiy krays, as well as in Amurskaya, Irkutskaya, Kemerovskaya, Magadanskaya, Novosibirskaya, Tomskaya, Tyumenskaya and Chitinskaya oblasts, including the Baikal-Amur Railroad route and other developed regions of Siberia and the extreme north.[66]

The Ekran satellites have operational lifetimes of some 2 or 3 years but future Ekrans are expected to have operational lives of up to 5 years.[67]

Transmission of television and radio broadcast programs ~~to~~ the Ekran satellites is conducted from a special ground transmitting complex with a transmitter output of 10 kW through a 12 m diameter antenna with a gain of 54 dB at 6 GHz uplink.

THE MOSKVA SYSTEM

The Ekran concept of a powerful transmitter and simple receiver is not always acceptable due to over-crowding of the frequency bands and the close positioning of satellites in the geosynchronous orbit. Restrictions caused by possible interference to the ground communication facilities of neighboring countries using the same frequency bands make it impossible to extend the zone of operation of the Ekran system to other regions of the U.S.S.R.

Progress in technology permitted the development of the Moskva system which, in conjunction with a network of microwave links and land lines, enables both First and Second Programs of Central Television to be relayed to a vast area. Gorizont satellites operating with a 4 GHz downlink through a 40 W transponder and narrow-beam antennas transmit to stations equipped with 2.5 m dish antennas. One such antenna, receiving signals from a Gorizont satellite, was displayed in Vienna during Unispace 1982.[68] The receiver rack has a weight of 120 kg and inputs 13.5 W to the associated cable network. An uncooled parametric amplifier with noise temperature less than 100K, mounted on the antenna, and receiver is used to demodulate and amplify the television and radio broadcast signals. The complete unit is small and does not require a special building for its accommodation. The number of components is so small that they can all be located, for instance, at a post office, in a village club or at low power TV repeater stations, and the fixed antenna can be mounted on the roof or in the ground using simple supports.

CENTRAL TELEVISION AND ALL-UNION RADIO

The Moscow-based services are supplied to five broadcasting zones each of which comprise two or three time zones. Zone 1, comprising time zones for Moscow time plus 8, 9 or 10 hours, covers the most eastern part of the Soviet Union. This receives the First Channel TV through the Orbita network and a Molniya 3 satellite.

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[66] Agadzhanov, P A., et al., idem.
[67] Satellite Week, vol 4, No 17, Apr 26, 1982, p 4.
[68] Satellite TV News, No 5, winter 1982, p 30, two photos

It is intended that the Second Channel will become available before the end of the current 5-year plan period through a new network to be called Double, using Gorizont-Statsionar 7. Molniya 3 will then be used exclusively for the far northern territories. Zone 2, for time zones with Moscow time plus 6 or 7 hours, receives First Channel through Orbita, Ekran or Molniya 3. Again there is the intention to add the Second Channel before the end of the current 5-year plan period through the new Double network, using Gorizont-Statsionar 6. As with Zone 1, the Moskva system will be used for Channel 1 and the Orbita system for Channel 2.

Zone 3, comprising time zones for Moscow Time plus 4 or 5 hours, covers the central parts of the U.S.S.R. including Novosibirsk and Irkutsk. These receive Channel 1 through the Ekran system and Channel 2 through Orbita or Ekran. Zone 4, for time zones with Moscow time plus 2 or 3 hours, receives First Channel through Moskva and Second Channel through Orbita. The fifth zone, European U.S.S.R., on Moscow time or Moscow time plus 1 hour, has the same service as Zone 4 but from the Statsionar 4 rather than the Statsioner 5 location. The First Radio Program and Mayak (Beacon) program are available to all zones through the Orbita network.[69]

GEOSYNCHRONOUS LAUNCH CONSTRAINTS

The right ascension of the ascending node of a satellite's orbit is the position of the point at which it crosses the equatorial plane, northbound, with reference to celestial coordinates. For a geosynchronous satellite in the equatorial plane this seemingly meaningless concept is taken to be the geostationary position but, for inclinations differing from the ideal zero degrees, the RA does have significance. Robert Christy, or the Kettering Group, pointed out that nearly all Soviet geosynchronous launches had similar RAs at launch and speculated that this was related to use of a Canopus sensor for alignment of the launch platform in the initial parking orbit. Nicholas Johnson showed that this resulted in a nearly linear relationship between hour of launch and the day of the year on which the launch occurred.[70] Notable exceptions to this rule are Molniya 1-S and Kosmos 637 and 775. The U.S. geosynchronous launches do not exhibit such a relationship implying major differences in approach. Johnson showed that, commencing with Ekran 1 in 1976, values of RA have been increasing, but at a decreasing rate, and that the curve for Gorizont satellites is displaced from the corresponding Ekran-Raduga curve.[71] Analysis by staff of Aerospace Corporation showed that luni-solar perturbations cause the inclination of the orbit to change with time. The rate of change can be minimized by choice of the initial value of the RA. This varies with date in a cyclic manner shown in figure 12 of Johnson's paper approaching a maximum in 1982.

The displacements of Raduga 8 and Gorizont 5, launched almost exactly 1 year apart, are more apparent from the plot of initial RA

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[69] Satellite Week, vol 4, No 17, Apr. 26, 1982, p. 4.

[70] Johnson, N L "The Development and Deployment of Soviet Geosynchronous Satellites." J. Br. Interplan Soc., vol. 35, No 10, October 1982, pp. 450-458.

[71] Ibid.

versus launch date than from the plot of hour of launch versus day of year.

METHOD OF ESTABLISHING THE GEOSYNCHRONOUS ORBIT

The theory for a minimum energy transfer from an initial near-Earth parking orbit to a circular orbit at geosynchronous height had been provided as early as 1925 by Dr. Walter Hohmann.[72] He showed that the minimum energy condition was met by an elliptical transfer orbit which was tangential externally to the parking orbit at its perigee and internally to the final orbit at its apogee. Refiring the rocket motor in the parking orbit produced an increase in kinetic energy from the change in velocity, or delta-V, which was traded for potential energy as the satellite climbed toward apogee, losing velocity as it went. Sometime later, at its apogee, it would begin to fall back around the ellipse because its velocity at apogee would be insufficient for a circular orbit at that height. However, the firing of an apogee motor to provide the necessary additional delta-V would result in a circular orbit being established.

The necessity for a plane change was an added complication. The Russian solution to the problem is illustrated in figure 42. A D-1-e launch from Tyuratam placed Kosmos 637, its transfer rocket and launch platform in a near-Earth parking orbit inclined at 51.6° to the Equator. Just over an hour after launch, as the spacecraft crossed the Equator over the Gulf of Guinea, the transfer rocket—possibly on command from a tracking ship in the Gulf—fired to raise the velocity from 7.8 km/s to 10.2 km/s and reduce the inclination to 47.2°. This amounted to a delta-V of some 2.5 km/s. The spacecraft separated from the transfer rocket and climbed on a path which took it across the Soviet Union and China to its apogee over the Equator some 5 hours later.[73] By then the velocity had dropped to 1.6 km/s—1.5 km/s short of the geosynchronous velocity of 3.1 km/s. However, this very low apogee velocity permitted circularization with the associated plane-change of 47.2° through a 2.3 km/s delta-V apogee burn.

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[72] Hohmann. W Die Erreichbarkeit der Himmelskorper. Munich, Oldenbourg, 1925

[73] Perry, G E Russian Geostationary and Early-Warning Satellites. R.A.F. Qy., vol. 17, No. 3, autumn 1977, fig. 2, p 272

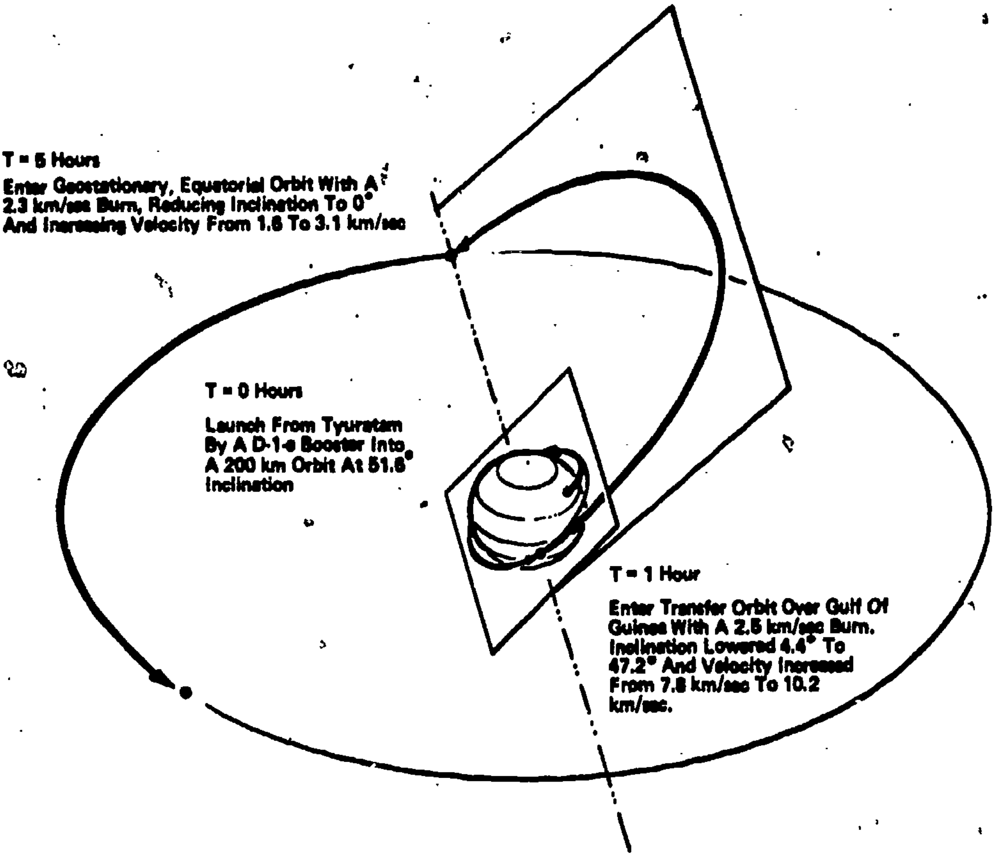

FIGURE 42.—Stages in Establishing a Geosynchronous Orbit from a Tyuratam Launch

Typically two fragments, labelled B and C by NORAD, remain in the near-Earth parking orbit from which they decay naturally in a few days. Two further objects, D and E, are cataloged in the transfer orbit while the payload, A, and a further fragment F reach the geosynchronous orbit. F is probably the apogee motor which is jettisoned once the final location is reached.

The sequence of events just described constitutes a two-impulse technique. Agadzhanov describes a three-impulse technique which is currently employed in which the apogee of the transfer orbit, although still in the equatorial plane, is higher than the geosynchronous altitude.[74] The second impulse raises the perigee from the height of the reference, or near-Earth parking, orbit to the geosynchronous altitude, also in the equatorial plane. The third impulse lowers the apogee to the geosynchronous altitude at the instant the satellite passes the perigee of the second transfer orbit. He points out the disadvantage of the two-impulse technique in being able only to place the satellite within an arc of 11.25 of longitude for a specific launch time such as dictated by consideration for minimizing lunisolar perturbations discussed at the end of the last section. The three-impulse technique is not restricted in the location of the

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[74] Agadzhanov, P.A., et al., idem.

final geosynchronous position by the launch time as this can be varied by suitable choice of apogee height for the first transfer orbit.

Other perturbations produce gradual changes in the geosynchronous location and, consequently, sporadic correction of the orbit is necessary. The number of corrections depends on the permissible amount of annual drift in terms of longitude. If such drift is not to exceed 4°/year, up to six corrections may be required.

It was soon realized that the geosynchronous orbit would become overcrowded with operational and exhausted satellites leading to a possibility of collision resulting in damage to an operational satellite. Steps are now taken to remove exhausted satellites from this orbit by transferring them to other orbits at the end of their active life. The Soviet Union removed Radugas 2 and 3 and the first two Ekrans from the geosynchronous orbit by placing them in elliptical orbits with slightly different orbital periods.

RECORD OF SOVIET GEOSYNCHRONOUS LAUNCHES

Table 33 lists the various Soviet geosynchronous payloads which have reached orbit, arranged in geographical location from west to east around the Equator.

TABLE 33.—SOVIET GEOSYNCHRONOUS PAYLOADS

Launch date	Unassigned	Location (°E longitude)													
		35E	44 5E	53E	58E	70E	80E	85E	90E	99E	140E	170E	190E	335E	346-7E
		Statsionar location													
		2	9		5		1	1.3.6	6	T	7	10	10	8	4
Mar 26 1974	Kosmos 637														
July 29 1974	Molniya 1 S														
Oct 8 1975	Kosmos 775														
Dec 22 1975							R-1								
Sept 11 1976								R 2							
Oct 26 1976										E-1					
July 23 1977		R 3													
Sept 20 [illegible]										E 2					
July 18 1978		R 4		1											
Dec 19, 1978															(G-1)
Feb 21 1979				E 3											
Apr 25 1979							R 5								
July 5 1979															G 2
Oct 3 1979				E 4											
Dec 28 1979				G 3											
Feb 20 1980		R 6													
June 14 1980															G-4
July 14 1980										E-5?					
Oct 5 1980								R 7							
Dec 26, 1980										E-6?					

Notes

1 The table arranges in geographical order from west to east the equatorial longitudinal stations registered at the International Telecommunication Union for Soviet geosynchronous satellites. The first line in the heading is in degrees East (E) or West (W) longitude, the second line in the heading shows the Statsionar designation. It should be noted that 190E is the same as 170W, 335E is the same as 25W, and 346-7E are the same as 13-14W

2 Satellites which have assumed a registered position through the end of 1980 had all been in the Statsionar series from 1 through 11 or T. Several of the registered Statsionar positions have not yet been utilized. There is some confusion about these locations in fact because Statsionar 1 satellites have gone both to 80E and 85E. Statsionar 6, has not been used yet, but may be at either 85E or 90E. Statsionar 10, also not used yet, may be at either 170E or 190E. Statsionar T is supposed to be at 99E, but at least 2 satellites in that system are at 53E

3 Kosmos 637 was the first flight to reach a geostationary position, but its equatorial location was not announced. It was presumed to be an engineering test. Molniya 1 S was a communications test at the frequencies also used by the 12-hour semisynchronous, inclined orbit Molniya 1 large family. Kosmos 775 was another test flight which reached geostationary orbit, but not to an announced equatorial spot. Speculatively, it was related to early warning missions

4. The rest of the flights have been announced as reaching Statsionar registered positions. The letter R refers to Raduga flights; the letter E refers to Ekran flights and the Statsionar-T series, and the letter G refers to Gorizont flights. Gorizont 1 reached geosynchronous orbit, but not geostationary orbit, instead tracing a figure-8 pattern

5. One is left to guess which replacement flights in a given Statsionar position are to provide reserve capacity, and which replace failed payloads.

6. The text of the main report describes missions, frequencies, and other details of each of these classes of payloads.

Sources: Flight dates are from app. III of pt. 1. Statsionar assignments of flights are as announced by Tass. Actual longitude positions from Raduga 1 through Gorizont 4 are from: Morgan, Walter L. Geosynchronous Satellite Log for 1980, in Comsat Technical Review, vol. 10, No. 1, spring 1980, pp. 233-262. Subsequent flights have been estimated based on Tass announcements.

BROADER PROPOSALS AND APPLICATIONS OF SOVIET COMMUNICATIONS SATELLITES

INTERNATIONAL LINKS

Intersputnik system

At the 1968 United Nations-sponsored meeting on the peaceful uses of outer space, the Russians unveiled their plans for an international consortium known as Intersputnik which would rival the Intelsat system in providing communications services. At Vienna the Russians discussed their future plans for Intersputnik which included progressing from the Molniya satellities to an advanced 24-hour synchronous system. The Russians did not discuss technical details but said that the satellite's operation would be compatible with the Intelsat system and that the satellite would be quite large and have a high power output.[75]

On November 15, 1971, nine countries signed an agreement in Moscow to establish the Intersputnik system. Parties to the agreement were: Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Mongolia, Poland, Romania, and the Soviet Union.

The first direct television transmission from the U.S.S.R. to Cuba was performed November 7, 1973, with the telecast of the Red Square Parade. Later, telecasts of Soviet Communist Party Secretary Leonid Brezhnev's state visit to Cuba were relayed to Moscow. The Intersputnik system was formally inaugurated in February 1974 with the commencement of regular relays, via Molniya 2 satellite, between Cuba and Russia. Telecasts were relayed by the Caribe Earth station equipped with a 12-meter dish antenna and located 30 kilometers from Havana in Haruco. Later, a Czechoslovakian station in Prague was completed on the eve of the 1974 May Day celebrations, and an Ulan-Bator, Mongolia station was finished before the October celebrations of the same year.

The Molniya satellites were replaced by Raduga satellites when they became available since their geosynchronous orbits were more advantageous than the highly elliptical Molniya orbits which required fully steerable antennas at the ground stations. Today Gorizont satellites have replaced the Radugas entirely.

Currently, Intersputnik leases four transponders on Gorizont-Statsionar 4 from the U.S.S.R. Two of these are used for radio-TV transmissions, one for voice and data links, and the fourth is spare. It also leases two transponders on Gorizont-Statsionar 5. One for radio-TV and the other for voice and data links. Eventually it is planned that Intersputnik will have its own spacecraft but probably not before the end of the decade.[76]

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[75] Aviation Week & Space Technology, New York, Aug. 26, 1968, pp. 19-20.

[76] Satellite Week, vol. 4, No. 17, Apr. 26, 1981, p. 5.

Although Intersputnik consists of socialist bloc countries it is an organization open to any state that wishes to join and abide by the agreements, principles and policies of the organization. A letter of intent is sent to the Directorate agreeing to pay annual dues of 15,000 rubles.[77] The government of Intersputnik consists of a board and directorate. The Board consists of one representative from each member state, each with an equal vote. It meets annually or more frequently if necessary to decide how Intersputnik should be operated, the technical specifications of ground stations, and to elect the Director-General and his deputy. The Directorate, consisting of these 2 persons and 10 technicians, is the main executive and administrative body of the organization. The Director-General is the representative to all outside international or state organizations and executes the Board's decisions.

Each member state must construct an Orbita ground-receiving station in compliance with the standard technical specifications of Intersputnik. These stations are the property of operating agencies under the Intersputnik agreement. They need not be purchased from the Soviet Union; in fact, Nippon Electric supplied the Intersputnik stations to Algeria and Iraq. The increased power of Gorizont over Molniya and Raduga means that some antennas are only 12 m in diameter instead of the 25 m diameter needed initially.

Providing they have the proper facilities, member countries may launch and control satellites belonging to Intersputnik on a bilateral agreement with Intersputnik.

The original member states have now been joined by Vietnam, South Yemen, Afghanistan, Syria, and Laos. Algeria and Iraq are not members but lease channels from Intersputnik. North Korea is preparing an Intersputnik Earth station and Intersputnik has had contacts with Libya, Angola, Mozambique, Madagascar, and Sri Lanka. Intervision countries of Intersputnik are not member states but use Intersputnik for television program exchange, telephone and telegraph links. During the 1980 Moscow Olympics more than 30 countries in Africa, Asia, Europe, and Latin America used Intersputnik to receive broadcasts. A total of 820 hours were broadcast.

Intersputnik services are considerably less expensive than those of Intelsat. The lease of one satellite-voice circuit costs $11,615 annually compared with the Intelsat charge of $19,358 and Earth station operations cost $383 for the first 10 minutes and $11 per minute subsequently as opposed to Intelsat's $968 and $30 respectively.[78]

Pirard claims that techniques developed and used by Intersputnik are currently not as advanced as those used in the Intelsat system but that Intersputnik appears to be working to lessen the technical disparities between the two systems. He speculates that, in the near future, Intersputnik may well prove to be a strong competitor for the world market.[79]

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[77] Pirard, T. Satellite Communications, vol. 6, No. 8, Aug. 1982, pp. 38–44.
[78] Ibid.
[79] Ibid.

Inmarsat

As early as 1966 the delegations of the United States and the U.S.S.R. to the newly established Inter-Governmental Maritime Consultative Committee [IMCO], considered it advisable to attempt to solve maritime satellite communications problems on an international level. In accordance with a Soviet proposal, a special Panel of Experts was set up in 1972, under the auspices of IMCO, to elaborate a concrete work program.[80]

In 1976, the Soviet Ministry of Merchant Marine set up an autonomous organization, charged with processing data received by means of Soviet and International Earth satellites necessary for ensuring communication and navigation on the high seas. Launched with capital of 40 million rubles, called Morsviazsputnik (maritime satellite communications), it is planned to operate ultimately as a self-supporting commercial concern. Its President, throughout its existence, has been Yuri S. Atserov.

The Convention and Operating Agreement on Inmarsat, adopted by the Third IMCO Conference Session on September 3, 1976, came into force on July 16, 1979, once sufficient member-states (26) had subscribed 95 percent of the initial share capital.

Membership of Inmarsat, as of January 1983, comprised 37 member states. The Byelorussian and Ukranian SSRs are counted as separate members of the Assembly, which decides on political matters. Each Assembly member has one vote, and the body elects four at-large members of the Council, which is responsible for Inmarsat management. Voting in the Council is weighted on the basis of each nation's percentage of ownership. The United States holds the largest share investment, 23.36 percent, followed by the U.S.S.R. (including the Byelorussian and Ukrainian SSRs) with 14.09 percent, the United Kingdom (9.89 percent), Norway (7.88 percent), and Japan (7.00 percent). The minimum holding permissible is 0.05 percent.

The operational plan for the first generation of the system provided for coverage over the Atlantic, Indian and Pacific Ocean zones via leased transponders, installed upon Marecs, Intelsat-5, and Marisat satellites. Initial tariffs were set at $5.25 per minute for the use of a telephone channel and $2.4 per minute for the telegraph channel. Distress messages and control tests of shipboard terminals were to be on a free-of-charge basis.

The Soviet Union is contructing coast-Earth stations for maritime satellite communications at Odessa (46.6° N, 30.3° E) on the Black Sea and Nakhodka (42.8° N, 132.8° E), a small port on the eastern Siberian coast 100 km to the east of Vladivostok on the Sea of Japan. These will be capable of operating both within the Inmarsat system and the internal Volna-Statsionar system. Coast Earth Station-I, at Odessa, will service the Atlantic and Indian Ocean zones, while Coast Earth Station-II, near Nakhodka, will cover the Pacific and Indian Ocean zones. The capacity of each of these centers is planned to be up to 80 equivalent telephone satellite channels.

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[80] National Paper: U.S.S.R., Sept. 2, 1981, pp. 72-73.

The Soviet-built "Standard-A" ship-Earth station with a 0.8–1.0 m diameter antenna, expected to be in mass production by 1982, meets all the specifications of Inmarsat and of the U.S.S.R. Register regarding the conditions of operating this type of equipment on board vessels, including arctic conditions.

As of January 1982, only nine Soviet ships were equipped with ship-Earth stations, all supplied with U.S. or Japanese-made terminals and operating through the Marisat system. Four of these were cruise ships, for which the terminal is provided as a passenger service facility. With a total of more than 17,000 vessels, operated by 17 different corporate organizations, including those devoted to inland waterways, to be equipped in due course, the U.S.S.R. took the logical view that its own domestic technology should be made to handle at least its own market. Further spread of terminals in the Soviet fleets was therefore halted until development of an indigenous ship-Earth station should be complete. Light-weight terminals of the "Standard-B" type, permitting duplex and simplex telegraph communications and reduced quality telephone communications, are also under development. Their mounting aboard any vessel, regardless of its displacement, envisages the use of a light-weight antenna of up to 0.5 m diameter.

According to Atserov, Soviet shipping companies will be free to choose whether to buy Soviet equipment or foreign-made terminals. The target plan is for 4,000 vessels to be equipped over 15 years, of which a large percentage will be fishing vessels, reflecting a policy of bringing high technology and tight management to the massive investment in the fishing industry. The majority, however, will be assorted commercial craft. Equipping with terminals is expected to proceed at an initial rate of up to 100 a year from 1983 when the Soviet unit is expected to enter production.[81]

With the Volna research program, a series of small traffic coast-Earth stations to be installed directly with the shipowners, is being developed. Work is also in progress on the creation of *Aerosat*, a satellite and communications system for aviation. This will be required to provide reliable communications with aircraft, primarily transport planes, in telephonic and telegraphic modes and the continuous determination of the aircraft's position.[82]

A feasibility study is also in hand towards the possibility of equipping some of the Molniya satellites for maritime use. The advantage would be their ability to provide quality links with latitudes too far north for coverage by geostationary satellites. Morsviazsputnik representatives at the 32d I.A.F. Congress in Rome in 1981 explained that in extreme northern and southern latitudes (greater than 72°), cargo, fishing and research vessels, drilling platforms and drifting stations of many countries were unable to use geostationary satellites. Experiments to provide TV transmissions to arctic ships, carried out in 1979, proved unsuccessful, requiring too large an antenna. Additional requirements for ship-Earth stations operating through Molniyas would be ensuring correct tracking of the satellite and compensation of Doppler shift due to the satellite's velocity relative to the ship by an automatic frequency

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[81] Ocean Voice, January 1982.
[82] Agadzhanov, P.A. et al., idem.

compensation system. To provide two 6-hour communication sessions from Earth segments outside latitudes lying between approximately 55° N and 55° S, ship antennas need to be able to track the satellite at angular velocities of up to 10°/hour, which is quite feasible.[83] The Soviets wanted Inmarsat to consider use of two or three satellites, based on Molniya and its highly elliptical semi-synchronous orbit inclined at 63° to the Equator, to supplement the U.S. Marisat and next Inmarsat geostationary systems.

The question of use of ship-Earth stations in Soviet harbours has yet to be resolved. Current regulations, basically allied to those governing the use of conventional radio, for use both in harbour and territorial waters, are quite restrictive. Free use of satellite communications is permitted only for ships in distress, aiding others in distress or when sailing through ice. Apart from this, special permission to use communication satellites can be obtained only when there is no shore radio station within a 10-mile radius of the port. Further development of this legislation may emerge including the issue of possible bilateral agreements as an instrument to solve these problems.

U.S.-U.S.S.R. cooperation

By mid-1975 the Soviet Union was in the final stages of testing a major Earth station close to L'vov in the Ukraine, near the Polish border (49.9° N, 24.0° E), to operate in international commercial communications with Intelsat. The Russians purchased from ITT Space Communications (International Telephone and Telegraph Corp.) 12 duplex voice-grade channels of Spade terminal equipment that makes possible operation with satellites on a demand-assignment basis. ITT-U.S.S.R. negotiations on the Spade equipment developed during the Washington-Moscow hotline discussions (see below). With Spade terminal equipment, the communicator can utilize satellite channels that may remain unused for long periods. Spade equipment installed at the L'vov station gives the U.S.S.R. direct access on a demand assignment basis to similarly equipped stations in the United States, Canada, Peru, Brazil, Argentina, United Kingdom, the Netherlands, France, Italy, Greece, Switzerland, West Germany, and Sweden.[84]

The Dubna station, 140 km north of Moscow, was built in time for the 1980 Olympic games and houses three Earth stations. The first, with an antenna 32 m in diameter, manufactured by the Nippon Electric Co., is used with an Intelsat-5 satellite for voice and data links with the United States, Canada, and between Tokyo and Brazil (with land link from Japan to Dubna). The second station is used for Intersputnik and the Moskva system through the Gorizont-Statsionar 4 satellite and has a 12 m dish made in the Soviet Union. The third station is to be used with Loutch satellites in the Ku-band and is expected to be ready in 1983. All three stations are served by a central control room. The Director of the Dubna station is Viktor Okhrimenko.[85]

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[83] Satellite Week, vol 3, No. 40, October 1981, p 4

[84] Aviation Week and Space Technology, New York, Sept. 22, 1975, p. 9.

[85] Satellite Week, vol. 4, No. 17, Apr 26, 1981, p. 6.

Neither the L'vov nor Dubna stations feature in the I.T.U. publication used as the source for table 24. Only the Moscow station is listed as working through the Atlantic Ocean Intelsat, but this may, in reality, be synonymous with the Dubna station.

Washington-Moscow hotline

The United States and U.S.S.R. on September 30, 1971, as part of the initial Strategic Arms Limitation Talks [SALT] negotiations, signed accords on the prevention of accidental warfare which authorized the establishment of a new Washington-Moscow "hotline" via satellite. The main objective of a satellite link would be increased reliability. Although the terrestrial hotline, which was established as a result of the Cuban missile crisis, has never been a target of planned sabotage, it has been subject to occasional disruption with sections of the cable blacked out by fire, pilfered, and once plowed by a Finnish farmer.

The hotline system consists of two duplex telephone-bandwidth circuits equipped for secondary telegraphic multiplexing and for ground stations for transmission and reception. One circuit is on the Molniya system and the other is on the Intelsat system. Encoded teletype messages go from the United States to Moscow in English via the Intelsat system and from Moscow to the United States in Russian via Molniya 3 satellites.

Originally, the Russians intended to use a station in the suburbs of Moscow for Intelsat and a Molniya station at Vladimir. However, because of severe winter weather conditions in the Soviet Union, the Russians have constructed a second Intelsat station, approximately 50 miles from L'vov, to ensure increased dependability.[86] The United States has a Molniya station at Fort Dietrick in Frederick, MD, and an Intelsat station at Etam, WV.

Although Soviet and American communications experts had successfully tested the new network, the system was not scheduled to begin operation until the second half of 1976.[87]

On January 16, 1978, the "hot line" began using two independent satellite systems to transmit messages between Washington and Moscow. It was expected to provide a communications service of higher reliability than the cable link or the recently discontinued high-frequency radio system. The DCL would be less vulnerable than those systems since it eliminated dependence on third-country facilities. In addition it was not susceptible to the interruptions caused by atmospheric interference problems common to HF radio systems.

Circuits are tested hourly, using a variety of sample messages. Normally, items such as nonpolitical passages from magazine articles and books are used in the text of the messages. All messages, including these transmission tests, are automatically encoded upon transmission and decoded upon receipt. Both United States and Soviet systems operate simultaneously so that if one system fails, the other continues to provide communications.

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[86] Undated State Department press release issued by the Direct Communications Link [DCL] Delegation.

[87] Wren, C. "Soviet and the U.S. Are Shifting Hot Line to Satellite Systems." New York Times, Mar. 23, 1976.

One notable use of the "hot-line" occurred during the Arab-Israeli Six-Day War in 1967 when President Johnson advised the Soviet Union of U.S. ship and aircraft movements in the Mediterranean following an Israeli attack on the U.S.S. *Liberty.*[88]

"Mars" portable ground station

The Soviet "Mars" portable ground station for the Molniya communications satellite system was first used in November 1973 to transmit television broadcasts to the Soviet Union of Brezhnev's visit to India. The Mars station was also used in Ulan Bator during the festivities for the 50th anniversary of the Mongolian People's Republic to transmit television programs between the Soviet and Mongolian capitals. It has also relayed television signals from Havana and Sofia.

The air-transportable, truck-mounted unit has a 7-meter dish antenna and contains essentially the same elements as the orbital permanent ground stations for Molniya and can be put in three containers 5 m long, 2 m wide, and 2.5 m high. The large power output of the Molniya satellites makes the use of this small transportable station possible. Mars, which can be moved from point to point while semi-deployed, has a capacity of one color television image and one audio channel. A distinctive feature of the portable station is its capability to operate with satellites which are either in an elliptical or geostationary orbit.

JOINT EXPERIMENTS WITH FRANCE

Like much of the rest of the world, the Soviet Union has not only had a rapid expansion of television services, but has moved toward use of color broadcasts, although not so fast a pace as the United States and Japan. After studying various technical alternatives to the achievement of color, the Soviet authorities selected the French SECAM 3 system, which they now build under license.

The Russians have also demonstrated color television exchanges with France via Molniya 1, using the main ground station at Moscow, while the French used their Intelsat station at Pleumeur Bodou in France. By this means, the video portion of a color program was sent on November 29, 1965, from Moscow to Paris. A return broadcast was made from Paris to Moscow on May 28, 1966. There followed 13-days of additional tests in both directions.

In 1966, when General DeGaulle visited Moscow, Molniya 1 was used not only to broadcast the program to Soviet outlets, but also was relayed to Paris.

KOSPAS-SARSAT

The idea of using satellites to perform a search and rescue [SAR] function dates back to 1959 when Space Electronics Corp. made the proposal to NASA and DARPA. This gained no support until the mid-1970s, when a U.S. interagency group recommended NASA to evaluate the technique. Initially this called for the distressed craft to carry a small emergency locator transmitter which would be turned on by impact or manually and transmit a distinctively mod-

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[88] Yasharoff. N. Spaceflight, vol. 20, No. 5, May 1978, p. 178.

ulated signal at 121.5 MHz and 243 MHz, ~~the civil and mi~~litary distress frequencies. The satellite would rebroadcast the received beacon signal to a ground station, which would determine the satellite's position at the instant of zero beacon-doppler shift. The distressed craft would be somewhere along the line perpendicular to the satellite's ground-track at that time and the rate of change of the received beacon-frequency would be a measure of its distance from the sub-satellite point.

Congressional action resulted in distress beacons becoming mandatory after July 1974 but similar action to establish a network to monitor such signals was not forthcoming. Scientists at NASA's Goddard SFC found that the distress beacon carrier frequency, especially from the very low cost units developed for general aviation, was not sufficiently stable for direct processing by the method outlined above. A new 406 MHz beacon system, still under evaluation, was specially designed for satellite system use. The more stringent requirements on transmitter-frequency stability should permit rapid, simple beacon-doppler processing on board the satellite using microprocessor techniques. This means that the position-fix, made by the satellite can be stored on board and later transmitted to Earth when the satellite comes in range of a local user terminal, ensuring global coverage for all distressed craft, regardless of whether there is a local user terminal in the region. In order to avoid possible interference from other beacons in the same area, the beacon will transmit for 440 milliseconds every 50 s. The silent interval will be changed slightly every cycle to prevent two beacons repeatedly transmitting simultaneously.[89]

The processed signal would be transmitted to Earth digitally in the L-band at 1.544 GHz. In March 1977, a technical team from the Soviet Union was briefed at Goddard SFC by NASA on ways in which the Soviets might participate in the proposed NASA-Canada SAR demonstration. A proposed experimental program was developed in which one or more Soviet satellites would be equipped with SAR transponders and Soviet ground stations would be established for SAR operations. In addition, the Soviet activity was to be compatible technically and in schedule with the NASA-Canadian program.[90]

By the beginning of 1980, NASA had commenced modifications of NOAA spacecraft and signed interagency understandings with the U.S. Department of Transportation, NOAA, and DOD. Internationally, an agreement had been signed during 1979 between NASA, the Canadian Department of Communication [DOC], and the French National Center for Space Study [CNES] which provided for SAR instrumentation to be carried onboard three U.S. NOAA operational meteorological spacecraft for a 15-month demonstration (called SARSAT). A second agreement signed between the SARSAT parties and the Soviet Union during 1979 established interoperability between the SARSAT system and a similar Soviet system (called KOSPAS). The KOSPAS-SARSAT agreement, which entered into force in August 1980, provided for a cooperative effort

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[89] Klass, P.J. Aviation Week & Space Technology, vol. 118, No. 9, Feb. 28, 1983, pp. 75-81.

[90] Protocol on Cooperation in an Experimental Satellite System for Search and Rescue of Vessels and Aircraft in Distress, signed at Greenbelt, MD, Mar. 18, 1977.

which would allow a more effective demonstration and evaluation to take place than would have been possible for either system alone. The Soviets were to launch at least two interoperable spacecraft beginning in mid-1982.

Roman Chernyayev, Deputy Director of the Central Institute of the Merchant Marine in Leningrad, speaking to TASS in 1981, said that full-scale testing of the system was planned for 1983 and that test operation of the system was scheduled for 1984.[91]

Further details of the Soviet approach are given in their submission to the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space and in Agadzhanov's booklet on *Communications Satellites.*[92]

The KOSPAS-SARSAT system (KOSPAS is a Soviet acronym for "Satellite System for Locating Vessels and Aircraft in Distress") operates in close cooperation with Inmarsat, IMCO and the International Consultative Committee on Radiocommunication [C.C.I.R.]. The latter is a body within the I.T.U., engaged, in particular, with the coordination of developments and experiments conducted by countries in choosing optimal principles of transmitting signals from marine EPIRBs (Emergency Position-Indicating Radio Beacons) and aviation ELTs via satellites.

The KOSPAS-SARSAT project consists of two distinct experiments involving separate frequencies. The first experiment uses the existing family of ELTs and EPIRBs which transmit at 121.5 and 243 MHz. The second experiment uses ELTs and EPIRBs specifically designed to transmit at 406 MHz. The key advantage of use of 406 MHz is that its higher power and improved frequency stability will greatly enhance the overall system performance by comparison with the 121.5/243 MHz system. In addition, the 406 MHz data message can be transmitted with information containing the vessel's code, its flag, type of vessel, the nature of damage or the time elapsed. The parties have agreed upon emergency procedures and the formats of exchange of emergency and operational information between the KOSPAS and SARSAT centers. Both systems are being developed so that their technical characteristics will be compatible and they will be able to function effectively both independently, separately, and together, in coordination.

Some satellites of the system will be placed in circular circumpolar orbits at an altitude of about 1000 km, as currently employed by navigation satellites in the Kosmos series. When the signal received is decoded a determination is made of the coordinates of the object in distress (initially with a precision of 2 to 4 km). It is calculated that, in the initial stages of experimental operation, it will take an average of no more than 2 hours from the moment the distress radio buoy is switched on until its signal is received by the "rescue" satellite. Calculations have also shown that the chances for saving objects in a state of distress and people having met with catastrophe increase dramatically with this short notification period.

Local User Terminals [LUT's], ground stations for the reception of satellite search and rescue information, are being established in

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[91] Moscow. Tass in English, Aug. 17, 1981, 1554 G.m.t.

[92] Agadzhanov, P.A., et al. National Paper: U.S.S.R., Sept. 2, 1981, p. 73.

Moscow, Archangel'sk, and Vladivostok for the KOSPAS system, and in the United States (in Illinois, California, and Alaska), Canada (in Ottawa), and France (in Toulouse) for the SARSAT system. Head of the Kospas project is Yuri Zurabov and Yuri Makarov is its technical manager.

Levels of financial contributions, in millions of U.S. dollars, have been estimated at U.S.S.R., approximately 40; U.S.A. 29.0 (NASA 24.0, DOD/USAF 2.5, DOT/Coast Guard 2.5); Canada, 14.0; and France, 10.0.

FUTURE OF COMMUNICATIONS SATELLITES

TECHNICAL CONSIDERATIONS

Soviet radio engineers and communications specialists are studying the optimum relationship between the power of on-board transmitters and the scale of the equipment at ground stations for the reception of information. The greater the power of the on-board transmitter, the simpler are the ground antennas and the receiving equipment. However, this is compensated for by a complication of the satellite and an increase in its weight. Thus, the question of alternative communication distribution systems arises. One alternative is the use of one relatively large antenna along with ground channels as is done in the Orbita system. Another alternative is the use of a more powerful satellite with receivers in each populated place similar to the Indian approach. Both these directions are technically feasible.[93]

The latter alternative has been adopted for the Ekran system described earlier and it is arguable that, in some instances, such use might be considered as a direct broadcast system.

Moves to use of the higher frequency bands in the West find parallels in Soviet thinking. The Ku-band at 10/15 GHz is specified for the Loutch satellites and, no doubt, research and development at 20/30 GHz is in hand.

DIRECT BROADCAST SATELLITES

Eventually, the power of the on-board transmitters will be increased to sufficient strength for direct television broadcasting from space. However, Soviet views on direct broadcasting from space are ambivalent. They have referred to such plans as means of aggression. They reason that such programming might involve the spread of hostile propaganda and would circumvent the carefully controlled programming now under the jurisdiction of the individual states. These fears inspired a Soviet-sponsored proposal on direct broadcast television satellites which would authorize any receiving nation to destroy or jam the satellite if it judged the broadcast illegal or erroneous. In the draft treaty presented to the United Nations by Foreign Minister Andrei Gromyko on October 12, 1972, specific illegal areas would include those that: were detrimental to the maintenance of international peace and security; interfered in intrastate conflicts; encroached on fundamental human rights; presented violent, horror-oriented, pornographic and

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[93] Konovalov, B. Lightning-Quick Communication, Izvestiya, Moscow, Dec. 31, 1974, p. 5.

drug propaganda; were against the foundations of local civilization, culture, mores or traditions; or presented misinformation. The sole judge of the illegality would be the receiver nation.[94]

At the same time the Russians have discussed in glittering generalities the vast potential of direct broadcast from satellites. According to academician Boris Petrov:

> Thanks to . . . direct transmissions of television programmes through sputniks to conventional television aerials, it will be possible to have a wider dissemination of scientific, medical and health and agricultural knowledge. Space television will become available to the population even in the most remote parts of the world.[95]

And, in 1974, Oleg Belotserkovets, rector of the Moscow Technical Institute of Physics, announced:

> Soviet specialists have developed devices which will make it possible in the near future to receive television broadcasts rom communications satellites directly through house aerials . . . The quality of the broadcasts will improve . . . When this work is completed there will be practically no places left in the country inaccessible to television reception.[96]

One of these "devices" could be the use of nuclear powered broadcasts. In 1972 it was announced that a nuclear power source was successfully tested in one of the Kosmos satellites. More powerful atomic reactors were to be installed on future sputniks which would enable the satellites to transmit a signal of such strength that reception directly on the television set antenna, without previous reinforcement at the Orbita station, would be possible.[97] No indication of the use of nuclear reactor power for such use has yet appeared, such use being solely for the radar ocean surveillance satellites of the Kosmos series.

TRACKING AND DATA RELAY SATELLITE SYSTEMS

Details of an Eastern Satellite Data Relay Network [ESDRN] lodged with the International Frequency Registration Board in 1981 show that the Soviet Union intends to operate a system employing frequencies in the Ku-band similar to the American Tracking and Data Relay Satellite System for communicating with Salyut stations and other spacecraft in low Earth-orbit, commencing no sooner than December 1985.

Data relay satellites are to be positioned at 16° W, and 95° E and Earth stations will be established at Moscow and Khabarovsk.

METEOROLOGICAL SATELLITES

Weather reporting by satellite was another of the early uses of satellites identified by the Russians, although an operational system was not developed until a much later date. Global weather

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[94] Aviation Week & Space Technology, New York, Oct. 23, 1972, p. 20.
[95] Pravda, Moscow, Dec. [illegible]
[96] Oleg Belotserkovets, TASS, Moscow, July 1, 1974, 1205 G.m.t.
[97] Moscow Radio, Feb. 7, 1972, 0930 G.m.t.

photos are important for a variety of reasons. First, weather is a total system involving interactions in the atmosphere of the whole planet. Hence, worldwide reporting of phenomena with frequent updatings is important to any forecasting other than immediate forecasting in a particular location. Second, weather distant from the home territory of a country such as the Soviet Union is important to operations of commercial and military aircraft, to the merchant and naval fleets on the seas, and to fishing interests. Former methods never gave an adequate or timely average because reporting stations were too few and communications were too slow. Satellites have the capacity to provide data needed to remedy these previous shortcomings.

EARLY EXPERIMENTS

An earlier section of this study has listed the types of missions assigned to Kosmos satellites, with several of those missions at least indirectly pointed toward development of meteorological satellites. These references included various kinds of solar studies, ionospheric studies, magnetic studies, and studies of the distribution of cloud cover.

KOSMOS 14 AND 23

These two satellites of April 13, 1963, and December 13, 1963, were originally described as conducting miscellaneous geophysical studies. Years later, they were specifically identified as the test beds of electro-technical systems to guarantee the orientation and stabilization of weather satellites, and as a means for testing power supplies using solar cell batteries.[98] The results of these tests were incorporated in Kosmos 122 and subsequent payloads of that series. A drawing of Kosmos 23 is given in figure 43.

KOSMOS 4, 7, 9, 15, 45, 65, AND 92

These flights were essentially part of the military observation recoverable payload series, but it was revealed later that they carried supplemental experiments to aid in the development of weather satellites. Kosmos 4, launched on April 26, 1962, was the first recoverable payload in the Kosmos series and was the first satellite to carry out experimental television of cloud cover. Kosmos 7 and 15, launched on July 28, 1962, and April 22, 1963, were cited in the announcement greeting the launch of the 400th Kosmos as making measurements of the Earth's radiation belt in the region of the South Atlantic Magnetic Anomaly and later to have also carried meteorological sensors, as was Kosmos 9, launched on September 27, 1962.

Kosmos 45, 65, and 92 were launched September 13, 1964; April 17, 1964; and October 16, 1965; respectively. Each measured the energy distribution in the Earth's thermal radiation with diffraction-scanning spectrophotometers, and semiconductor bolometers as infrared sensors. Photometric determinations of the cloud cover were made along with measurements of scattered solar ultraviolet

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[98] Trud Moscow, Jan. 24, 1968, p. 4.

radiation. These results, too, were employed in developing Kosmos 122 and subsequent flights of that series.

KOSMOS 44, 58, 100, AND 118

There four flights have never been described as to mission by the Russians, but they flew so nearly the orbit of Kosmos 122 that it must be presumed that they were precursors to the weather satellite series. Either they were to test the basic hardware alone, or they also carried weather cameras for TV and infrared detection, which failed to function. These flights were launched on August 28, 1964; February 26, 1965; December 17, 1965; and May 11, 1966. All four were in circular orbits approximately 640 kilometers in altitude.

THE ANNOUNCED WEATHER SATELLITES OF THE KOSMOS SERIES

KOSMOS 122

Kosmos 122 was launched on June 25, 1966, though without an announced specific mission at the time. The Soviet Union and the United States already had an agreement to exchange pictures gathered by weather satellite over the so-called Cold Line between Moscow and Suitland, MD. For some months, no satellite data were transmitted over the line because reciprocity was the rule and there were no Soviet pictures forthcoming to match those of the U.S. TIROS series.

However, after some months during which the Russians apparently experimented with this payload, they finally acknowledged that it was a weather satellite.[99] For a few weeks, then, pictures on a selective basis were transmitted to the United States over the Cold Line with reciprocity on the part of the United States. The pictures received in the United States by cable were not of good quality, and they arrived too late for real-time use in weather prediction. Part of the trouble lay in the inadequacy of the cable link, but slow Soviet processing in Moscow also seems to have been a factor. The pictures ceased coming after a few weeks, strongly suggesting that the payload instrumentation had had only a short life.[100] This flight was the last one of its series flown from Tyuratam with an A-1 vehicle at a 65° inclination.

Although Kosmos 122 was not very successful as a long-term-use operational device, it pioneered some important techniques in weather reporting, more nearly matching in concept the complex U.S. Nimbus series rather than the smaller and simpler original U.S. Tiros type.

Instrumentation

Kosmos 122 carried instruments for a television survey of the cloud cover, other cameras for the infrared survey of clouds by day and night, and further instruments for measuring the radiation of the Earth's atmosphere. The instrumentation of Kosmos 122 made use of the 8 to 12 micron window of transparency for its day and

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[99] Izvestiya, Moscow, Aug. 19, 1966, p. 4.

[100] This was confirmed as 4 months by Izvestiya, Moscow, Mar. 17, 1967, p. 5.

night scanning of infrared. Ordinary television was used for daytime cloud cover pictures, and for measuring limits of ice fields in the absence of clouds. The downward intensity of radiation was measured in three bands. Measurements in the 0.3 to 3 micron range (visible light and lower infrared) made it possible to measure the intensity of reflected radiation, about 70 to 80 percent from clouds, most of the rest from oceans. Studies in the 8 to 12 micron band made it possible to estimate the temperature of the Earth or of clouds visible from the atmosphere into space. Data from the satellite were processed through a computer on Earth with appropriate allowance for the position of the satellite to derive radiation intensity maps of the Earth. It was made clear that Kosmos 122 was still experimental and reported data for only parts of its total orbit.[101] (Kosmos 122 is shown in figure 43.)

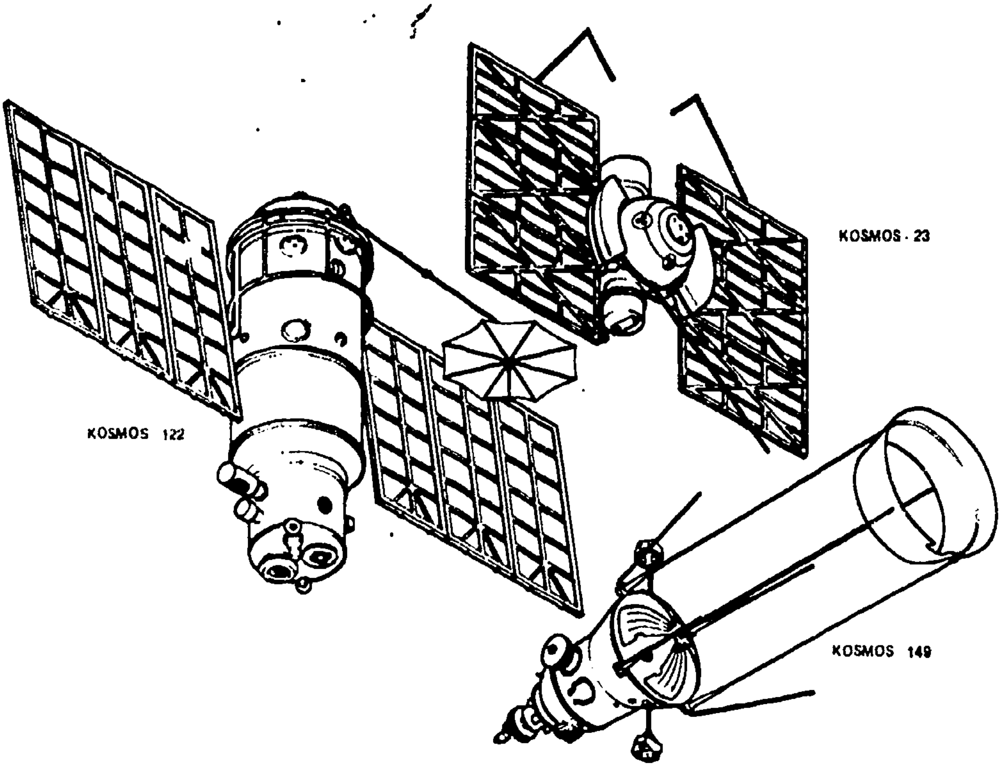

FIGURE 43.—Kosmos 23, 122, and 149 Satellites

Payload appearance

When pictures of Kosmos 122 were released, it was revealed to be a fairly large cylinder, perhaps 1.5 meters in diameter and 5 meters long, and extending from opposite sides were two large solar panels of three segments each. It was three-axis stabilized with fly wheels driven by electric motors; it could tilt the panels to

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[101] Izvestiya, Moscow, Aug. 21, 1966, p. 5.

collect the maximum amount of solar energy; and it was pointed vertically toward the Earth in order to have its cameras properly aligned. A long arm carried a steerable groundplane antenna to return data to Earth. A more complete description will be given shortly, as it is apparent that the later operational system uses essentially the same design.

KOSMOS 144

This was the first launch of a weather satellite from Plesetsk, and came on February 28, 1967. With this launch the Russians began placing the satellites of this configuration in circular 650 kilometer orbits at an inclination of 81°, using the A-1 vehicle. (Today these satellites are placed in an even higher orbit 900 kilometers above the Earth.) Kosmos 144 represented an improvement over Kosmos 122 in that the solar cell arrays are even larger, arranged on four folding panels to a side instead of three. The more extreme inclination of the orbit to the Equator comes closer to giving global coverage than did the 65° inclination flights from Tyuratam.

A series of important scientific problems having great significance in the field of space engineering were solved as a result of the development of meteorological satellites. Experience with the continuous operation of Kosmos 144, among others, proved that it was possible for solar batteries to operate in a stable manner for long periods of time in outer space under sharply changing temperatures causing thermal "shocks." These "shocks" are experienced when spacecraft pass into shadow and depart from it.[102]

In a number of respects, Kosmos 144 was an advance over its predecessor which had operated only a few months, and then left the Soviet Union with no operating satellite of this type until Kosmos 144 appeared. The newer satellite operated continuously instead of intermittently. The television system was described as having a resolution of several kilometers, for purposes of defining cloud formations. It still left unsolved a Soviet goal of investigating the vertical temperature profile of the atmosphere and other unspecified tasks.

Kosmos 144 was specifically described as equipped with two television cameras, an infrared sensor, a radiation sensor, and a magnetometer. Its picture revealed essentially the same structure as Kosmos 122: a main cylindrical body, with a Sun-sensor at the upper end. On the opposite sides were the large four-segment panels covered with solar cells for power supply. At the bottom was a complex smaller cylinder containing the two downward pointing television cameras, the orbital control devices, the radio antennas, the senors for infrared, magnetic data, and actinometric data. Television camera resolution was described as three times that of the ESSA satellites orbited by the United States. The television cameras switched on automatically any time the Sun was more than 5° above the horizon. Because Earth illumination varied so much, automatic sensors adjusted the camera apertures to produce high-quality photographs under varied lighting conditions. The picture width of the areas covered by each sweep of the satellite was 1,000

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[102] Andronov, M. Space Meteorology. Pravda. Moscow, Oct. 26, 1967, p. 3.

kilometers on the surface of the Earth. The infrared equipment performed a scanning motion perpendicular to the flight plane of the satellite, covering a belt of 1,100 kilometers in width. The heat radiation detected was converted electronically into signals proportional to the intensity of the radiated flux and recorded for later playback. In addition to the several scanning instruments, two other wide-angle cameras covered the entire disk of the Earth visible from the satellite. On completion of each 96-minute orbit, the entire load of data was dumped to a receiving and processing station in the Soviet Union, clearing the tapes for storing of fresh data from the next orbit.[103]

Kosmos 144 remained in operation for more than a year.[104]

KOSMOS 156, 184, 206, AND 226

Kosmos 156 was launched on April 27, 1967, and seems to have been a close repeat of the still functioning Kosmos 144, but so timed and phased as to extend the coverage of weather reporting over more hours of the day when operating with its predecessor.

Kosmos 184 was launched on October 24, 1967, possibly because of a deterioration in the quality or even failure of data from Kosmos 156. It had the same characteristics as the others of this group.

Launched on March 14, 1968, Kosmos 206 represented a further continuation of the same series and may have reflected deterioration in data from Kosmos 184. Kosmos 226 was the last Kosmos named satellite specifically identified close to the time of launch as an operational weather satellite, and was in the same series as its predecessors. Collectively, all of them were referred to as the experimental phase of the Meteor system.

THE METEOR SYSTEM OF WEATHER REPORTING

In April of 1967, the Congress of the World Meteorological Organization met in Geneva, Switzerland. Over 300 scientists from 129 countries discussed a world weather service. Although the meeting coincided with the flights of Kosmos 144 and Kosmos 156, the Russians waited 2 months before revealing the operational status of their new "Meteor" system of weather reporting.[105]

Even this delayed announcement of the operational Meteor system was later qualified to be referred to as interim in nature. Satellite instrumentation descriptions, although generally compatible, vary slightly from year to year. Thus, when further details of the satellites were supplied in the papers prepared for the 1968 Vienna meetings on peaceful uses of outer space, the television camera resolution was described as 1,200 meters, and the two television cameras were described as each covering a path 1,000 kilometers wide, with slightly overlapping fields. The control stabilization system was termed unique. As previously mentioned, stability was maintained by flywheels driven by electric motors. The kinetic

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[103] Izvestiya, Moscow, Mar 17, 1968; Aviatsiya i Kosmonavtika No. 9, 1967, pp. 30-35; and Pravda, Moscow, Mar 9, 1968.

[104] Perry, G E "The Cosmos Programme." London, Flight International, Sept. 4, 1969, pp. 395-396

[105] Tass, Moscow, June 1, 1967, 1525 G.m t.

energy of these flywheels was dampened by using electromagnets on board the spacecraft interacting with the magnetic field of Earth. (This has also been used in some U.S. spacecraft.) [106]

The Meteor system includes: (1) artificial Earth satellites, (2) a regular prediction service, (3) stations for reception and processing of data, and (4) service for the control and operation of the on-board systems and their regulation.

THE FULLY OPERATIONAL METEOR SATELLITES

The Russians tested individual components of weather satellites in the Kosmos program with a variety of payloads and orbits, culminating in Kosmos 122. The third stage of the program involved the interim introduction of the Meteor system with the referenced flights from Kosmos 144 through 226, all launched at Plesetsk.

Yet, the U.S.S.R. did not signal the completely operational status of the Meteor system until 1969 when it began naming certain satellites Meteor, without further designations by number. (Westerners, for convenience, add numbers to the Meteor name.)

A second generation satellite, designated Meteor 2, was launched on July 11, 1975. Following this, six more first generation satellites flew under the Meteor designation—five before the second Meteor 2 appeared in January 1977. The 28th satellite with the Meteor designation marked the introduction of a Sun-synchronous orbit for a Soviet satellite. Two more Meteor satellites have subsequently flown such retrograde orbits.

RECORD OF METEOR LAUNCHES

Table 34 which follows is a summary of the main sequence of similar payloads.

TABLE 34.—METEOR AND RELATED KOSMOS WEATHER SATELLITES

Launch date	Kosmos	Meteor				Launch site		Apogee	Perigee	Inclination	Period	Remarks
		1-low	1-high	2-high	1-retro	TT	PL					
195												
Aug 28	44					X		860	618	65	99.5	Precursor.
1965												
Feb 26	58					X		659	581	65	96.8	Test Meteor.
Dec 17	100					X		650	650	65	97.7	Do.
1966												
May 11	118					X		640	640	65	97.1	Developmental Meteor.
June 25	122					X		625	625	65	97.1	First announced Meteor.
1967												
Feb 28	144						X	625	625	81.2	96.9	Early Meteor.
Apr 27	156						X	630	630	81.2	97	Do.
Oct 24	184						X	635	635	82.2	97.1	Operational Meteor.
1968												
Mar 14	206						X	630	630	81	97	Do.
June 12	226						X	650	603	81.2	96.9	Do.
1969												
Mar 27		1					X	713	644	81.2	97.9	First under Meteor name.

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[106] See Space Exploration and Applications, issued by the United Nations, covering the meetings of Aug. 14-27, 1968, at Vienna, Austria A/CONF. 34/2. Vol. 1 of the original language of the participants. The papers were made available in mimeograph form as early as the previous April.

TABLE 34.—METEOR AND RELATED KOSMOS WEATHER SATELLITES—Continued

Launch date	Kosmos	Meteor				Launch site		Apogee	Perigee	Inclination	Period	Remarks
		1-low	1-high	2-high	1-retro	TT	PL					
Oct. 6		2					X	690	630	81.2	97.7	
1970:												
Mar. 17		3					X	643	555	81.2	96.4	
Apr. 28		4					X	736	637	81.2	98.1	
June 23			5				X	906	863	81.2	102	First operating in 900 km orbit.
Oct. 15		6					X	674	633	81.2	97.5	
1971:												
Jan. 20		7					X	679	630	81.2	97.6	
Apr. 17		8					X	646	620	81.2	97.2	
July 16		9					X	650	618	81.2	97.3	
Dec. 29			10				X	905	880	81.2	102.7	
1972:												
Mar. 30			11				X	903	878	81.2	102.6	
June 30			12				X	929	897	81.2	103	
Oct. 26			13				X	904	893	81.2	102.6	
1973:												
Mar. 20		14					X	903	882	81.2	102.6	
May 29		15					X	909	867	81.2	102.5	
1974:												
Mar. 5		16					X	906	853	81.2	102.2	
Apr. 24		17					X	907	877	81.2	102.6	
July 9		18					X	905	877	81.2	102.6	
Oct. 28		19					X	917	855	81.2	102.5	
Dec. 17		20					X	910	861	81.2	102.4	
1975:												
Apr. 1		21					X	906	877	81.2	102.6	
July 11				1			X	903	872	81.3	102.5	First Meteor 2.
Sept. 18		22					X	918	867	81.2	102.3	
Dec. 25		23					X	913	857	81.3	102.4	
1976:												
Apr. 7		24					X	906	863	81.2	102.3	
May 15		25					X	908	866	81.2	102.4	
Oct. 15		26					X	904	871	81.3	102.5	
1977:												
Jan. 7				2			X	932	830	81.3	103	
Apr. 5		27					X	909	869	81.2	102.5	
June 29					28	X		685	602	98	97.5	First retrograde Sun-synchronous.
Dec. 14				3			X	906	872	81.2	102.5	
1978:												
Dec. 23	1066						X	908	848	81.2	102.2	Possible Meteor 2 failure.
1979:												
Jan. 5					29	X		656	628	98	97.4	
Mar. 1				4			X	908	857	81.2	102.3	
Oct. 31				5			X	904	877	81.2	102.6	
1980:												
June 18					30	X		678	589	98	97.3	
Sept. 9				6			X	906	868	81.2	102.4	

Notes

1 The table lists all identifiable Soviet weather reporting satellites launched on the A-1 class vehicle, mostly under the Meteor label, with some clearly related Kosmos flights, some of which were identified by U.S.S.R. as supporting the Meteor system.

2 To highlight distinct characteristics, separate columns are shown for Kosmos flights, and consecutive Meteor (Meteor-1) and Meteor-2 flights, with a further breakdown of the Meteors (1) among the lower orbit posigrade, the higher orbit posigrade, and lower orbit retrograde groups.

3 Launch sites are indicated with an X in the column for Tyuratam (TT) and for Plesetsk (PL).

4 Orbital elements are as announced by Tass, in kilometers for heights, degrees for inclinations, and minutes for periods.

5 There are an increasing number of other A-1 launched flights in orbits very similar to the original lower orbit Meteor flights. Some analysts call them military weather satellites. They have not been included in this table because they seem a better fit for a late generation military elint ferret mission program.

Sources: App. III of pt. 1, Tass announcements.

Meteor 1 was announced a day after launch as a weather satellite, and given a description indistinguishable from its Kosmos predecessors. The speedy identification of its mission was notable.

It was described as reporting on cloudiness, snow and ice cover both day and night and on radiation by the Earth and atmosphere.[107]

The meteorological satellite program of the U.S.S.R. was summarized in 1977 in a publication of the world Meteorological Organization.[108] Four systems were reported: (1) "Meteor," the original operational meteorological satellite system, (2) "Meteor-2," an improved operational system, (3) "Meteor," experimental meteorological satellites, and (4) geostationary operational meteorological satellites [GOMS]. In all cases the organization responsible for carrying out the programs was named as the Central Administration of the Hydrometeorological Service with the Council of Ministers of the U.S.S.R., and the State Research center for the Study of the Environment and Natural Resources was named as the organization operating the system. These will be considered in the following sections.

METEOR (1)

The original operational system operated with satellites named "Meteor"-1, 2, 3, etc., but specifically excluded the 18th, 25th and 28th Meteors. Twenty-five satellites were reported to have been launched to the date of the summary and the schedule for further work announced that it was planned to complete the program in 1978. In any event, no further launches were made in this series. The 28th Meteor was the first of three Sun-synchronous retrograde launches from Tyuratam. Although the orbit was stated to be near-polar at a height of 900 km with an inclination of 81° and a period of revolution of 102 minutes, this did not take into account the early launches with the lower periods close to 97.3 minutes. The 5th Meteor was the first to operate in the 102 minute orbit which did not become standard until the launch of the 10th Meteor at the end of 1971.

The operational purpose of this first series was defined as to obtain operational data relating to the global distribution of cloud, ice and snow cover, radiation temperature of the underlying surface and height of cloud tops. The sensory equipment consisted of television cameras, an infrared scanning radiometer, and a three-channel scanning radiometer. Data were transmitted to only three receiving points: Moscow, Novosibirsk and Kharbarovsk. Although no mention is made of an automatic picture transmission [APT] system, Meteor 10 was the first to carry such a system.[109]

Details of the construction of the Meteor satellite were given by Engineer Marina Marchenko.[110] There are two separately sealed compartments; the instrument compartment, situated in the lower part, containing meteorological instrumentation, and the power-plant compartment, housing the radio telemetry system, thermal regulation system, and the chemical batteries for the electric supply system. The large flat panels of the solar cells, which are

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[107] Tass, Moscow, Mar. 27, 1969, 1625 G.m.t.

[108] World Weather Watch Global Observing System—Satellite Subsystem. W.M.O. No. 411. Geneva, World Meteorological Organization, 1975. With supplements.

[109] Andronov, I. "The Meteors Are on Watch." Moscow, Pravda, May 25, 1972, p. 3.

[110] Marchenko, M. Tekhnika—Molodezhi, No. 9, 1979, p. 23.

deployed after separation of the satellite from the last stage of the launch vehicle, are attached to the outside of this compartment and can be rotated in such a way that they are normal to the incident solar radiation, except for periods when the satellite is in the Earth's shadow. A drawing of a Meteor satellite is given in figure. 44.

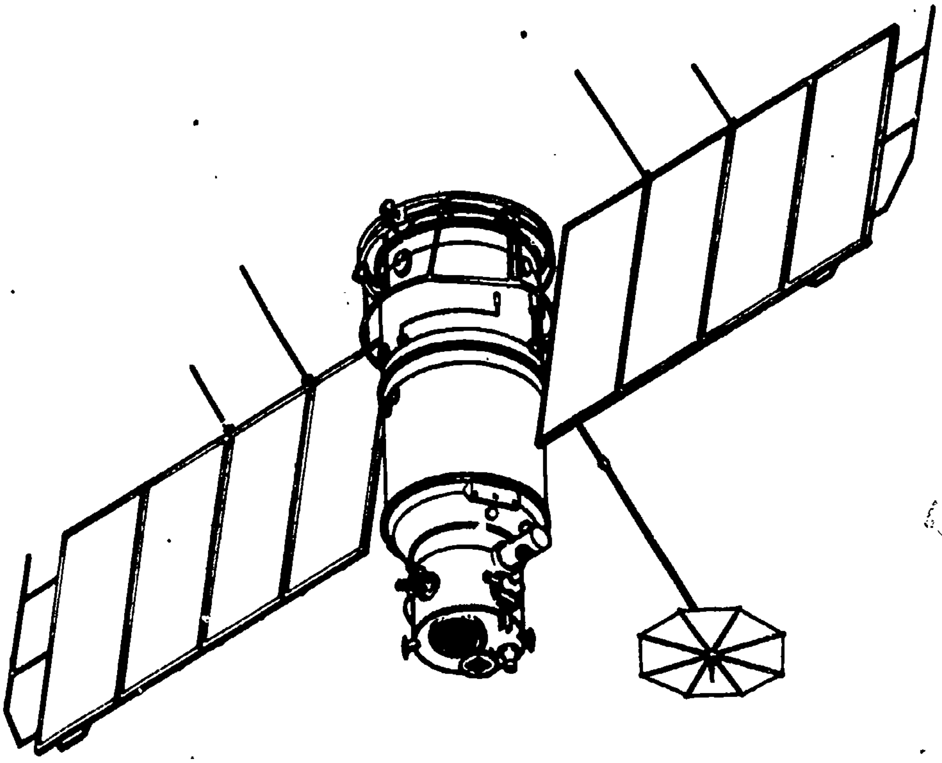

FIGURE 44.—Meteor Satellite

The longitudinal axis of the satellite is, at all times, directed towards the Earth's center. Stabilization along a second axis perpendicular to this is maintained by a combined electric flywheel system in combination with a magnetic moment drive, making use of the Earth's magnetic field. The orientation of the satellite axis is monitored using infrared sensors which operate regardless of whether the satellite is over the daylight or nighttime side of the Earth.

There are three types of meteorological instrumentation: television, infrared, and actinometric. These can operate in cycles of differing durations. Switching is accomplished both in accordance with a preplanned program and by commands from the control center. The data are registered by onboard apparatus with a memory and then transmitted to the ground stations of the "Meteor" system.

The TV equipment is used in making observations of the cloud cover on the daytime side of the Earth. The survey is made with two cameras, one of which scans the right, and the other, the left side of a band along the satellite trajectory. The width of the band scanned by the TV cameras is about 1,000 km.

The IR equipment is used for observations of cloud cover for the most part on the nighttime side. It is adjusted for registering the thermal radiation of clouds or the Earth's surface. The range in which the IR apparatus operates (8-12 microns) makes it possible to carry out observations on both the daytime and nighttime sides of the planet. In these observations a band also with a width of about 1,000 km is scanned.

The TV and IR information together make possible a more reliable evaluation of synoptic conditions and the nature of the development of atmospheric processes.

The actinometric apparatus registers the radiation fluxes emanating from the Earth in the ranges 0.3-3 microns, 3-30 microns and 8-12 microns. A band with a width of about 2,500 km is "scanned." These observations make it possible to compute the heat "budget" of our planet, determine the temperature of the land and ocean surface, ascertain the boundaries of ice cover, and calculate moisture content in the atmosphere.

Since the early days of the Meteor program there have been a variety of modifications in the Meteor payloads. The Meteor 1-10 satellite launched on December 29, 1971, was the first Meteor that carried APT equipment which is compatible with U.S. APT ground receivers. The Meteor 1-10 was also used to test ion-plasma electroject engines which use solar energy to create thrust by means of plasma accelerated in electromagnetic fields. The Russians announced that these orbital correction engines were developed to guarantee stabilizing capability for flights of long duration.[111] Also, for the first time, using the orbital correcting engines with the stabilizing plasma engines, it was possible to change the orbital altitude of the satellite by 16.9 kilometers. The higher orbit allowed improved scanning of the Earth's surface and increased the accuracy of the geographic tie-in.[112]

The Meteor 1-8 satellite which was launched on April 17, 1971, contained spectrometric apparatus for determining the vertical temperature profile of the atmosphere to an altitude of approximately 35 kilometers. With this instrument it became possible for the Russians to measure the radiation spectrum of a "column" of air in the infrared range of electromagnetic waves and to determine a vertical cross section of temperature.

METEOR-2

The improved operational system operates with satellites in the Meteor-2 series, the first of which was launched on July 11, 1975. As with the original Meteor series, the Soviets do not give numeri-

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[111] Andronov, L., ibid.

[112] Artsimovich, L.A., et al. Development of a Stationary Plasma Engine [SPE] and Its Testing on the Meteor Artificial Earth Satellite. Moscow, Kosmicheskiye Issledovaniya, vol. 12, No. 3, 1974, pp. 451-568.

cal designations beyond the series name in the launch announcements and Western analysts add a serial number for their own convenience. According to the Russians the satellite has improved onboard equipment: an experimental optical-mechanical television scanning apparatus operating in the visible part of the spectrum for obtaining images of cloud cover and the underlying surface, an experimental optical-mechanical television scanning apparatus operating in the infrared portion of the spectrum, and a complex of radiometric apparatus intended for continuous observations of streams of penetrating radiation in near-Earth space. In addition to the scientific apparatus, the satellite carries a precision electromechanical triaxial system which provides orientation of the satellite toward the Earth, an electrical supply system with independent solar aiming and tracking for the solar cells, a radiotelemetry system for transmitting to Earth data on the operation of the satellite service systems, a radio system for precise measurement of orbital parameters, and a radio complex for transmitting scientific information to Earth.[113] A drawing of a Meteor-2 appears as figure 45.

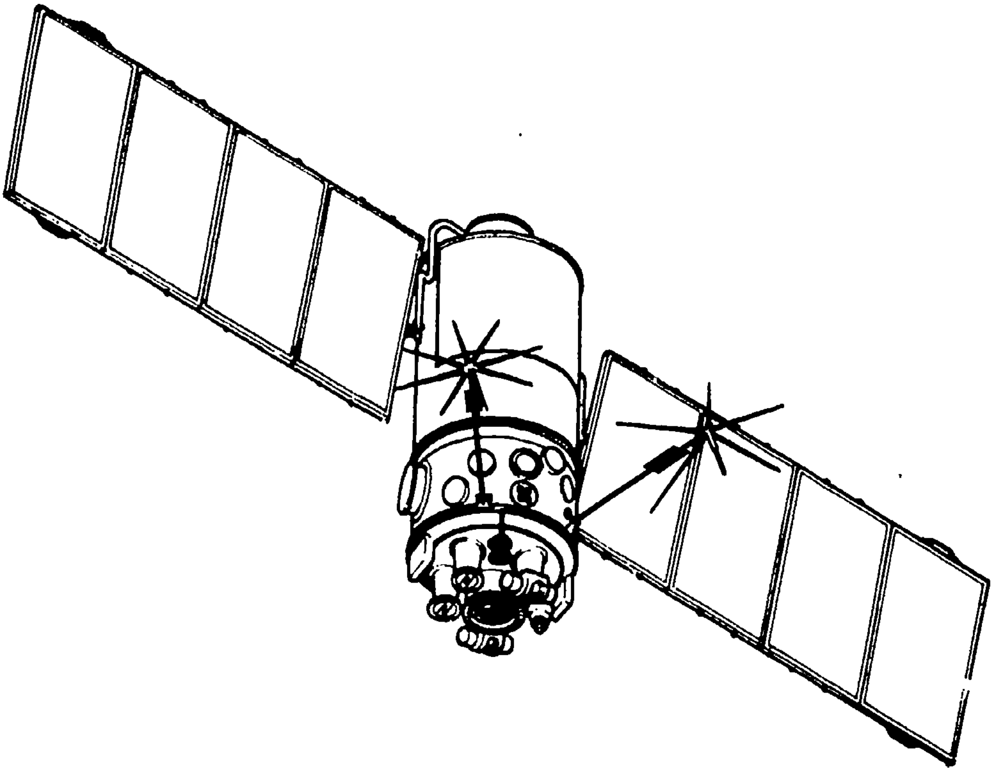

FIGURE 45.—Meteor 2 Satellite

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[113] "Meteor-2 in Flight" Pravda Moscow, July 13, 1975, p. 3.

The collection of data was said to be worldwide on an operational basis twice daily at times approximating the synoptic hours (0300 and 1500 Moscow time—0000 and 1200 G.m.t.). Observations by Western amateurs together with information provided in the FANAS messages (see below) show that this aim has rarely been attained for the APT which is switched off periodically when a satellite is not over the daylight portion of the Northern Hemisphere. Moreover, the low-frequency signals for infrared pictures have not, so far, been received for more than a few weeks following the launch of a new satellite. The steady change of local time at which one of these satellites is overhead at a given point is the result of the choice of a non-Sun-synchronous orbit. This choice may be dictated by the desire to operate at the 900 km height which may not be attainable for the given payload-mass by the A-2 launched retrograde from Tyuratam. Additional aims were to obtain on an operational basis, regional data on the distribution of cloud; to obtain on an experimental basis, worldwide data on the vertical distribution of temperature; and to observe fluxes of penetrating radiation in space near to the Earth.

It was stated that one to two satellites would be launched annually, a claim that has been substantiated. The system would remain in operation until 1985, but no decision had been made as to what would happen after that.

The sensory equipment was described as:

1. A scanning telephotometer for APT in the visible band of the spectrum (0.5–0.7 microns) giving a coverage of 2600 km, with a resolution of 2 km;
2. Television-type scanning equipment in the same spectral range giving a coverage of 2200 km with a resolution of 1 km;
3. An infrared scanning radiometer (spectral range 8–12 microns) giving a coverage of 2600 km with a resolution of 8 km in the nadir;
4. An eight-channel scanning radiometer (spectral ranges II,I; 13,33; 13,70; 14,24; 14,43; 14,75; 15,02; 18,70 microns) giving a coverage of 1000 km with an angular resolution of 2°—this instrument to be installed on only some Meteor-2 satellites; and
5. A penetrating radiometer.

It is possible that the radiometers may have provided the desired twice-daily coverage close to the synoptic hours but there have been no reports of reception of such signals by Western amateurs and the transmission frequencies for these signals are not announced.

Full details of the signals for the APT were given and these are presented together with those for the experimental meteorological satellites in table 35.

Technical details of the seventh Meteor-2 as given in the FANAS message transmitted at 0945 G.m.t. on May 26, 1981, are reproduced below. These are similar to those for the fourth, fifth and sixth Meteor-2s but lack reference to the scanning telephotometer "APT" TV (0.5–0.7 MKM) which appeared in those three cases.

START ON MAY 15, 1981, INCLINATION 81,3 GRAD
2000 KM COVERAGE. 2 KM RESOLUTION
RADIOSIGNAL:

MODULATION-FM
DEVIATION-PLUS-MINUS 15 KHZ
LOW FREQUENCY SIGNAL:
2400 HZ SUBCARRIER PLUS-MINUS 10 PROCENT
SUBCARRIER MODULATION-AM, "WHITE" LEVEL CORRESPONDS TO AMPLITUDE
MAXIMUM LINE PHASING SIGNAL IS TRANSMITTED BY 256 HZ SUBCARRIER
AMPLITUDE MODULATION,
PHASING SIGNAL DURATION IS 90-100 MSEK
RECORDING:
INDEX OF COOPERATION -264
SKAN RATE -120 LINE PER MIN
SKAN DENSITY -3,8 PER MM
NUMBER OF GREY LEVELS-NOT LESS THAN 12
SCAN DIRECTION-FROM RIGHT TO LEFT
IMAGE LINE SIZE-176 PLUS-MINUS 3 PROCENT
SCANNING MODE-EQUALLY ALONG THE SPHERE
IMAGE SCALE -1:12000000
NEXT FORECAST WILL BE TRANSMITTED 02.06.81

This information correlates well with that given in table 33.

TABLE 35.—CHARACTERISTICS OF AUTOMATIC PICTURE TRANSMISSION [APT] SIGNALS FROM SOVIET METEOROLOGICAL SATELLITES

	Meteor-2 improved operational system	Meteor experimental system
Characteristics of radio signals:		
Carrier frequency	[1] 137.3 MHz	137.15 MHz.
Modulation	Frequency	Amplitude-frequency.
Deviation	±15 kHz	9.6 kHz.
Output power of radio transmitter.	Not less than 5 W	Not less than 5 W.
Characteristics of low-frequency signals for television pictures:		
Subcarrier frequency	2400 Hz ± 15 10 percent	2400 Hz.
Subcarrier modulation	Amplitude with coefficient of modulation up to 90 percent, level "white" corresponds to maximum amplitude.	Amplitude, level "white" corresponds to maximum amplitude.
Automatic control signals	The line phasing signal is transmitted by amplitude modulation of the subcarrier frequency 256 Hz with relative instability not worse than 5 parts per million, intensity of modulation approximately 100 percent, length of phasing signal 90–100 microseconds.	
Characteristics of recording equipment for television pictures:		
Index of cooperation	264	528.
Scanning speed	120 line/min	240 line/min.
Scanning density	3.8 line/mm	7.6 line/mm.
Dimension of picture	195×290 mm	195×290 mm.
Number of halftones	Not less than 12	Not less than 12.
Direction of Scanning	Right/left	
Characteristic of low-frequency signals for infrared pictures:		
Subcarrier frequency	2400 Hz	
Subcarrier modulation	Amplitude with coefficient of modulation up to 90 percent, level "white" corresponds to maximum amplitude.	
Automatic control signals	Line phasing signal transmitted by amplitude modulation of subcarrier frequency 512 Hz with relative instability not worse than 5 parts per million, intensity of modulation approximately 100 percent, length of phasing signal 0.15–0.2 seconds.	

TABLE 35.—CHARACTERISTICS OF AUTOMATIC PICTURE TRANSMISSION [APT] SIGNALS FROM SOVIET METEOROLOGICAL SATELLITES—Continued

	Meteor-2 improved operational system	Meteor experimental system
Characteristics of recording equipment for infrared pictures:		
Scanning speed	20 line/min	
Scanning density	1 line/mm	
Direction of scanning	Right/left	
Number of half-tones	Not less than 9	

[1] Meteor-2 No. 6 transmitted on 137.4 MHz, probably to avoid interference with transmissions from Meteor-2 No. 5.

Len Maxim, of Wellington, New Zealand, has observed that the Meteor-2 cloud-cover pictures have differing numbers of phasing lines at their edges, depending on which satellite is transmitting the pictures. Meteor-2 Nos. 1 and 2 both had 23 phasing lines. The third Meteor-2 had 14 phasing lines and the fourth and fifth both had 15. Meteor-2 No. 6 had 11 phasing lines and No. 7 had 13. Maxim suggested that, if Kosmos 1066 was indeed a Meteor failure, then the first six satellites could have been built in pairs with Kosmos 1066 having 14 phasing lines, but that due to possible shortcomings (night-visible imagery was promised for Meteor-2 No. 6), the last two were "one-offs." No reports of APT imagery from Kosmos 1066 have been confirmed. Maxim points out that the reduction in the number of phasing lines increases the width of the picture.

Meteor-2 APT imagery has an analog binary edge-code which correlates well with the angle of incidence of solar illumination at the subsatellite point.[114] Reading from left to right, the least significant bit is the first of the six bits to be transmitted, as with the case of the Morse code telemetry from the second-generation photoreconnaissance satellites (described in chapter 5). Peter Wakelin showed that the maximum value of 63 is transmitted when the subsatellite point has a solar elevation of the order of 8, i.e., it is the first value to be transmitted when the satellite leaves eclipse. When the value reaches 10, for solar elevation angles of the order of 75, discontinuities occur and the edge-code sometimes disappears altogether. A third member of the Kettering Group, Grant Thomson, drew attention to the fact that 64 levels of brightness values, or grey scale, are sufficient for most digital imaging techniques and are used for recording band 7 data from Landsat's multispectral scanners.[115] It would therefore seem reasonable to interpret the edge-code reading as a measure of the illumination across the scan which could be used to assist automatic control of exposure in both picture-taking and APT processing regimes. This would explain observations of the edge-code suddenly increasing by one unit during a decreasing sequence of values.

A Meteor-2 No. 3 picture, produced in Austin, Texas, by Ken Johnson on September 2, 1978, showed a curious discontinuity with successive edge-code values of 12, 11, 4, 7, 0, 10 at the end of a

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[114] Perry, G.E. Proceedings 1979 Australian Astronautics Convention, Perth, Western Australia, vol. 1, 1981, pp. 75–83.

[115] Landsat Data Users' Handbook (revised ed.), U.S. Geological Survey, pp. 4–6.

southbound pass at 1903 G.m.t. (1630 local time). The value four was of short duration and the value seven even shorter. Greg Roberts, in Cape Town, Republic of South Africa, had observed a similar sequence (10, 0, 3, 12) at the commencement of a southbound pass on March 2, 1978, when the satellite was far to his north. He speculated that certain sensors are switched off for sell-protection when the received brightness exceeds a critical maximum value and reported that he had frequently observed Meteor-2 No. 2 to switch off abruptly in the middle of an overhead pass at local noon when the picture was mostly cloud and therefore very white. This phenomenon was also observed at Kettering on five occasions between June 12 and 20, 1978, when signals from the third Meteor-2 switched off abruptly and then reappeared abruptly after intervals varying between 3 minutes 14 seconds and 7 minutes 26 seconds.

An explanation for this, advanced by Wakelin, and supported by pictorial evidence, is that brightness changes in received imagery coincide with changes in the value of the edge-code. Technicians in Bahrain had been trying to clear a "fault" which caused sudden changes in picture brightness during passes from the second Meteor-2. Wakelin's imagery, received in Dubai, showed similar changes and pinpointed the cause residing in the satellite. Smaller, but more frequent, brightness changes occurred in the Meteor-2 No. 3 imagery and it would appear that the variable aperture stop used in the vidicon to insure uniform brightness was made more sensitive after the first two satellites in the series.

As mentioned earlier in this section, infrared APT signals have been observed only in the first few weeks following the launch of a new Meteor-2 satellite. These images, transmitted at a scan-rate of 20 lines per minute as compared with the 120 lines per minute of the visible APT, produce very low resolution of cloud cover. Not many examples of these have been published. One of the earliest was due to Virgil Neher from the first Meteor-2.[116] Alan Salmen, of Lower Hutt, New Zealand, has produced an example of the change of visible to infrared APT from the eighth Meteor-2 in June 1982. Neither of these images approaches the clarity of infrared imagery from the current NOAA satellites.

Meteor-2 No. 4 was switched off whenever it became near-simultaneous with No. 5. These periods occurred at intervals of 23.6 days due to the 0.3 minute difference in their orbital periods. The daily difference of 4.2 minutes divided into the 102 minutes orbital period gives the 23.6 interval between periods of simultaneity. Such inconvenience was avoided by choice of a different transmission frequency, 137.4 MHz, for the sixth Meteor-2 and 137.85 MHz for Meteor-2 No. 8, although initial transmissions from the latter were on 137.3 MHz.

EXPERIMENTAL METEOR

Certain satellites, given the "Meteor" designation at launch, were identified in the W.M.O. publication as being "experimental." The launch announcement of Meteor No. 18 stated that it was "chiefly programmed to collect meteorological information," imply-

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[116] Winkler, L.R. CQ, vol. 32, No. 10, Oct. 1976, p. 51.

ing an additional unspecified function, and noted that the scientific information was being received at the State Center for Research of Environment and Natural Resources as well as the usual Hydrometeorological Center which features in the standard announcements.[117] Later, the 25th satellite with the "Meteor" designation was also referred to as Meteor-Priroda (Nature).

The operational purpose of the experimental meteorological satellites was defined as:

1. To obtain multizonal pictures of clouds and of the underlying surface over limited areas;
2. To obtain data relating to the spatial distribution of areas of precipitation, the total water-content of cloud, the position of the limit of ice cover and the compactness of the ice;
3. To obtain data on the exchange of moisture content in the atmosphere;
4. To obtain data on the temperature of the underlying surface;
5. To measure reflected radiation and the polarized component of the radiation in order to determine the phase composition of the cloud;
6. To measure the intensity of fluxes of corpuscular radiation; and
7. To measure radiant heat in the upper atmosphere.

As a rule, pictures of the U.S.S.R. and neighboring regions would be transmitted from these experimental satellites, but the possibility of obtaining pictures of any part of the world in daylight hours was not precluded. Observations of the Kettering Group and other amateurs in the United Kingdom show that the transmitter is switched off on passes to the west of the European land mass but, from time to time, Len Maxim has received imagery from these satellites and occasionally this has occurred in the hours of darkness, when all that is received is a totally black picture with the usual numerical edge-code.

Meteor 18 and Meteor 25 were identified as belonging to this experimental system, as was the first Sun-synchronous payload, Meteor 28. It was stated that a launch during the operational period of the First GARP Global Experiment [FGGE] was planned but that the program for further launchings had not been decided. Additional Sun-synchronous satellites were launched in 1979 and 1980 and both of these were operational as of December 31, 1980. Meteor 18 and Meteor 25 were placed into the 102 minute, 900 km circular orbit used by the Meteor-2 satellites.

The retrograde orbit

Meteor 28, the third of the experimental Meteor satellites, was the first Soviet satellite to be placed into a retrograde orbit by being launched on an azimuth at which the Earth's rotation provided a velocity component opposing the thrust of the launch vehicle. At such orbital inclinations greater than 90 the precession of the orbital plane about the Earth's axis of rotation due to the equitorial bulge is eastwards. Careful choice of orbital period for a

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[117] Tass, Moscow, Oct. 10, 1974, 1529 G.m.t.

given inclination can produce a precession rate of 0.986°/day which is exactly the same as the precession rate due to the motion of the Earth in its orbit around the Sun. Such an orbit is said to be Sun-synchronous and satellites in these orbits have the property of passing over a given point on the Earth's surface at the same local time throughout the year. This has an important application in the fields of Earth resources survey, photographic reconnaissance and meteorology. The United States made use of a Sun-synchronous orbit as long ago as January 31, 1961, with the launch of the U.S.A.F. Samos 2 satellite, and currently uses retrograde Sun-synchronous orbits for the applications detailed above.

However, there is a penalty to pay for failing to make use of a contribution from the Earth's rotation to assist in orbiting the payload and even choosing to oppose it. This is a reduction in the payload-to-orbit capability of the launch vehicle. It is quite possible that the reduced capability of the A-1 launch vehicle in this mode is responsible for the choice of the 600 km, 97 minute orbit rather than the 900-km, 102 minute orbit of the Meteor-2 satellites.

Orbit insertion

Special considerations rule out the use of Plesetsk as a launch site for these retrograde orbits. A southbound launch would take the satellite and the spent first stage core and boosters on a course passing over populated areas and close to Moscow, whereas a northbound launch would be open to misinterpretation as an attack against the United States. Similar consideration might also apply to a northbound launch from Tyuratam. The ground-track actually adopted with the southbound launch from Tyuratam is shown in figure 46. Passing over the mountainous terrain of Iran, with the spent stages falling short of the Soviet-Iranian border, it passes across the United Arab Emirates, southbound over the Indian Ocean along the east coast of the Malagasi Republic, before swinging across Antarctica to pass northbound over the Pacific Ocean.

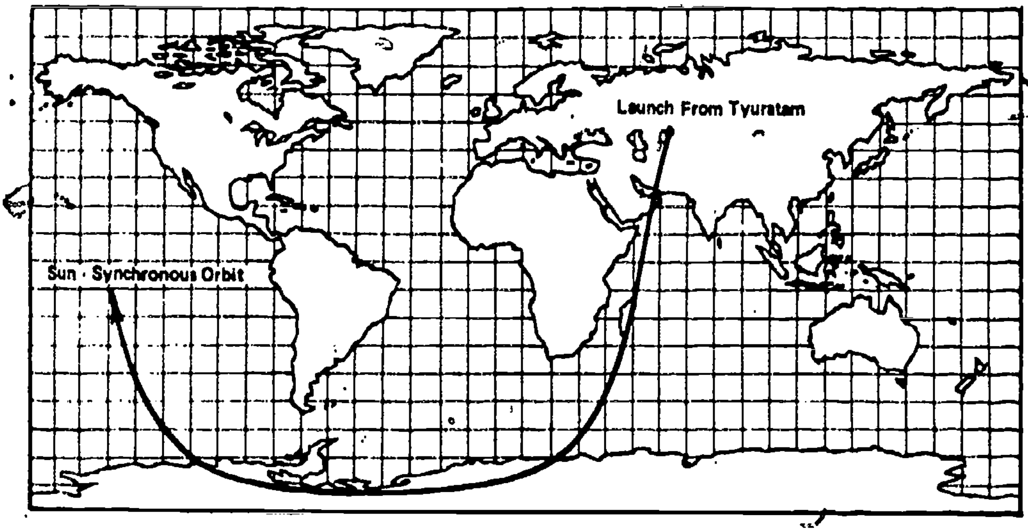

FIGURE 46.—Initial Ground Track of Experimental Meteor Satellites Launched into Retrograde Orbits

The Meteor 28 orbit

Meteor 28 was placed initially into an orbit with a period of 97.46 minutes at heights ranging between 600 and 670 km. In this orbit the ground-track came close to repeating itself every 4th day after 59 revolutions but could not be regarded as stabilized. After 3 months in this orbit the apogee was lowered and the resulting orbit between heights of 600 and 660 km had a period of 97.32 minutes. This was ground-track stabilized with repetition of tracks every 5th day after 74 revolutions. A study by Anthony Taylor at Kettering Boys School showed that the orbital period then decayed naturally to 97.29 minutes, by February 25, 1978, causing the 5-day pattern to drift eastward at a rate of almost 0.5° per cycle. Corresponding transits were coming some 35 seconds earlier at each cycle. Another correction, raising apogee by only 2 km, stabilized the ground-track once more. No further orbital corrections were made.

Reference to these maneuvers, using a stationary plasma engine with an average thrust of 0.2 to 0.25 newtons, which had been flight tested during the 1973–74 period, was made in a 1981 review article. A technique was created and worked out for making optimal (with respect to time and energy consumption) corrections for the purpose of establishing repeated orbits, in connection with which the developers determined the optimum strategy for alternating active periods when the correction engines were turned on and passive ones when orbital measurements were being made. In one experiment, a repeating Sun-synchronous orbit with a 5-day repetition period was established.

The article went on to say that a matter of considerable interest for the solution of remote sensing problems is the establishment of not simply a repeated orbit, but one for which the spacecraft passes over a given region with a given periodicity. It claimed that in one experiment, possibly the same as observed by Taylor, this was accomplished with the accuracy of track guidance over the required region being 5 to 10 km for a daily repetition period.[118]

It seems probable that the degradation of the ground-track stabilization due to natural decay was not considered so disadvantageous as to warrant the provision of an orbital correction system for later missions. No evidence has been found of onboard propulsion in Meteors 29 and 30. One further departure of these two satellites from the Meteor 28 mission is that whereas Meteor 28 transmitted APT during daylight on the northbound pass in the northern hemisphere, the daylight APT was transferred to the southbound passes of Meteors 29 and 30. These transmissions were not continuous and were usually confined to those passes over the European mainland. The APT imagery shows a better contrast between land and water than that from the Meteor-2 satellites. Both Meteor 29 and Meteor 30 were still operational at the end of 1980.

Numerical edge-code

The APT imagery from these satellites is accompanied by a four-digit numerical edge code of 1 minute frame-duration. The first number to be transmitted has been shown to be a time count, changing by unity every minute. Then follows a grey-scale step wedge and 10 more 4-digit numbers.

Initially, the time count on Meteor 28 registered 170 minutes after standard Moscow time. Observations by G.R. Kennedy, in the United Kingdom, reveal that at some time between August 1 and September 19, 1976, the onboard clock was corrected and that thereafter the count registered minutes after midnight Moscow time.

Shortly after its launch the time count on Meteor 29 registered 360 minutes after midnight Moscow time (M.T.+6 hours). By January 1981, the time count had been amended as determined from a picture produced by Leslie Currington at Welwyn Garden City and was registering a 720 minute difference from minutes after midnight, Moscow time, but who is to say this is M.T.+12 hours or M.T.−12 hours?

It would appear that the onboard timers on these satellites always need amending after launch. Meteor 30's time count registered M.T.+600 minutes 1 month after launch on a picture produced in Wellington by Maxim but was correctly registering minutes after midnight, Moscow time, by December 3, 1980.

THE FANAS MESSAGE

On March 8, 1978, the Secretary-General of the World Meteorological Organization based in Geneva, Switzerland, wrote to members of the W.M.O at the request of the Permanent Representative of the U.S.S.R. with the W.M.O. to inform them that, starting on January 15, 1978, the Hydrometeorological Service of the U.S.S.R. would transmit over the Global Trunk System orbital data and predictions for Meteor 2 satellites in the national code from FANAS [Forecast for Ascending Node for Automatic Satellites]. Annexes

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[118] Trifonov, Y V. Issledovaniye Zemli iz Kosmosa, No. 5, September-October 1981, pp. 8-20.

were enclosed, giving a copy of the text of the FANAS code form and an example of the orbital data message for a Meteor-2 satellite.[119]

The message is in five sections, the first of which gives information on the satellite's orbital period and longitudinal increment, as well as daily data on the ascending node. This takes the form of time as hours, minutes and seconds in G.m.t., and longitude in degrees and decimals of a degree in the specified octant of the globe. First and last ascending nodes are given for odd numbered days of the month and first ascending nodes only for even numbered days.

The second section in plain language (English) gives information on the operating mode of the onboard TV system, the radio frequency of APT transmissions and allows for the possibility of a change in frequency. The third section gives the time in minutes and seconds, measured from the ascending node epoch, at which the satellite crosses circles of latitude at 10° intervals. It has become customary to provide information only for the part of the orbit over which the TV transmitter will be operating.

The fourth section, which is rarely used, carries, in plain language, an explanation of the content of the FANAS message and definitions of the relevant digital groups of the transmitted message. The final section provides information on latitude in degrees and decimals of a degree but ignores the hemisphere, longitude in degrees and decimals of a degree within the specified octant, and height above the Earth's surface (over the Krasovsky ellipsoid) in 10ths of a kilometer, for each even minute measured from the ascending node epoch. This section may also contain nonregular information on the operation of the onboard set of instruments, changes of operating modes, recommendations, requests, as well as the time of transmissions from geosynchronous satellites.

Code numbers are provided for the countries of the European community, Japan, U.S.A., and the U.S.S.R. as launching agencies with others held in reserve. Code numbers are also provided for the American ATS and NOAA series of satellites in addition to the Meteor-2 series of the U.S.S.R.

These messages are transmitted at 0945 G.m.t. on Tuesday mornings on radio frequencies of 3.33, 5.14, 7.685, 9.19, and 13.53 MHz.

METEOR OPERATIONS

Meteor satellites were described as having a strip 1,000 kilometers wide within their observation range, while their sensors of radiation and heat emission cover a territory of 2,500 kilometers.[120] Later, the Russians announced that the vision band in the modified meteorological satellites had been increased by approximately 50 percent.[121]

The data are recorded and stored for relase by radio link when the satelites are over Soviet territory. In addition, some satellites now carry automatic picture transmission [APT] equipment making available real time pictures anywhere within receiving range (see below). There are three receiving centers for satellite

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[119] W.M.O. Ref. W/MS/SB 2, Mar. 8, 1978.

[120] Pravda, Moscow, Aug. 7, 1970, p. 6.

[121] Tass, Moscow, Mar. 4, 1972, 1340 G.m.t.

weather information: Moscow, Novosibirsk, and Khabarovsk. Individual satellite pictures are fitted together to create a large photo montage of the area under study. These pictures are then relayed by phototelegram to Soviet and foreign weather services.[122] According to the Russians, the satellite data are not only used by the Soviet Hydrometeorological Service, but are also instantly relayed to the World Meteorological Service.[123]

The Russians continuously stress the benefits derived from weather satellites. Meteorological satellites provide information on clouds, ice cover, and atmospheric radiation. They permit the study of weather fronts and jet stream currents. One article describes the assistance provided by the Meteor satellites during the towing of an unweildy floating drydock from Klaypeda around the Cape of Good Hope to Vladivostok. The typhoon Juliette threatened to sink the heavily listing drydock, but weather reports from space gave information on the center of the storm and its direction of movement so that a new course could be chosen which saved the drydock and its tugs.[124]

Warnings to populated places of approaching tropical storms have saved many lives. Accurate satellite weather reports have resulted in economic savings as well. The ability to choose optimal routes has meant a sailing time savings of 5 to 7 percent for oceangoing ships.[125] It was estimated that the use of satellite information by the Soviet marine fleet alone provides an annual saving of over one million rubles.[126] Civil air transports have also benefited from more accurate and timely weather data, particularly information on cloud cover.

The period of navigation along the Arctic route has been considerably extended with the assistance of satellite data on polar ice conditions. The Russians have published an ice map of the Antarctic in the Moscow journal Zemlya i Vselenaya (The Earth and the Universe). The map was drawn as a result of an experiment in which the ice boundaries were determined simulatenously by information from two satellites employing two different methods of data collection: a satellite in the Kosmos series measuring the thermal radiofrequency radiation of the Earth in the microwave band, and a Meteor satellite scanning the Earth with a television camera. The two maps compared favorably. However, the Russians concluded that data obtained from measuring the Earth's radiation enjoyed certain advantages. The Earth's atomsphere is virtually transparent to radio waves; neither clouds nor percipitation can block radio waves.[127]

There are three receiving centers for satellite weather information: Moscow, Novosibirsk, and Kharbarovsk (135.10° E, 48.33° N). Four downlink frequencies for four separate satellites are given in the I.F.R.B. publication used as the source for table 4-1: 461.5, 464.0, 466.5, and 469.0 MHz. The satellites are merely referred to as URS 1 through 4. A block diagram for the receiving centers was

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[122] Pravda, Moscow, Aug. 7, 1970, p. 6.
[123] Tass, Moscow, Apr. 29, 1970, 1315 G.m.t; Tass, Moscow, Apr. 30, 1970, 0815 G.m.t.
[124] Sovetsky Voin, Moscow, No. 13, July 1970, pp. 35-36.
[125] Andronov, I., op. cit., p. 3.
[126] Tass, Moscow, Feb. 4, 1975, 1437 G.m.t.
[127] Tass, Moscow, Dec. 25, 1974, 1425 G.m.t.

published in the National Paper to the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space.[128] The antenna, driven automatically via the motion program unit and automatic tracking unit, feeds the received signal to the receiving unit. This is coupled to the relay link transmitter through a data transducer. Signals from the timer are fed simultaneously to the relay link transmitter and the motion program unit. Signals from the relay link receiver are fed simultaneously to a memory unit and a channel divider. Here, the data is sent to the main frame computer and the photorecorder. Input from the ground-based instruction metering complex is also fed to the photorecorder giving information on orbit and vehicle attitude and the frame and geographic location data. Output from the photorecorder is in the form of processed photographic images. These are sent to the meteorological data processing center together with direct computer output and printed tables and files.

The same report claimed that the "Meteor-2" system constantly provided twice-a-day information on cloud distribution and ice and snow cover over the Earth as TV images in the visible and infrared band; twice-a-day global data on temperature fields and cloudtop heights, as well as over water surfaces; twice-a-day global information on the radiation situation in near-Earth space; and two- or three-times-a-day TV images of cloud, ice and snow covers in areas of 6 to 7 square kilometers each, being received in any region of the Earth at self-contained receiving points. This latter information could be received all over the world since the radio-link frequency is international and image formats are similar to those transmitted by American satellites (referred to as APT in the foregoing sections).[129]

The report went on to list trends which were envisaged for the system in the period up to 1985. These were an increase in the orbital altitude to ensure complete coverage of the Earth's surface in the equatorial zone; the introduction of torque motors to synchronize the three vehicle system and to increase its efficiency; the introduction of improved, higher resoluton infrared equipment with direct transmission for local coverage [APT]; and execution of experiments and introduction of microwave equipment (super high frequency, SHF) into the sensor complex to perform all-weather observations of ice and snow cover and to determine the cloud moisture content.[130]

A 1979 article describing the "Meteor" system gave greater detail of the output products from the Meteor-2 satellites. The APT scanning telephotometer operating in the visible region of the spectrum from 0.5 to 0.7 microns, with a width of field-of-view of 2,100 km and a resolution of 2 km at the nadir, produced individual photographs and photo-mosaics made from the photographs of two to three orbits for the region of the receiving station in a radius of up to 2,200 km (2 to 3 times per 24-hour period). The television-type scanner with image-storage capability, also operating in the same visible band, and with a 2,200 km width of field-of-view and 1 km

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[128] National Paper, U.S.S.R., Sept. 2, 1981, pp. 26, 29.

[129] Ibid.

[130] Ibid.

resolution at the nadir, gave individual photographs and photo-mosaics from photographs for various regions of the globe (2 to 3 times per 24-hour period), and photo-mosaics for the Arctic and Antarctic Seas from photographs of the ice cover (once every 5 days). An infrared scanning radiometer, operating in the 8 to 12 micron range, also with image-storage capability, and with a 2,600 km width of field-of-view and 8 km resolution at the nadir, provided global photo-mosaics separately for the Northern and Southern Hemispheres; individual photographs and maps of the radiation temperature of the Earth's surface and the altitude of the upper boundary of the clouds for various regions of the globe (twice per day); and the coordinates of tropical cyclones and data on the quantity of the clouds at the nodes of a regular grid for the entire globe (twice-a-day using images in the visible region of the spectrum). Finally, an eight-channel scanning infrared radiometer operating at discrete frequencies within the 11 to 19 micron range, with an angular resolution of 2° and a width of field-of-view of 1,000 km, furnished global data for the thermal sensing of the atmosphere.[131]

SOVIET WEATHER ROCKETS

Like many other nations, the Soviet Union also has vertical rocket probe launch facilities for weather reporting purposes. Although the reports are localized, they provide a rapid response and a more complete vertical profile than do satellites. Of particular interest is the rocket sounding station operated by the U.S.S.R. in Antarctica, the world's "weather kitchen." This station is linked by radio with its main meteorological station in Moscow.

A review of information on Soviet metorological rockets in the period up to the end of 1966 is to be found in a handbook produced by the staff of the Battelle Memorial Institute.[132] It describes the MR-1 series rocket, developed and flight-tested in the 1948-50 period by the Central Aerological Observatory, exclusively for researching the upper atmosphere. Some 10 m long with a diameter of 0.5 m, it had a mass of around 1 ton including the solid-fuel booster section. The payload of mass exceeding 100 kg separated from the main body at about 70 km with its peak trajectory occuring between 80 and 100 km. Both nose cone and main-body sections were recovered by parachute close to the launch site.

A simple steel launching stand, about 12 m high, permitted MR-1's to be launched from portable launching sites and research ships. It could be tilted at launch to compensate for the effect of cross winds. The position of the rocket in flight was determined by use of synchronized cameras with mutually orthogonal optical axes.

MR-1's were equipped with resistance thermometers for measuring atmospheric temperature. Four such thermometers were mounted in the center section of a thin boom projecting from the top of the nose cone and the temperature of this boom was measured by another thermometer wrapped around it. Four bolometers located at the base of the boom measured the intensity of radiant

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[131] Vetlov, I.P. Issledovaniye Zemli iz Kosmosa, No. 2, 1980, pp. 11-27, table I.

[132] Wukelic, G.E., ed. Handbook of Soviet Space-Science Research. N.Y., Gordon and Breach. 1980, pp. 6-7, 137-138.

energy affecting the thermometer readings. The standard deviations of temperature measurements obtained in this way varied from 5 K at heights of up to 40 km to 20 K at heights above 70 km. Results were compared with values deducted from pressure measurements.

Pressure measurements were made with diaphragm transducers sensitive to the range from 760 to 5 mm Hg and two types of Pirani (hot-wire) gauges, sensitive to pressure ranges from 5 to 0.1 mm Hg and 0.3 to 0.005 mm Hg.

Atmospheric densities at meteorological rocket altitudes are usually computed from measured values of temperature and pressure by application of the equation of state. The Soviets also experimented with direct density measurements using a lithium-ion densitometer but initial reports indicated that density values obtained by this technique exceed accepted values by between 20 and 30 percent.[133]

In the 10-year period from 1957 to 1966 the Soviets launched more than 1,000 meteorological rockets, covering a geographic area extending from the Arctic to the Antarctic regions, from ships in the Pacific Ocean and Black Sea and bases at Franz Joseph Land and Kapustin Yar. With the increased cover available from satellites of the Meteor and Meteor-2 series, such frequent launches became less necessary and sounding rockets were used for determination of other parameters of the atmosphere between heights of 20 to 120 km.

In 1979, a collection of papers relating to the use of the MR-12 geophysical rocket was published by the Order of Labor Red Banner Institute of Applied Geophysics, in Moscow.[134] Measurements of the Earth's magnetic field and the field of solar radiation were used to determine the orientation of the spin-stabilized rocket. A magnetometric sensor measured the rate of rotation of the rocket's orientation angles with respect to the direction vector of the Earth's magnetic field and an FD-8K photodiode with a narrow acceptance angle and time constant of only 0.1 millisecond, installed in the nose cone, measured the angle between the longitudinal axis of the rocket and the direction of the Sun to within 1,5 °.

The paper dealing with the "Meteorite" radar station for tracking the MR-12 rockets refers to an analysis of more than 200 flights which revealed maximum differences between calculated and measured values of 0.05° in elevation, 1° in azimuth, and 100 meters in slant ranges of up to 150 km. SR-184 and SR-185 spectroradiometers, for measuring the brightness of the Earth's upper atmosphere, were reported to have been installed on an MR-12M geophysical rocket. MR-12 rockets were also reported to have been used for optical sounding of the atmospheric aerosol, submicron size particles occurring between 20 and 90 km, by investigating the angular pattern of the polarization scattering indices.

In eight launches between 1972 and 1978, measurements of the concentration and distribution, by size, of aerosol particles in the atmosphere were made using M-100 meteorological rockets

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[133] Bragin, Yu. A. Trudy Tsentral'noy Aerologicheskoy Observatorii, No. 42, 1962, pp. 116-118.

[134] Various authors. Methodika Raketnykh i Sputnikovykh Issledovaniy v Verkhney Atmosfere, No. 36, 1979, pp. 3-86.

equipped with photoelectric counters.[135] Currently, Soviet M-100 rockets are launched from the United Nations-sponsored Thumba Equatorial Rocket Launching Station in India on the magnetic equator (8.55° N, 76.85° E).

OTHER WEATHER-RELATED FLIGHTS

Meteorological data were gathered by other experimental satellites outside the main series of flights related to the Meteor series and their precursors. The chief of these are described in the commentary to follow.

MOLNIYA 1-3 AND MOLNIYA 1-4

At least two and perhaps more of the Molniya 1 communications satellites already discussed have carried a television camera in addition to their communications relaying equipment. One of the first revelations came when it was reported that Molniya 1-3 from a height of about 40,000 kilometers had photographed almost a hemisphere of Earth, showing that 80 percent of the visible part of the Northern Hemisphere was cloud covered. A succession of such pictures during the course of a day was expected to make it possible to trace the formation and movement of cyclones, hurricanes, and other formations important to weather prediction. This was to supplement data from regular weather satellites at much lower altitude. The first picture was taken May 18, 1966.[136]

Further details of the system came with the launch of Molniya 1-4 in October 1966. The television camera system was steerable from Earth, and included both wide-angle and narrow-angle lenses, together with various filters, so that several kinds of observations could be made through remote controls from Earth. The purpose, again, was to trace synoptic processes transpiring over large regions of the Northern Hemisphere.[137]

KOSMOS 149 AND 320

Kosmos 149, launched on March 21, 1967, has already been mentioned as a small satellite launched from Kapustin Yar with a B-1 launch vehicle. It represented the first attempt to stabilize a spacecraft through aerodynamic forces while still in orbit. Four rods attached a ring-shaped conic section to the main body of the satellite where the very thin upper atmosphere between 240 and 300 kilometers above the Earth stabilized the craft as to pitch and yaw. A two-stage gyro gave stability as to roll. Gas jets were used to achieve the initial stabilization after separation from the carrier rocket, and thereafter no other active devices were required, such as gas jets, reaction wheels, orientation sensors, or other attitude controls. A drawing of Kosmos 149 appears in figure 43.

The satellite had two multichannel photometers to scan the Earth in two mutually perpendicular directions to determine Earth brightness in a narrow region of the spectrum, including the molec-

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[135] Orishich, T.I., and A.V. Cherkasov. Kosmicheskiye Issledovaniya, vol. 19, No. 4, July-August. 1981, pp. 641-645.

[136] Izvestiya, Moscow, May 20, 1966, p. 6.

[137] Krasnaya Zvezda, Moscow, Oct. 22, 1966, p. 1.

ular absorption band of the visible region. Another instrument was a radiation meter in the 8 to 12 micron visibility window to measure the radiation temperature to an accuracy of 1 °Celsius. The TV system on board measured escaping radiation only in narrow regions of the spectrum in contrast to the wide spectrum coverage of the TV system used in Kosmos 122 and 144. The data returned to Earth was concerned with temperature regime of Earth's surface and clouds along with quantitative characteristics of the brightness of Earth as seen from space. The payload decayed in 17 days.

Kosmos 320 had the same characteristics of orbit, and remained in orbit for 25 days. Similar results were obtained from the second flight.

KOSMOS 243 AND 384

These satellites were also regular military observation satellites, recovered after 11 and 12 days in orbit respectively. But they also carried a supplemental scientific payload, designed to explore some of the areas of shortcoming of conventional weather satellites. The Meteor satellites are unable to penetrate thick cloud cover. Consequently, for the first time, experiments were carried to study thermal radiation of the Earth from the atmosphere and surface in the 8 mm to 8 cm microwave wavelengths. The sensors were oriented toward Earth, constituting an automatic radioastronomical observatory in space. There was also a narrow-band infrared receiver.

Among the possible measures from such studies are the water drop content of cloud, and the foci of precipitation previously obscured by cloud cover. Further, measuring the water vapor resonance attenuation of these wavebands against corresponding wavebands permits the determination of the humidity of air. Also the satellite was able to measure solid ice limits in Antarctica despite cloud cover, and to give a profile of Pacific Ocean surface water temperature from the Bering Sea to Antarctica.[138]

THE FUTURE OF METEOROLOGICAL SATELLITES

The awarding of the Lenin Prize for 1970 in the field of science and technology for work on the Meteor system is indicative of the importance the Russians attach to the meteorological satellites, which represent a considerable improvement over Earth-based weather reporting techniques. In a single revolution around the Earth a Meteor satellite collects the amount of data which would require from 15,000 to 20,000 Earth-based weather stations. The Meteor satellites transmit as much data over a period of 24 hours as is gathered by all the Earth-based meteorological stations on the planet in 6 months.[139]

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[138] Pravda, Moscow, Jan 21, 1969, p 3.

[139] Tass, Moscow, Feb. 4, 1975, 1437 G.m t. This is one of the facts from the book Kosmos i Pogoda (Outer Space and Weather) published in Leningrad. It is a photographic chronicle of Soviet space meteorology The authors are designers of rockets and scientific equipment. They have accompanied their text with over 150 color photographs taken from Soviet spacecraft.

GEOSYNCHRONOUS (GOMS)

The World Meterological Organization [WMO]'s Global Atmospheric Research Program [GARP] Numerical Experimentation Program adopted simulation techniques to determine objective requirements for a rational planning of observational systems. This was in preparation for the First Global GARP Experiment [FGGE], a 1-year campaign of measurements, one of the objectives of which was to qualify an optimized global observation system to be used as a reference by the operational World Weather Watch [WWW] program.

One of its earliest findings was that long-range forecasting would be unreliable even at mid latitudes if the Earth's tropical belt were not suitably monitored with wind observations. Furthermore, it was apparent that correct parameterization of convection in the belt of tropical cyclones is essential for the description of the meridian transfer of energy on the Earth's surface.

These findings created a demand for the development of geostationary satellites. It was estimated that a chain of four (possibly five) spaced equally round the Equator would satisfy the need for wind estimates in the tropics and for surveying convection; two (possibly three) polar satellites would complete Earth coverage, providing vertical atmospheric temperature and humidity profiles (the most essential data at high and mid latitudes).

While the need for polar satellites was apparently satisfied by the American NOAA satellites and the Soviet Meteor, a large void was still to be filled in the field of geostationary spacecraft, the only advanced program being the American SMS for two satellites over the eastern Pacific and western Atlantic.[140]

It was eventually agreed that two of the geostationary satellites, positioned to provide contiguous weather coverage around the globe in tropical and mid latitudes, would be provided by the United States and one each by Japan, the European Space Agency [ESA], and the Soviet Union.[141]

The 1975 WMO publication, dealing with the WWW, stated the operational purpose of the Soviet Geostationary Operational Meteorological Satellite [GOMS] to be:

1. To obtain data on the distribution of clouds at equatorial and middle latitudes on the light and dark sides of the Earth;
2. To obtain data on wind speed and direction at two or three levels;
3. To collect data from observing platforms (including international platforms); and
4. To disseminate cloud pictures, actual and forecast weather charts on a regional and international basis.

Although it was stated that it was planned to launch a satellite in 1 or 2 years' time, this had not taken place at the end of 1980. The first GOMS was to have been launched for tests after 1979. GOMS would be situated over the Equator at a point approximately 70° east in a geostationary orbit at a height of approximately 36,000 km. Three types of sensory equipment were listed:

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[140] ESA Bulletin, No 3, Oct. 1975, pp 52-53.

[141] Aeronautics and Space Report of the President, 1978 Activities, NASA, 1979, pp. 59-60.

1. Television-type scanning equipment operating in the visible band of the spectrum with a resolution of 2 to 4 km;
2. Infrared scanning equipment operating in the 8 to 12 micron band with a resolution of about 12 km; and
3. Transceiver equipment.

The data collection system and APT were planned having regard to the recommendations of the Coordination on Geostationary Meteorological Satellites [CGMS] meetings.[142]

By 1975, coordination meetings between those contributing satellite systems to the FGGE, namely ESA, Japan, the United States and the U.S.S.R., were taking place once or twice a year.[143]

In late 1977, the United States was informed that Russia could not provide the satellite which was to be located over the Indian Ocean. Since the loss of this satellite would have produced a gap in data coverage, the United States and ESA were asked to work together to provide for a replacement satellite. In less than a year, GOES 1 was moved to 59° E to fill the void (NOAA's designation for its Geostationary Operational Environmental Satellites is GOES). A data acquisition station was constructed at Villafranca, Spain; ESA's Control Center at Darmstadt, Germany, was modified to accept GOES data; personnel were provided and trained to operate and maintain the GOES system; and a data processing facility was established at the University of Wisconsin.

By the end of 1978 the fifth satellite system was fully installed, tested, and turned over to ESA for operation.[144]

The FGGE, organized by the WMO and the International Council of Scientific Unions [ICSU], began on December 1, 1978, and continued until the end of November 1979. This ambitious undertaking involved nearly 150 countries in a program coordinated by the WMO. Taking part were: 9,200 ground-based stations, 7,000 ships, 80 scheduled aircraft, 5 geostationary satellites, and 4 satellites in polar orbit.[145]

GOES 1 remained under control of the European Space Agency until November 30, 1979. It was then commanded to drift eastward at 2° longitude per day. GOES 1 was scheduled to arrive at its destination of 90° W during March 1980.[146]

Maps showing the disposition of the five geostationary satellites and their zones of coverage depict these zones as ellipses centered on the subsatellite points. The ellipses indicate: 10° elevation, communication range; 20° elevation, useful cloud information; 30° elevation, 10 knot wind accuracy measurement; 40° elevation, 5 knot wind accuracy measurements. Spaced as they were, the satellites provided global coverage only between latitudes 15° N and S for 40° elevation; 35° N and S for 30° elevation; 50° N and S for 20° elevation; 65° N and S for 10° elevation. This was for the greatest spacing of 80° of longitude between GOES 1 and the Japanese GMS 1.[147]

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[142] W.M.O. No. 411, Geneva, 1975. With supplements.

[143] ESA Bulletin, No. 3, Oct. 1975, p. 35.

[144] Aeronautics and Space Report of the President, 1978 Activities, NASA, pp. 59-60; ESA Bulletin, No. 15, Aug. 1978, p. 59.

[145] Spaceflight, vol. 21, No. 5, May 1979, pp. 205-206.

[146] Aeronautics and Space Report of the President, 1979 Activities, NASA, 1980, p. 63.

[147] Illustrated Encyclopedia of Space Technology, Salamander Books, 4981, pp. 102-103.

At some time between October 31 and November 20, 1979, the following Soviet message was received in New Zealand:

FOR INFO:
SOVIET GOMS (GEOSTATIONARY OPERATIONAL METEOROLOGICAL SATELLITE) TENTATIVELY SCHEDULED FOR LAUNCH IN DEC. AND ASSUMING LAUNCH SUCCESSFUL WILL BE POSITIONED NEAR 60 DEGREES E. SENSORS WILL INCLUDE VISSR TYPE SYSTEM AS WELL AS WEFAX COMPATIBLE SYSTEM AND A DCS SUBSYSTEM.

(VISSR = Visible and Infrared Spin Scan Radiometer; DCS = Data Collection System from ground platforms.)[148] Nothing came of this and speculation as to the reason why must be left to the reader.

Plans for GOMS have not been abandoned. The Soviet Union's National Paper to the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space states that the U.S.S.R. is considering problems of designing operational geostationary meteorological satellites [GOMS] equipped with TV systems in visible and IR-bands (8 to 12 microns) with resolutions of 1 to 2 km and 5 to 8 km respectively, as well with the acquisition systems, transmission of data from data collection platforms and facsimile meteorological information retransmission systems.[149]

OTHER

Among future scenarios for Soviet weather reporting is a three-tier system. The orbital altitudes for the three tiers range from several hundred to 36,000 kilometers. In the first tier of the weather reporting system there would be long-term orbital manned stations which would make visual observations of geological and meteriological phenomena such as tides, landslides, dust and sand storms, tsunami, hurricanes and earthquakes. In the second tier Meteor satellites would circle the Earth in polar or near-polar orbits at an altitude of 1,000 to 1,500 kilometers. Finally, the third tier would contain meteorological satellites at an altitude of up to 36,000 kilometers for continuous observation of the dynamic processes in the Earth's atmosphere such as overall air mass circulation.[150]

Discussions of the future of the Soviet weather observation system include plans for creating a single international network for ocean observations by automatic buoys. Information transmitted from the buoys by radio would be collected by satellites.[151]

Implementation of such a program began with the launch of the Kosmos 1076. Possibly Kosmos 1025, with similar orbital parameters, was a development flight for the subset. Some analysts believe that satellites in this subset perform an electronic intelligence (ELINT) gathering role and this is considered in the following chapter. Kosmos 1076 was followed by the Interkosmos 20 and Kosmos 1151 satellites both with announced oceanographic missions.

The satellites' scientific equipment complex is controlled by a special unit that also assigns the working modes for the measuring equipment and the system for collecting and transmitting the in-

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[148] Maxim, L. Private communication to G E. Perry, Nov. 20, 1979
[149] National Paper, U S S R . Sept 2, 1981, p. 17
[150] Tass, Moscow, May 25, 1972, 0737 G m t
[151] Vetlov, I Celestial Patrol, Izvestiya Moscow, May 1, 1975, p. 5.

formation from buoys and ships. The latter constitute a system of reference points and make direct measurements in the ocean for the purpose of monitoring and calibrating the satellite's equipment.

The equipment of the satellites regularly collects information accumulated by the automatic buoy stations and retransmits it to reception centers for processing.[152]

From 1979 through 1982, the U.S.S.R. conducted the "Ocean" experiment with the Kosmos 1076 and 1151. Observations from the satellites made it possible to obtain data on the radiative characteristics of the ocean's surface and the atmosphere synchronously, over a broad band of electromagnetic radiation frequencies. The joint processing of all the data made it possible to increase the accuracy of the determination of a number of oceanographic and atmospheric parameters.

The "Ocean" experiment should be regarded as the first step in the solution of a finite problem, the realization of which will place the problem of studying the ocean and making rational use of its resources on a quantitatively new level.[153]

A description of the buoys was given by Sagdeyev.[154] Each buoy consists of two parts. The first part is a standard unified radio terminal with its own memory; the second is a system of measuring instruments, the makeup of which can vary depending upon the problems formulated. The satellite plays the role of a central computer. It collects all the information from the buoys and retransmits it to a ground station (the matter of processing these data for the time being has not been assigned to it). The satellite can carry on a dialog with the buoys. It not only receives data from them, but also sends them commands to change the mode of operation, switch to a reserve set, etc.

Some indication of the importance attached to this work is conveyed by Soviet statements at the time of the twentieth anniversary of the introduction of the Kosmos program and at the launch of Interkosmos 20.

> The weather "kitchen" on our planet is its oceans, over the expanses of which powerful atmospheric vortices, hurricanes and typhoons are born.[155]
>
> The importance of data on water temperature in the oceans is indicated by the following example. The deviations in the distribution of warm and cold waters in the Atlantic Ocean observed in the spring and summer of 1972 exerted an influence on the peculiarities of the movement of air masses, as a result of which there was a severe drought in a number of regions in the central part of the U.S.S.R.[156]

Also being discussed is the problem of launching similar satellites into orbits with polar inclination and 24-hour revolution peri-

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[152] Nelepo, B., and Yu. Terekhin. Aviatsiya i Kosmonavtika, No. 12, December 1979, pp. 40-41.

[153] Nelepo, B.A., et al. Issledovaniye iz Kosmosa. No. 3, May-June 1982, pp. 5-12.

[154] Sagdeyev, R. Izvestiya, Nov. 3, 1979, p. 3.

[155] Lyndin, A. Aviatsiya i Kosmonavtika, No. 3, March 1982, pp. 43-44.

[156] Sagdeyev, R., idem.

ods to observe the regions situated northward and southward of 50° N and S latitudes respectively that cannot be observed from the geostationary satellites.[157] Although, at first sight, this might seem to have its attractions, it should be remembered that such satellites would not remain stationary over the polar regions. Circular 24-hour orbits would provide only two periods of 5 hours 20 minutes duration each day in which the subsatellite point lies at latitudes in excess of 50°, one in each hemisphere, although coverage of the polar region would be available for longer periods. Use of orbits having eccentricities of 0.74, such as those of Molniya satellites, give a period cf 17 hours at latitudes in excess of 50° over one of the polar regions and two such satellites would be necessary, one for each hemisphere.

NAVIGATION SATELLITES

While navigation help from satellites is likely to become a universal service for many classes of ships and aircraft, the early uses of such systems have been military, and the sponsorship of flights has been military. In the United States, the Transit system was developed by and for the Navy, becoming an essential element in the Polaris submarine and missile system. Later Transit was withdrawn from public discussion during the period when the U.S. Department of Defense operated under the greatest restrictions on public information. The U.S. system is now declassified and made available to civilian users.

The Soviet navigation system was advertised by the Russians as in operation as long ago as 1966 but no Russian satellite was specifically identified as having such a mission until the launch of Kosmos 1000 on March 31, 1978. Although no separate and distinctive name, such as Meteor and Molniya, has been given to later satellites in the series, a model of Kosmos 1000 was diplayed at the 1979 Paris Air Show at Le Bourget under the name of Tsikada. Because the Russians also have long range submarine launched missiles, they probably used their system also to support submarine operations, and by now may be using them more widely, as does the United States. One is encouraged in this interpretation of how Soviet navigation satellites were first used when one notes the Russian Yankee class nuclear-powered submarines carry 16 launch tubes so closely copying the American Polaris and Poseidon classes.

Many proposed civil navigation systems discussed in the open literature involve an interaction two ways between the ships and aircraft being navigated and the satellites in space. Typically, the mobile ship or aircraft sends a signal which is received by several satellites, and they relay the signal to a ground computer which compares signal differences, computes a position for the mobile ship or aircraft, and this position information is relayed back via a satellite to the mobile ship or plane. Such navigation systems not only have moderate costs for the mobile unit but also can serve to support traffic control purposes as well.

The early military navigation systems are different in concept from the system just described. In general, it is better for the

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[157] National Paper: U.S.S.R., Sept. 2, 1981, p. 17.

mobile ship to remain radio silent, not to disclose its position. Submarines in particular rely upon concealment, and at worst want to do no more than stick out of the water an unobtrusive receiving antenna to pick up satellite signals. The Transit system has been described as consisting of satellites in polar orbit which broadcast on 150 MHz and 400 MHz holding to these frequencies with great precision. The listening submarine or ship measures the Doppler shift of signals to determine the relative positions of listener and satellite. The satellite periodically give an accurate and updated set of emphemerides for its own position. Then a computer on the listening vessel combines the Doppler shifts in the harmonic signals and the position information on the satellite (fed in by satellite ground tracking stations) to calculate the position of the listener. This permits accurate locations to within a very few meters. Such a system with its accuracy helps the submarine or other ship to navigate, and to keep an update on missile target locations. The trade press has reported that the same system can be used for tactical fire controllers in ground warfare as well. By using satellite navigation data and the same grids, a fire controller out of view of a gun battery can still give directions permitting the very accurate placement of artillery rounds on selected targets.

Although the Russians have not described their system, the same compelling circumstances have applied, and observations by Wood and Perry of the Kettering Group confirm that they went along the same technical route as the Americans.[158]

Whereas the United States developed Transit first for use with its Polaris submarines, and then by stages extended the use to other naval vessels, and now makes navigation satellite data available to merchant ships of any nation willing to acquire the necessary receiving equipment and computers which permit the use of the data on satellites, from which ship position may be derived, the Soviets have not yet adopted such an open posture.

SOVIET REFERENCES TO NAVIGATION SATELLITES

Leonid Sedov stated as early as 1965 that space was already being used for communications, weather reporting, and precise maps of the world.[159] In January 1966, the new 5-year plan made specific reference to using space for communications, weather reporting, and navigation.[160]

Mstislav Keldysh was quoted shortly thereafter as saying that "the utilization of satellites and rockets for radio and television communications, navigation, and meteorology has been put into operation." [161] He repeated similar words at a meeting of the Soviet Academy of Sciences held June 27, 1966. He made similar statements in April 1967, and in November 1967.[162]

One of the most explicit references to Soviet navigation satellites appeared in 1966 in a magazine article which stated that the preci-

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[158] Wood, C.D., and G.E. Perry, Phil. Trans. R. So. Soc. London A., vol. 294, 1980, pp. 307-315. The section of this paper describing the coding of the telemetry is reprinted by permission of the Royal Society as the second annex to this chapter.

[159] Tass, Moscow, Dec. 31, 1965, 1612 G.m.t.

[160] Tass, Moscow, Jan. 5, 1966, 1130 G.m.t.

[161] Pravada, Moscow, Apr. 3, 1966.

[162] Moscow Radio, Apr. 12, 1967, 1355 G.m.t.; Moscow Radio, Nov. 5, 1967, 0905 G.m.t.

sion of such devices is constantly improving as reference points for shipboard and aircraft navigation systems. Coordinates can be determined to an accuracy of 200 meters.[163] A short book devoted to the subject was issued in 1969.[164]

A 1968 broadcast mentioned a proposal for an air and ship navigation and traffic control system which would use 24 satellites to give complete coverage. There is no positive clue that such a system is in the process of being implemented at the present time.[165]

Also, as mentioned elsewhere in this study, in connection with the launch of eight satellites by one launch vehicle on April 25, 1970, an article in Red Star hinted vaguely at the uses of such multiple launchings—for science, communications, and navigation; watching ionospheric processes, and radio astronomy by the interferometer technique. This is not sufficiently specific to be conclusive, for any one of these uses, although today the preponderant Western view is that they serve a communications purpose rather than forming a navigation system.

The launch of the 1000th satellite in the Kosmos series on March 31, 1978, produced a more than usually explicit announcement from the TASS News Agency.

> The Kosmos 1000 satellite which was orbited on March 31 starts a new direction in the extensive utilization of space technology for the national economy. The speciality of new satellite is sea navigation.
>
> Traffic on sea lanes is steadily increasing, and in order to ensure safety there is a need for more efficient navigational information.
>
> Traditional coastal services and even global ground systems have a number of shortcomings, one of them being that they are dependent to a large extent on the weather. Navigation by stars, which had been used by seafarers since time immemorial, also depends on weather conditions.
>
> Space radio beacons open up new horizons, providing the opportunity to establish a global all-weather system for navigation which will be highly accurate. The satellite constantly sends out signals of a definite frequency. These are received by ship serials and enter an electronic computer for processing.
>
> In establishing the coordinates, use is made of the Doppler effect. The frequency of the signals changes because of the speed of the satellite. Using these data an "electronic navigator" can produce navigational information in a convenient form—geographical coordinates and precise astronomical time. This makes it possible to automate ship navigation to a very large extent.

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[163] Nadezhdin, D Space Science in the Service of Mankind. Sovetskiy Patriot, Moscow. June 22, 1966

[164] Sivers, A P . and Yu I Tarakanov, Kosmos i More. Leningrad. Izd-Vo "Sudostroyenyi," 1969

[165] Moscow Radio. Apr. 1. 1968, 1400 G.m.t.

> Together with Molniya and Meteor satellites which ensure trouble-free communications through outer space and efficient transmissions of weather reports, navigation satellites will help enhance considerably the effectiveness of the use of the sea fleet and ensure the safety of navigation in all parts of the world ocean. Geodesists and geologists, for whom astronomically accurate coordinates are also of great importance, have long been dreaming of such apparatuses.

An article explaining in detail how to use the Transit system to determine ship position, claimed that when the elevation of the satellite from the ship was between 26° and 66°, an accuracy of between 60 and 130 meters was attainable.[166] It is worthy of comment that, as recently as 1975, a Soviet writer was still describing the American system.

NAVIGATION SATELLITE SYSTEMS

The position of the orbital plane in space relative to the fixed stars is specified by the right ascension of the ascending node, R.A., or northbound Equator crossing. For satellites in near-circular orbits at 1000 km altitude, the rate of change of R.A. remains reasonably constant over long periods of time, and thus it is possible to compute values of R.A. at given epochs from known values of R.A. at two widely separated epochs.

By computing the R.A.s of operational satellites at an epoch close to the launch-date of a new satellite, it is possible to observe the relative orbital plane spacings and note which satellite has the same R.A. as the newcomer. It is not unreasonable to assume that this satellite has been replaced at the end of its operational life, and decoding of radio transmissions given the satellite's identity number by the Kettering Group since 1976 confirms the assumption.

THE FIRST OPERATIONAL SYSTEM

In 1972, Perry employed the orbital plane spacing technique to show that five satellites placed in near-circular orbits at 74° orbital inclination with orbital periods close to 105 minutes had their planes spaced at 120° intervals, thus giving rudimentary global coverage by three satellites.[167] Table 36 gives the R.A.s of these satellites at epochs close to their launch dates. The satellites fall into three groups with their R.A.s spaced at 120° intervals. Moreover, it will be seen that Kosmos 475 and 489 replaced Kosmos 385 and 422. The intervals between replacements of 440 and 350 days respectively point to an operational life of about 1 year.

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[166] Referativnyy Zhurnal 51 Astronomiya' Otdel'nyy Vypusk, No. 8, 1975, 8.51.160.

[167] Perry, G E Flight International. London, vol. 102, Nov. 30, 1972, pp. 788a-790.

TABLE 36.—DEVELOPMENT OF THE FIRST OPERATIONAL SYSTEM

[Values are R.A.s of ascending node in degrees]

Kosmos	385	422	465	475	489
385	284				
422	17	258			
465	37	279	159		
475	(278)	159	40	281	
489		(37)	278	158	39

THE SECOND OPERATIONAL SYSTEM

Kosmos 514, launched on August 16, 1972, differed from these five satellites only in having an inclination of 83° instead of 74°. In 1973 it was joined by Kosmos 574 at an orbital plane spacing of only 60°, followed 3 months later by Kosmos 586 a further 60° away. These were followed at regular intervals by Kosmos 627, 628, 663 and 689, all of which were placed into the same orbital planes as the first three. Orbital plane spacing analysis dispelled the belief, held in some quarters, that Kosmos 628 was an immediate replacement for Kosmos 627 which had failed in its mission—their planes were 120° apart. Table 37 shows the replacement sequence of this second operational system of navigation satellites.

TABLE 37.—REPLACEMENT SEQUENCE OF THE SECOND OPERATIONAL SYSTEM

C	A	B	C
	514		
		574	
			586
	627		
			628
			663
		689	
	729		
800			
	823		
		846	
	890		
		962	
994			
	1027		

A major change occurred on February 3, 1976, with the launch of Kosmos 800. Instead of directly replacing Kosmos 663, it was placed in a plane separate from that of Kosmos 663 by 180°. This had the effect of moving the orbital planes of the second operational system away from those of the third system, which had been introduced at the end of 1974 and was being extended to a six-satellite system.

The near-polar inclination of 83° meant, in effect, that satellites in orbital planes spaced 180° apart were virtually in the same orbital plane but traveling in opposite senses. Thus it was only necessary to cover an arc of 180° with the orbital planes to achieve complete global coverage.

THE THIRD OPERATIONAL SYSTEM

Kosmos 700, launched at the end of 1974, did not fit the general pattern of replacement for the second operational system, being offset by 20° from Kosmos 627. Kosmos 726 was also offset from the second system and was 120° away from Kosmos 700. The gap in this third system was filled by Kosmos 755, placed midway between them. When Christopher Wood undertook his search for the radio transmissions from these satellites, he was unaware of the separate systems discovered by Perry and Ian Wildman at Kettering. Consequently, he was perturbed to discover two different types of modulation on 150 MHz which he designated types A and B. Further confirmation of the existence of separate systems came from the subsequent correlation of type A signals employing frequency-shift keying, f.s.k., between five sidebands with satellites of the second operational system and type B signals employing f.s.k. between three sidebands with satellites from the third operational system.[168] The type B' signals reported in that paper and in annex 1 to chapter 6 of the 1975 report, Soviet Space Programs, 1971-75, were later found to be type B with empty parameter blocks in the 2d minute of each 2-minute frame.

The launch of Kosmos 778 on November 4, 1975, signalled a further development. Placed midway between Kosmos 726 and 775, it marked the growth of the third operational system into a six-satellite system with orbital planes spaced at 30° intervals.

Wood's discovery of identity numbers within the telemetry from these satellites eased the problem of determining which satellites were really operational and revealed that certain satellites remained operational for some time after their replacement had been launched. This is only to be expected as a replacement would be launched before a satellite degraded to the point of failure and not after it had failed, unless failure was unpredictable, as was the case of Kosmos 1064.

Kosmos 1064 was launched as a replacement for Kosmos 991 in December 1978.[169] It failed to circularize its orbit and remained in the 99 min elliptical transfer orbit. Nevertheless, it was given the identity No. 1 and transmitted data for a time. It was in turn replaced by Kosmos 1072, with identity No. 8, in January 1979.

Despite this failure and subsequent early replacement, Kosmos 1064 was found, by David Wilson of Kent, OH, to be transmitting "time only" data during October, November and December 1979. Table 38 shows the replacement sequence of third operational system, which is still in use at the time of writing.

The identity numbers found in bits 19 through 23 of the third word of the parameter blocks, transmitted in the second half of each minute, are not unique and originally related to a particular satellite only during its operational lifetime. They were then reallocated to replacement satellites but, until mid-1979, no replacement took the identity number of the satellite it was replacing. Identity numbers are given in parentheses following the Kosmos numbers in table 36.

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[168] Perry, G.E., and C.D. Wood, Journal of the British Interplanetary Society, vol. 29, 1976; pp. 307-316.

[169] Flight International, London, vol. 115, Feb. 24, 1979, p. 515.

TABLE 38.—REPLACEMENT SEQUENCE OF THE THIRD OPERATIONAL SYSTEM

1	2	3	4	5	6
700 (1)				726 (2)	
		755 (3)			
					778 (4)
	789 (5)				
			864 (6)		
				887 (7)	
894 (8)					
		928 (1)			
	951 (2)				
					971 (3)
985 (4)					
				991 (5)	
			996 (7)		
		1011 (6)			
				1064 (1)	
				1072 (8)	
	1089 (5)				
			1091 (7)		
1104 (2)					
1104 (1)	1089 (2)	1011 (3)	1091 (4)	1072 (5)	971 (7)
					1141 (6)
1104 (1)	1089 (2)	1011 (8)	1091 (4)	1072 (5)	971 (7)
		1150 (3)			1141 (6)
1104 (1)	1089 (2)	1011 (8)	1091 (7)	1072 (5)	1141 (6)
		1150 (3)	1153 (4)		
1104 (1)	1089 (2)	1150 (3)	1091 (7)	1072 (8)	1141 (6)
			1153 (4)	1181 (5)	
1104 (1)	1089 (7)	1150 (3)	1153 (4)	1072 (8)	1141 (6)
	1225 (2)			1181 (5)	

Complete reallocation of identity numbers occurred at some time between August 5 and November 16, 1979—probably around the time of launch of Kosmos 1141 on October 16, 1979. This led to a logical sequency of numbering, from 1 through 6, in orbital-plane position round the Equator. Since then, replacement satellites have assumed this logical number and the satellite being replaced has been renumbered 7 or 8 for the remainder of its operational life.

AN OPERATIONAL SYSTEM FOR CIVIL USE

Kosmos 883 was placed in one of the six groups of the third operational system and had its ascending node in the opposite hemisphere. Although its signal format was type B it carried the identity No. 11. Nos. 9 and 10 have never been observed. It was followed by Kosmos 926 with an identity No. 12 and ascending node 45° away from that of Kosmos 883 in the hemisphere opposite to that of the third operational system. All became clear with the launch of Kosmos 1000 a further 45° away and No. 13. This was the first Kosmos satellite to be specified as performing a navigation mission and references to civil usage strongly suggests that satellites with identity numbers of 11 and upwards form a civil system. This hypothesis was strengthened by the launch of Kosmos 1092, No. 14, a further 45° away, completing a four-satellite system with orbital planes spaced at 45° intervals giving complete global coverage. The development of this system is given in table 39. Identity numbers are given in parentheses following the Kosmos number.

Kosmos 1179 has been included because some analysts have been tempted to consider its elliptical, 103.6 min., orbit as a failed element of a navsat system. Table 39 shows that it was placed precisely 30° out of plane with Kosmos 1168 and this was 15° away from Kosmos 1141 in the gap between the third operational system and the civil system. We do not consider it to be a failure but rather to be carrying out some unspecified mission other than navigation.

TABLE 39.—DEVELOPMENT OF THE CIVIL NAVIGATION SATELLITE SYSTEM

[Values are R.A.s of ascending node in degrees]

Kosmos	883	926	1000	1092	1168	(1179)	1226
883 (11)	323						
926 (12)	170	216					
1000 (13)	334	21	67				
1092 (14)	56	104	149	195			
1168 (11)	(164).	213	257	303	168		
(1179)		171	214	261	125	95	
1226 (13)		16	(59)	106	330		61

DESCRIPTION OF THE KOSMOS NAVIGATION SATELLITE

The first satellites with an orbital inclination of 74° and orbital period of 105 minutes were both reported to be performing scientific research related to the ionosphere.[170] [171] Kosmos 378 had an elliptical orbit from which it decayed naturally within 2 years. Since Kosmos 381 was placed into a near circular orbit only 2 weeks later it may be speculated that a similar orbit was intended for Kosmos 378 but not achieved. A full-scale model of Kosmos 381 was displayed at the 1971 Paris Air Show. This was a cylinder 1.4 meters tall and 2.0 meters in diameter. Gravity-gradient stabilization was used with the long boom reaching up to the roof of the hall. The curved surface was covered with solar cells. Perry [172] speculated that the navigation satellites in the Kosmos series would be similar in appearance and dimensions. This speculation was substantiated when a full-scale model of Kosmos 1000 was displayed in 1979. The major modification was an increase in the height-to-diameter ratio. The ionospheric probing antennas were also omitted. Figure 47 shows drawings of the Kosmos 1000 and 381 satellites, not both to the same scale. The gravity-gradient stabilization boom is unfurled to its full length from the disc-shaped housing mounted in the trussed structure attached to the hemispherical end of the inner cylinder.

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[170] Shtern, M I. "Investigations of the Upper Atmosphere and Outer Space Conducted in 1970 in the U S S R." (translated by NASA in 1972), p. 28.

[171] Soviet News, Jan 12, 1971

[172] Perry, G.E. R.A.F. Qy., vol. 18, 1978, p. 278.

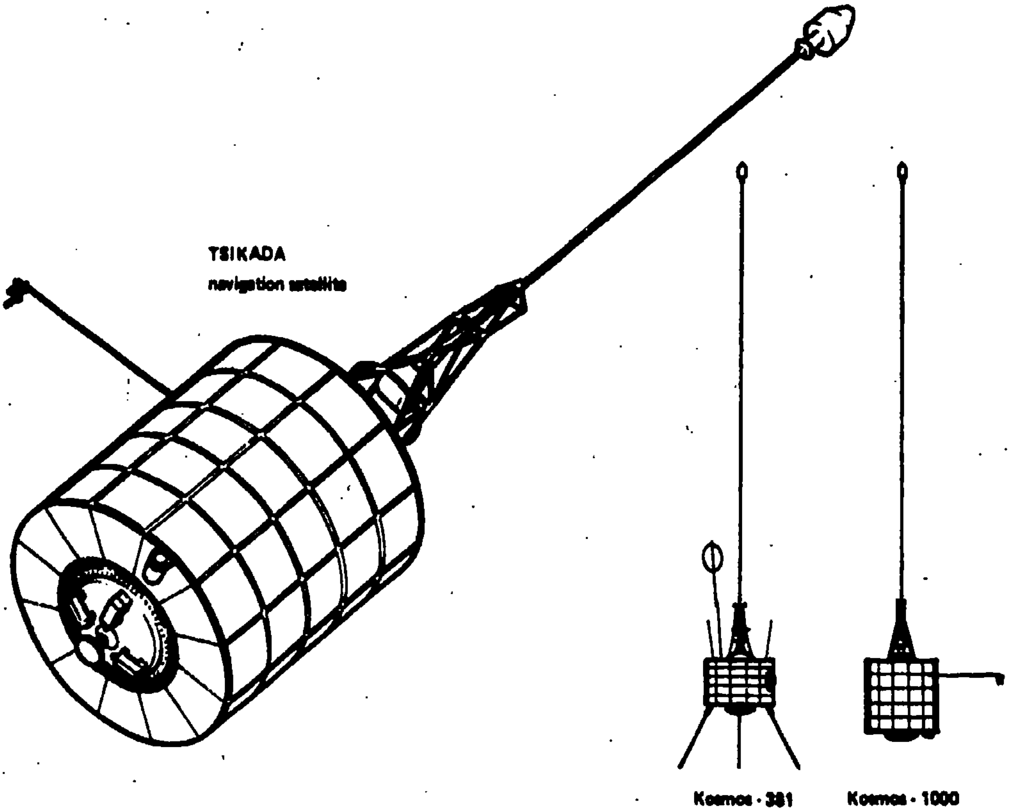

FIGURE 47.—Kosmos 331 and 1000 (Tsikada) Satellites

EARTH RESOURCES SATELLITES

Although the Soviet Union had often expressed a definite interest in Earth resources satellites, at the time of the previous report in this series it did not have an operational program and it remained unclear whether it proposed to create unmanned systems for gathering such data on a regular basis or would defer such work until an operational manned space station was established.[173]

At a scientific conference held in Zvenigorod, near Moscow, the problems of studying the Earth from space were discussed. Commenting on this conference, Academician Roald Sagdeyev, director of the Space Research Institute in the Societ Academy of Sciences, stressed that the main task of the conference was to work out unified scientific principles and methods for exploring the Earth's resources from outer space and for organizing systematic control over the environment with the help of artificial satellites. Sagdeyev mentioned the international aspects of Earth resources study: man-

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[173] Raleigh, Lani H. Soviet Space Programs, 1971-75. Washington, U.S. Government Printing Office, 1976, p. 367.

made influence on the environment reaching beyond national borders, and the assessment of natural resources from space for the developing nations. Although Sagdeyev called for international cooperation for a global Earth resources monitoring system, there was no mention of immediate plans for an operational system for the U.S.S.R.[174]

However, it was announced at the conference that initial steps had been taken to establish a research center, Kaspii, its purpose to develop new methods of using remote sensing to study the natural resources of the Caspian region. The conferees were also informed that plans were underway to build a central scientific institution to study the Earth's resources from space.[175]

EARTH RESOURCES DATA FROM METEOR SATELLITES

Geologists were among the first to use space photographs. They have long used aerial photography for research. However, the maximum area of the Earth's surface that can be photographed at any given time from an aircraft is 1,000–2,000 square kilometers. The dimensions of geological structures—folds, depressions, and faults in the Earth's crust—are measured in hundreds and thousands of kilometers. Such large geological formations can only be seen as a whole from space.[176]

Soviet geologist cite numerous geological discoveries resulting from the use of space photographs. Images of the Earth from space have enabled geologists to see faults which have not been discovered by ground expeditions. They have also been able to correlate such geological anomalies with mineral deposits and increased seismic activity.[177] Russian scientists also claim that satellite imagery led to the discovery of iron at Malyy Khingan and coal in the Amurskaya Oblast.[178]

Geologists in the Soviet Union are now revising existing geological maps. Many regions which earlier had been considered well-explored geologically, such as the Urals and the Caucasus, have appeared entirely different after a space survey.[179] Thus, a space map of a territory comprising 6 million square kilometers has enabled the All-Union Aerogeological Trust to formulate new theories about the tectonic structure of the region.[180]

Television pictures taken from Meteor satellites are available for the entire Siberian platform and have been used in tectonic studies in the western portion of the region.[181] Multispectral images from Meteor 25 were interpreted to ascertain new geological features of the eastern region of the Soviet Union from the Omolon basin to the Bering Sea.[182]

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[174] Tass, Moscow, Mar. 13, 1965. 2015 G.m.t.

[175] Tass, Moscow, Mar. 10, 1975. 1757 G.m.t.

[176] Andronov, I, Pravda, Moscow, May 25, 1972, p. 3.

[177] Idem

[178] Prushkar. A. High-Altitude View, Izvestiya, Moscow, Aug. 1975, p. 5.

[179] Bryukhanov, V. Aerogeologiya Trust, Orbital Geology, Izvestiya, Moscow, July 25, 1974, p. 2.

[180] Op. cit., p. 3

[181] Gerasimov, L.M., and V. Yu. Luskina, Novosibirsk Tektonika Sibiri, vol. 8, 1980, pp. 102–120.

[182] Filatova, N.I., et al., Geotektonika, No. 5, September-October 1980, pp. 105–118.

By studying space photographs taken by Meteor 28, on a 1:5,000,000 scale, and from Salyut 4, researchers at the M.V. Lomonosov Moscow State University were able to conclude that the presence of gas and oil deposits is strongly correlated with the existence of linear structures but not circular ones. The Buzuluksskaya depression, lying mainly within the area bounded by Kuybyshev, Orenburg and Ural'sk was chosen for the study because of the exceptional clarity of the landscape features as viewed from space, comprehensive geological knowledge about several levels of its vertical structures, and the large number of gas and oil deposits already discovered there.[183]

The U.S.S.R. Ministry of Geology is one of the main consumers of the widely distributed multispectral imagery produced in the Meteor-Priroda program. According to the estimates of geologists, the annual economic effect from the use of multispectral information in detecting and defining more precisely tectonic structures and the lineaments of the Earth's crust alone is about ten million rubles. Data from photographs have been used to compile space tectonic maps of the U.S.S.R. on scales of 1:5,000,000 and 1:2,500,000 that are used as the basis for predicting the presence of useful minerals and determining the overall strategy of prospecting work. Data have also been obtained for predicting potential oil-bearing and gas-bearing structures in several regions and the confinement of gold ore manifestations to areas where annular structures and linear faults intersect has been established in one of the eastern regions of the Soviet Union. According to some estimates, the monetary savings when territorial geological structures are studied by space methods are about three rubles per square kilometer.[184]

Using satellite images, agronomists can monitor crop growth over large areas. It has also been discovered that with satellite imagery it is possible to detect the degree of moisture of various types of soil—from the most arid desert to irrigated farm land.[185] More accurate information on snow cover in the Tien Shan and Himalaya Mountains has enabled farmers to irrigate crops more effectively. Space surveys also make possible the study of the formation and dessication of intermittent lakes.[186]

The Russians plan to use Earth resources data from space in a variety of fields. Space surveys will be used for estimating crop yields and monitoring insect infestation. Forests and large land reserves will be monitored for blights as well as for fires.[187]

This has now come to pass. Forest management specialists have achieved significant results through the use of satellite information to detect forest fire nuclei and monitor their propagation. Special techniques for using satellite information for this purpose, as well as for the operational evaluation of the weather situation in hazardous fire periods in areas that are being protected and the orga-

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[183] Trofimov, D.M., and B.I. Dmitriyeva, Issledovaniye Zemli iz Kosmosa, No. 4, July-August 1981, pp. 39–44.

[184] Trifonov, Yu. V., Issledovaniye Zemli iz Kosmosa, No. 5, September-October 1981, pp. 8–20.

[185] Vinogradov, B.V., and A.A. Grigor'yev, Viagooborot V Prirode i Yego Rol'v Formir, Moscow, Resursov Presn Vod, Stroyizdat, 1973, pp. 204–217.

[186] Idem.

[187] Andronov, I., op. cit., p. 3

nization of the utilization of airborne firefighting facilities, have been developed and introduced into operational practice at forest conservation establishments.[188]

The Trifonov paper appears in an issue of Issledovaniye Zemli iz Kosmosa devoted entirely to remote sensing. Titles of the papers listed below reveal the great extent to which remote sensing techniques are being used today. The majority of the work is based on data provided by the "Fragment" unit installed onboard experimental Meteor satellites.

Danube delta dynamics study using satellite photographs.

Development of shore relief of Gulf of Riga from analyzing satellite images.

Study and mapping of agricultural land use from satellite images.

Mapping of forest vegetation by means of satellite images.

Study of anthropogenic influence on natural environment from multiband scanner image data.

Study and mapping of erosion relief of Kalach upland from multiband scanner images.

Satellite images obtained by means of Fragment system as basis of landscape mapping and physical geographical zoning of arid lands.

Earlier papers in the same issue deal comprehensively with the design of the satellites and their onboard instrumentation including the Fragment multizonal scanning system.[189] This consists of an optico-mechanical scanning unit with calibration devices, a system of photo-receivers with a fiber-optics collector, and analog-to-digital converter, synchronization, commutation and multiplexing devices, and a digital radio transmission unit operating in the 1 GHz band. The system measures the spectral energy brightness of natural formations in eight spectral bands with differing degrees of accuracy, using onboard calibrating and standard light sources during the measurements. Wavelengths of the eight bands are 0.4–0.8, 0.5–0.6, 0.6–0.7, 0.7–0.8, 0.7–1.1, 1.2–1.3, 1.5–1.8, and 2.1–2.4 microns giving a resolution of 80 meters at the nadir from an operational height of 650 km. The creation of the Fragment complex was assisted by specialists from Karl Zeiss-Jena in the GDR, who developed and manufactured a reflecting telescope of 1 meter focal length and 240 mm diameter. In addition to the Fragment complex, Meteor 30 carried a BIK-E experimental on-board information complex consisting of a medium-resolution multizonal scanning unit with a tapered optico-mechanical scanner (MSU-SK), operating in the 0.5–0.6, 0.6–0.7, 0.7–0.8, and 0.8–1.0 micron bands, and a high-resolution multizonal scanning unit with electronic scanning using charge-coupled devices (MSU-E), operating in the 0.5–0.7, 0.7-0.8, and 0.8–1.0 micron bands, an information conversion and multiplexing unit, and a digital radio transmission unit operating in the 460–470 MHz band. Resolutions of these two units are 170 and 30 meters respectively. A third complex on Meteor 30 is the

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[188] Trifonov, Yu. V., op. cit.

[189] Various authors, Issledovaniye Zemli iz Kosmosa, No. 5, September–October 1981, pp. 5–138

Translated in JPRS L/10266, U.S.S.R. Report, Space, (FOUO 1/82), Jan. 20, 1982, pp. 1–89, and JPRS 81552, U.S.S.R. Report, Space, No. 17, Aug. 17, 1982, pp. 81–88.

operational radio and television complex [RTVK] consisting of a duplicated complex of multizonal optico-mechanical scanning units with low (MSU-M) and medium (MSU-S) resolution, memory units and two radio systems operating in the meter and decimeter bands that are standard equipment on satellites of the Meteor series. The MSU-M operates in the 0.5-0.6, 0.6-0.7, 0.7-0.8, and 0.8-1.0 micron bands with a 1 km resolution and MSU-S operated in the 0.5-0.7 and 0.7-1.0 micron bands with a resolution of 240 meters.[190]

Earlier, it was reported that Meteor 18 carried a microwave polarimeter operating on a wavelength of 80 mm and that Meteor 25 carried a scanning infrared polarimeter operating in the 1.5-1.9 and 2.1-2.5 micron bands.[191]

Design criteria for remote sensing platforms include provisions of high dynamic accuracy and temperature stabilization for the placement of the measuring instruments relative to the optical axes, being general-purpose making it possible to install various sets of experimental equipment easily, and, above all, suitability for the installation of correction engines for the initial setting of the correct orbit and subsequent control of it. The Meteor series spacecraft possessed all of these requirements to a considerable degree, both in the first-generation and (particularly) second-generation versions, having electrical and radio systems-power supply, orientation, thermal regulation, monitoring and programmed-command control—highly reliable designs.

Figure 48 shows drawings of Meteor-Nature satellites based on both generations of Meteor spacecraft, prepared from photographs in the U.S.S.R. National Paper referred to previously.

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[190] Issledovaniye Zemli iz Kosmosa, No. 1, January-February 1981, pp. 5-6.

[191] W.M.O., No. 411, op. cit.

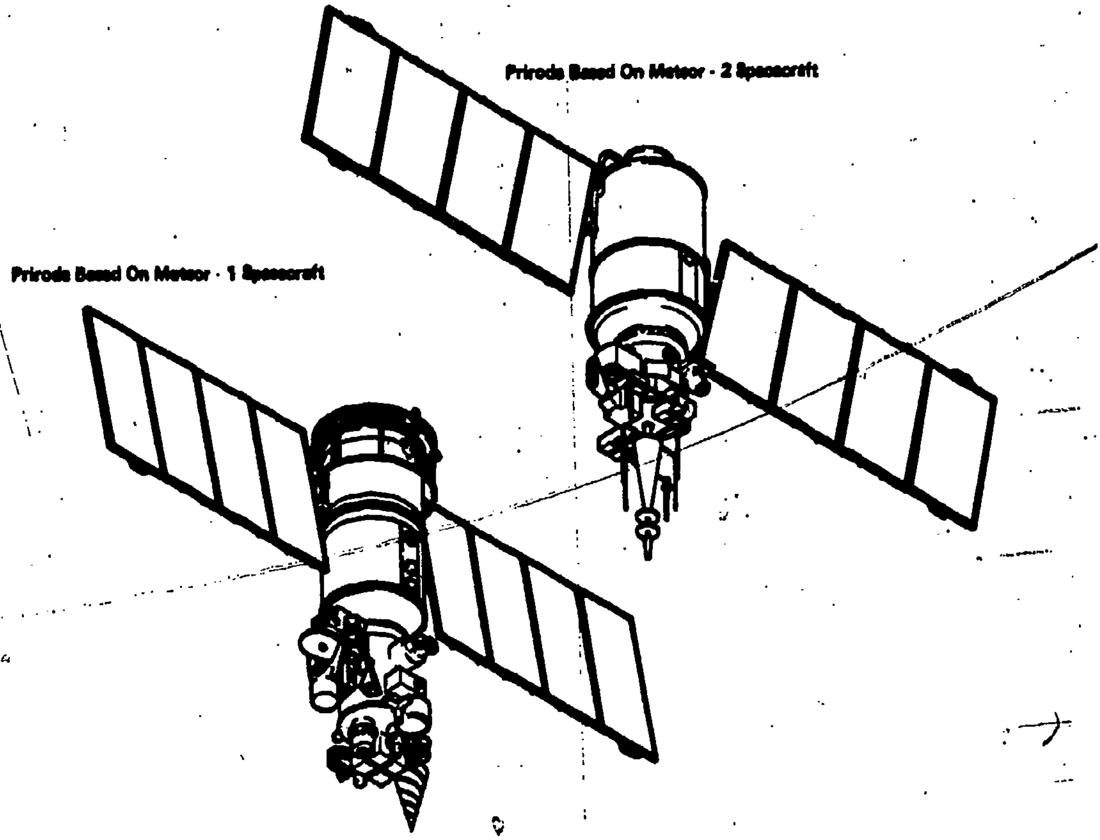

FIGURE 48.—Meteor-Priroda (Nature) Satellites

In order to ensure the maximum coincidence of the spacecraft's optical axes as a whole, as determined by its orientation sensors, with the optical axes of the instruments, which require precise orientation on the Earth the latter are placed on a single instrument platform. The platform is standardized to a considerable degree, making it possible to place different instruments on it. Most of the instruments' sensors were placed outside the spacecraft's sealed body, making it possible to avoid the use of windows, which would reduce the overall useful signal level and distort its spectral composition. The instruments have their own microclimate. Electronic and electrical units, which were not designed for use in open space, were assembled in the form of sealed monolithic units. Instruments that were particularly sensitive to vibrations and linear overloads arising during the launch phase or to vibrations arising during the rotation of inadequately balanced dynamic masses inside the spacecraft were mounted on special shock absorbers. When it was necessary to preserve high geometric accuracy, the entire instrument platform holding the sensors was mounted on shock absorbers. Problems of providing nonintersecting fields of view for the sensors and the use of stationary transmitting antennas were solved.[192] It

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[192] Trifonov, Yu. V. Issledovaniye Zemli iz Kosmosa, No. 5, September–October 1981, pp. 8–20.

would appear that Meteor 18, 25, 28 and possibly 29 were based on the first generation Meteor bus.

Second generation buses were used with the introduction of the Fragment system on Meteor 30 and 31. These are distinguished from the first-generation buses by possessing increased accuracy of triaxial orientation and stabilization of the angular velocities, which make it possible to employ instruments with optico-mechanical scanning and local resolution of up to 80 meters, as well as an enlarged energy supply system capacity. There are also expanded capabilities for automatic timed-programmed control of the processes for obtaining and transmitting information, including control over the light conditions and sensitivity levels of the measuring equipment. Additional structural configuration and mass-to-size capabilities made it possible to install a multiband instrument complex and several radio telemetry links. A general-purpose automatic-testing system and technique, using the control computer's hardware and software, made it possible to carry out ground checks of instrumentation performance and ensure reliable on-orbit operation. The adoption of the improved Meteor-2 bus made it possible to continue operating the RTVK, which provides low and medium resolution multispectral information as APT.[193]

The operational purpose, retrograde orbit and some details of the telemetry of the experimental Meteor satellites have been discussed earlier in section III.D.4 of this chapter and will not be repeated. The first FANAS for an experimental Meteor satellite was issued for Meteor 30 on June 16, 1981, almost exactly 1 year to the day following the launch of that satellite. It is reproduced, as received, below:

TV SET 2 CONNECTED:
CHANNEL 2, 0.6-0.7 MKM—EVEN DAYS
CHANNEL 4, 0.8-1.1 MKM—ODD DAYS
LAUNCH IN 18 JUNE 1980, INCLINATION—98 GR
SCANNING FOUR CHANNEL TELESPECTROPHOTOMETER
THE SECOND SET IS SWITCHED ON, ANY FOUR SPECTRAL CHANNELS
SWATH WIDTH 1800 KM, RESOLUTION IN NADIRE 1 KM
RADIOSIGNAL:
TRANSMISSION FREQUENCY—137.15 MHZ
AMPLITUDE-FREQUENCY MODULATION
DEVIATION—9.6 MHZ
LOW-FREQUENCY SIGNAL:
SUBCARRIER FREQUENCY—2400 HZ
SUBCARRIER MODULATION-AMPLITUDE PEAK AMPLITUDE CORRESPONDS TO
WHITE LEVEL
REGISTRATION:
INTERFACE INDEX—350
SCANNING SPEED—240 LINES PER MINUTE
SCANNING DENSITY—5 LIN./MM
LINE DIMENSION—161 MM
NUMBER OF HALF-TONES—NOT LESS THAN 12
SCANNING:
SETS 1 and 2—LINEAR
INCLINATION OF SCAN PLANE FOR THE FIRST SET IS MINUS 4 MINUTES
FOR THE SECOND ONE—MINUS 19GR35'

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[193] Trifonov, Yu. V Issledonvaniye Zemli iz Kosmosa, No. 5, September-October 1981, pp. 21-27.

There would appear to be a misprint in the units for deviation which should, in fact, be kilohertz, KHZ.

It will be seen that the spacecraft operated in different modes from day to day. Imagery produced by Leslie Currington, at Welwyn Garden City, England, around the time of this FANAS announcement revealed that channel 4, transmitted on June 1, lacked synchronization lines, whereas these were retained on channel 2, causing some difficulty in lining up the facsimile printer. Differences in ground detail, particularly in the rendering of snow cover on the Alps (better in the visible, channel 2) and the distinction between land and water (better in the infra-red, channel 4) are quite marked. The density wedge between synchronization was latitude-dependent, being more pronouncedly contrasted at 66° N than 33° N. Depth of modulation differed between channels being 85 percent on channel 2 and 95 percent on channel 4.

MANNED FLIGHTS GATHERING EARTH RESOURCES DATA

Although manned spaceflight missons are discussed in great detail in part 2 of this study, it is appropriate to consider some of the aspects relating to Earth observations in this section.

SOYUZ 9

The scientific and organizational principles of aerospace studies of physical geography were laid in the Department of Atmospheric Physics at Leningrad University. During the period 1968-72 it carried out fundamental investigations in this field for the first time in the Soviet Union. First programs were drawn up for photographing natural formations for manned spaceships, beginning with the joint flight of Soyuz 4 and Soyuz 5 in January 1969. Initial studies for the comprehensive interpretation (geological, geomorphological and soils-geobotanical) of space photographs taken from Soyuz 3 in 1968 and subsequent manned spaceflights. The Department developed programs and carried out the first subsatellite experiments—coordinated ground aerial and space surveys, commencing with the "troika" mission of Soyuz 6, 7 and 8 in 1969 and Soyuz 9 in 1970.[194] In the course of its 18-day mission, Soyuz 9 went a long way in gathering Earth resources data, both because of the amount of time available for such work and because it built upon the more limited experience of its predecessors. On the 5th day of the mission, Nikolayev and Sevastyanov watched a large tropical storm in the Indian Ocean and observed surf on a continental shore. The next day they observed forest fires in Africa near Lake Chad. They used both black and white and multispectral color film to photograph the Earth's surface which was expected to throw light on problems of identification of different kinds of Earth rock and soil, the moisture content of glaciers, the location of schools of fish, and estimation of timber reserves. They also made studies of aerosol particles in the atmosphere by observing twilight glow.[195]

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[194] Vinogradov, B.V. Vestnik Akademii Nauk S.S.S.R., No. 12, 1979, pp. 86-94.

[195] Soviet Space Programs, 1971-75. Washington, U.S. Government Printing Office. Aug. 30, 1976, p. 186.

Photographs of the Sal'skiy dry steppe region of the Rostovskaya Oblast obtained from Soyuz 9 in 1970 were compared with those of the same area taken from Salyut 6 in 1978 and revealed numerous changes to have occurred over the 8-year period. The structure of crop rotation had become more complicated, many fields had been subdivided and efforts had been made to overcome monoculture in order to preserve soil fertility. New highways had been constructed, reservoirs had been built, populated places had grown, and the extent of virgin land had been reduced. Some fields had been abandoned, mostly due to surface erosion and the surveys made it possible to make a linear forecast of land exploitation up to 1986.[196]

SOYUZ 22

This 8-day mission, with cosmonauts Bykovskiy and Aksenov, launched on September 15, 1976 was the only Soyuz to fly at an inclination other than 51.6°. The choice of a 65° inclination was to permit photography of the territory of the German Democratic Republic, much of which lies to the north of 52° N, latitude. A major item of equipment was the MKF-6 camera made by Karl Zeiss-Jena, which was accommodated atop the orbital module. The flight of the Soyuz 22 spaceship and the "Raduga" (Rainbow) experiment conducted on the basis of the flight were devoted to perfecting methods and equipment for photographing the Earth from space. It was based on multispectral photography and the visual-instrumental interpretation of images obtained by the optical-photographic synthesis of multispectral photographs. The camera obtained thousands of photographs of the territories of the G.D.R. and U.S.S.R.

A special feature of the Raduga experiment was that in addition to perfecting the methods of multispectral space photography it pursued the goal of creating standard apparatus for regular investigations of the Earth's natural resources using space technology. Scientific documents summing up the program were prepared by scientists of the U.S.S.R. and published as a collective monograph "Soyuz 22 Investigates the Earth" [197] and the atlas "Interpretation of Multispectral Aerospace Photographs: Techniques and Results," which was released in 1982.[198]

The MKF-6 camera and the associated MSP-4 multichannel synthesizing projector together form a unique set of equipment. Photographs taken with the camera are distinguished by their high resolution (up to 200 lines per millimeter) and narrow spectral bands (up to 40 nanometers). The projector can be used not only to produce high-quality, enlarged, synthesized color photographs, but also for the direct interpretation of images produced on the instrument's screen. Later versions, the MKF-6M and MSP-4B, developed on the basis of the results of the first tests on Soyuz 22 are being produced in series by the East German company and an MKF-6M was installed in the Salyut 6 orbital space station.[199]

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[196] Vinogradov, B.V., A.S. Ivanchenkov, V.V. Kovalenok, A.G. Nikolayev and V.I. Sevast'yanov Doklady Akademii Nauk S.S.S.R., vol. 249, No. 6, 1979, pp. 1501-1504.

[197] Izdatel'stvo "Nauka," 1980; Adademie-Verlag Berlin, 1980.

[198] Sidorenko, A.V. Issledovaniye Zemli iz Kosmosa. No. 2, March-April 1982, pp. 5-9.

[199] Idem

Further details of this version are to be found in the following section.

SALYUT STATIONS

The Salyut 4 orbital station, launched on December 26, 1974, functioned in orbit for more than 2 years. More than 4.5 million square kilometers of the territory of the U.S.S.R. were photographed during this time. As a result of this photography, a deposit of fresh water was discovered in the Kyzylkumy desert as were potential regions for prospecting for oil. The Kaskad (Cascade) system was developed in order to realize economical orbital orientation of the station, in an automatic mode, when photographing the Earth's surface.[200]

The importance of visual-instrument studies of the Earth was manifest during the long-duration missions to Salyut 6. Such observations are those made both by using the naked eye and using various instruments: binoculars, optical range finders, colorimeters, etc. The results are documented using cameras, television and spectrometers. Plans for a program of Earth observations from Salyut 6 for the first long-duration crew were based on results and reports from earlier Soviet manned missions. [201] A characteristic feature of this program was the fact that the planned observation problems could be more precisely defined by the specialists and the cosmonauts themselves in flight. Besides the traditional operations of controlling remote sensing equipment, the program assigned the crew the duty of more precise definition of the objects of investigation and selection of the time to study them as a function of illumination conditions, meteorological situations and other factors. Thus, the success of the entire experiment was determined by the creative capabilities of the crew, their training and fitness, and also the level of operative consultations between the cosmonauts and the assigners of the individual missions. [202]

The Salyut 6 station and its fixed position Earth observation instrumentation demanded that active stabilization of the station, using low-thrust engines, was used maintaining the longitudinal axis parallel to the Earth's surface. The cosmonauts were also permitted to make visual-instrument observations when the station was in the drift mode and they soon discovered that, in a number of cases when approaching the target area, the station was oriented so that the solar panels cut off the view of the Earth from the binoculars and portable cameras that had been set up. The cosmonauts hit on the idea of orienting the station with its longitudinal axis along the local vertical and giving it an angular velocity in the orbital plane equal to its mean motion, obtaining the required initial conditions by manual control of microthrusters, using a wide-angle viewer. This provided them with an almost panoramic view from the five windows of the station's transfer compartment. In view of this, it is possible that later generation space stations will have their remote sensing instruments aimed along the longitudi-

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Feoktistov. K.P. Zemlya i Vselennaya, No. 5, September-October 1981, pp. 10-17.

[201] Grechko, G.M., Yu. V. Romanenko, et al. Issledovaniye Zemli iz Kosmosa, No. 1, January-February 1982, pp. 5-13.

[202] Idem.

nal axis of the orbital complex so that pictures will be taken in the gravitational stabilization mode. The resulting increase in atmospheric drag will be counteracted by in-orbit refueling.[203]

Another factor in favor of the use of portable rather than fixed position instruments is their ability to be trained on targets remote from the station's ground track. The choice of a 31-revolution repeating ground track on alternate days in support of launch-to-rendezvous considerations implies that targets midway between ground tracks separated by 16 revolutions, a longitude separation of some 11.5°, never fall within the field of view of fixed position instrumentation. Using portable cameras and binoculars, cosmonauts are able to observe and record off-track targets.

Although not part of the station's original equipment, binoculars were delivered to the cosmonauts to support the program of observations. It was determined that 6X and 12X magnifications were the most convenient. The cosmonauts also requested that topographical maps for their use should be colored in accordance with the true color of different landscape zones. During the second long-duration mission to Salyut 6 the number of shades of color was increased to 196.[204]

Observations of the natural environment were grouped into six sections: geology, geography, oceanology, glaciology, meteorology, and environmental control. The glaciological investigations and experiments aboard the Salyut 6 orbital station were described in an article by joint authors, including cosmonauts Grechko and Ivanchenkov. Observations were made for the first time in 1978 by two expeditions aboard Salyut 6. Visual observations were made using binoculars. The scales of photographs taken from about 350 km were 1:2,000,000 and 1:5,000,000, the surveyed features sometimes being far from the subsatellite point and in most cases the photographs were oblique. In the first observations emphasis was on the Pamir region. Other glaciological observations were made in South America and Africa.[205]

Writing in Pravda at the beginning of the Soyuz 39 mission, under the title, "A Look at the Earth," A. Koval' summarized the observations of the Earth made during the series of international flights to Salyut 6 under the Interkosmos program. During the first two of these, the MKF-6M multispectral camera was used to take pictures of the territories of Czechoslovakia and Poland. The third flight continued the work of the "Raduga" program initiated during the Soyuz 22 mission. This necessitated cooperation between the Priorda State Center of the U.S.S.R. and the G.D.R. Academy of Sciences' Central Geophysical Institute. After this, analagous joint experiments were prepared by Soviet specialists and those from the countries of all other international crews. Although Soyuz 33 was unable to dock with Salyut 6, the Bulgarian-produced spectrometer, "Spektr-15," was delivered to the station in the unmanned Progress 5 and used to investigate the spectral reflective characteristics of different natural objects and their variations from place to place and from time to time.

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[203] Idem

[204] Idem.

[205] Denisov, L.V., et al., Issledovaniye Zemli iz Kosmosa, No. 1, 1980, pp. 25-34.

During the flight of the Hungarian cosmonaut, synchronous observations by aircraft and a mobile information and measurement complex operating along the station's ground track were used for ground-truth investigations at test ranges in the Hungarian P.R. at Abadsalok, Pents, Balaton, and Dunay. However, in an article in the Hungarian press, published after the flight, it was reported that Farkas has been unable to take pictures of Hungary with the MFK-6M camera because it had been late afternoon when Saluyt 6 flew over Hungary and the amount of light had been insufficient for photography. When Salyut 6 had been in the region during lighter periods, Hungary had been "just on the horizon." [206] On the next international flight, 23 photographic sessions provided pictures of the territory of Vietnam, silt deposits in the Mekong Delta, and geological structures. The latter have a potential for the discovery of useful minerals.

Pictures of Cuba taken on the next flight in the series revealed salt-dome structures in the center of the island. Studies of the Pinar-del-Rio zone and an analysis of the color characteristics of the sea surface around the island were also carried out. The Mongolian cosmonaut's flight was to continue ground-truth investigations and perform a variation of the "Biosphere" experiment, first performed on the third flight, under the name "Biosphere-Mon."[207]

Details of the two special cameras, MSF-6M and KATE-140, were given by Kuchumov.[208] He claimed that, in the Salyut 6 mission, practically all of the Soviet Union south of 52 °N. had been covered by photographs taken in different seasons and that the territories of all countries participating in the Interkosmos program had been photographed.

The MKF-6M camera, built by Karl Zeiss-Jena, has six spectral channels, each with its own lens and filter. Four of these lie in the visible part of the electromagnetic spectrum and the other two in the near infrared region. Each of the six simultaneously obtained 56 by 81 mm spectral frames bears an image of the same area of the Earth's surface covering some 35,000 sq. km. Each cassette has a film supply of 1,200 frames. Precisely calibrated shutter speeds, fixed relative-aperture values, and a calibration device built into the camera for the printing in of an optical step wedge and fiducial marks give the camera photometric capability. Image-movement compensation and the use of fine-grained film produce a resolution of between 10 and 30 meters.

The outer surface of the porthole over which the camera is mounted is protected by a cover which is opened only when photography is in process. Operation of the MKF-6M is from a control panel which receives a signal at the end of the film or if the film breaks. Additionally, a number of parameters are transmitted over the radio link to Earth which provide data on exposure times and the intervals between exposures as well as an indication of the camera's operational status. Although the electronics unit malfunctioned during the extended Salyut 6 mission it was replaced by a

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[206] Peto, P G Budapest. Nepszabadsag, Jan 28, 1981, p. 2.

[207] Koval, A Pravda, Moscow, Mar 28, 1981, p 3.

[208] Kuchumov, V Aviatsiya i Kosmonavtika, No 1, January 1982, pp 40-41.

reserve unit delivered to cosmonauts Kovalenok and Ivanchenkov during the second long-duration mission. The breakdown was said to have had minimal effect on the planned program of photographic observation.

The KATE-140 is a large-format topographic camera capable of producing photographs suitable for precision photographic-survey work. The 85° field of view enables a single frame to contain an image 450 by 450 km from the 350 km Salyut 6 orbit. The camera can be programmed for both single and strip photographs with a given interval and a punching machine is used to separate the strips. The camera has two film cassettes, each with a 600-frame film supply. The camera can be controlled from several panels at various locations within the station as well as by the programmable device. It can also be operated on radio command from Earth without the crew's participation. The times at which the shutter is activated are recorded and telemetered to Earth.

Another instrument, developed by specialists in Bulgaria for use on the Soyuz 33 mission to Salyut 6 was the Spektr-15 satellite spectrometer which had been delivered to the orbital station by Progress 5 earlier in 1979. Rukavishnikov, the commander of Soyuz 33, said before launch, "Ivanov and I are looking forward to performing responsible and complex work in orbit. The Bulgarian side has planned an interesting series of experiments. They have all been worked out and prepared by Bulgarian scientists. The Spektr-15K experiment in spectroscopic surveying of the Earth from space promises to be particularly interesting. Such a study has so far not been undertaken anywhere at any time."[209] Following the abortive attempt at docking and the subsequent premature return to Earth, the Spektr-15 was operated by Lyakhov and Ryumin. On June 27, 1979, they studied optical phenomena in the atmosphere and also atmospheric pollution near large industrial areas using the Spektr-15 and Duga instruments.[210] The Spektr-15 recorded light reflected from the Earth in 15 spectral bands making it possible to distinguish ripe from unripe crops, or to define boundaries of ocean currents and accumulations of plankton. The Duga (Rainbow) was designed for study of phenomena in the upper layers of the atmosphere.[211]

PHOTO RECONNAISSANCE RECOVERABLE FLIGHTS

The subset of recoverable satellites within the Kosmos program is considered in greater detail in chapter 5. However, the Soviets now identify certain flights within this subset as performing missions "to continue the study of the Earth in the interests of different sectors of the national economy of the U.S.S.R., and international cooperation." For some, but not all, of these flights, the TASS announcement states that "the incoming information is being turned over to the Priroda (Nature) State Scientific Research and Production Center for processing and use." The description of the Priroda Center follows.

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[209] Tass, Moscow, Apr 11, 1979 1610 G.m t

[210] Moscow Home Service, June 27, 1979 0230 G m t.

[211] Moscow Home Service, July 3, 1979 800 G m t

First indications of such a program within the recoverable Kosmos program came in 1968 when two satellites, Kosmos 210 and 214, flew at a new inclination of 81.3°. Both launches occurred in April and were not repeated that year. It was suggested that their objective was to secure photographic data relating to the breakup of Arctic ice on the sea routes along Russia's northern coastline.[212]

Further flights with this near-polar inclination followed in succeeding years, usually in pairs during April but with each member of the pair having different resolution characteristics. As time passed, other flights appeared with this inclination at different times of the year, often associated with scientific secondary missions. Table 40 lists possible Earth resources missions within this subset since September 1975.

TABLE 40.—POSSIBLE EARTH RESOURCES MISSIONS WITHIN THE PHOTO RECONNAISSANCE PROGRAM

Launch date	Kosmos number	Launch vehicle	Apogee	Perigee	Inclination	Period	Decay date	Days life	Pickaback
1975									
Sept 25	771	A-2	247	219	81.3	88.9	Oct. 8, 1975	13	No
1976									
May 21	820	A-2	236	214	81.4	88.8	June 2, 1976	12	No
1977									
May 26	912	A-2	257	219	81.4	89	June 8, 1977	13	Yes
Sept 2	948	A-2	265	217	81.4	89	Sept. 15, 1977	13	Yes
1978:									
Oct 3	1033	A-2	268	223	81.4	89.1	Oct. 16, 1978	14	Yes
1979									
May 17	1099	A-2	274	224	81.4	89.2	May 30, 1979	13	Yes
May 25	1102	A-2	288	222	81.4	89.2	June 7, 1979	13	Yes
June 8	1105	A-2	281	223	81.4	89.2	June 21, 1979	13	Yes
June 12	1106	A-2	264	222	81.4	89.1	June 25, 1979	13	Yes
June 22	1108	A-2	272	224	81.4	89.1	July 5, 1979	13	Yes
July 13	1115	A-2	263	222	81.4	89.1	July 26, 1979	13	Yes
July 27	1118	A-2	273	222	81.4	89.1	Aug. 9, 1979	13	No
Aug 17	1122	A-2	260	218	81.4	89.1	Aug. 20, 1979	13	No
Aug 21	1123	A-2	266	221	81.4	89.1	Sept. 3, 1979	13	Yes
Sept. 5	1127	A-2	300	226	81.4	89.4			
			271	259	81.4	89.8	Sept. 18, 1979	13	No
1980									
May 23	1182	F-2	278	221	82.3	89.2	June 5, 1980	13	No
June 6	1185	F-2	308	226	82.3	89.5			
			275	261	82.3	89.9	June 20, 1980	14	No
July 15	1201	F-2	274	220	82.3	89.1	July 28, 1980	13	Yes
July 31	1203	F-2	303	227	82.3	89.5			
			274	261	82.3	89.9	Aug. 14, 1980	14	No
Aug 22	1207	F-2	282	218	82.3	89.2	Sept 4, 1980	13	Yes
Sept 3	1209	F-2	306	222	82.3	89.4			
			274	261	82.3	89.9	Sept 17, 1980	14	No
Sept 26	1212	F-2	275	216	82.3	89.1	Oct. 9, 1980	14	Yes

Notes:

1 The table lists by date of launch Kosmos flights by number which had possible Earth resources missions, in most instances as announced by the U.S.S.R. and in a few instances implied.

2 Most of these flight are indistinguishable from military recoverable photographic missions, and are launched on the A-2 vehicle. By 1980, the recoverable missions had switched from the typical 81.3° or 81.4° inclination to 82.3° inclination. It is a temptation to label these as F-2 flights, and this has been done tentatively, but with some hesitation.

3 Apogee and perigee are given in kilometers, inclination in degrees, and period in minutes.

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[212] Perry, G. E., Flight International, London, vol. 94, Dec. 26, 1968, pp. 1077-1079.

4 An indication is given as to whether the mission also carried a separable pickaback. This identification is not always easy, as some maneuvering engine units or other pieces of debris may give a radar signature which is not so different from a pickaback. On earlier missions, the Kettering Group could distinguish those payloads carrying a pickaback by listening for "word 7" which on pickaback flights started out short and lengthened during the flight.

5 In the cases of a few listed flights, there was a distinct upward adjustment of the orbit during the flight, and the new orbit is also listed.

Source: App. III of pt. 1, based on Tass reports, plus tabulations of the Royal Aircraft Establishment.

Kosmos 771 was the first satellite to have a TK recovery beacon since the phasing out of the Morse code telemetry satellites nearly 2 years earlier. TK's are received from some satellites with announced Earth resources missions but others send TF on recovery. Attempts to correlate the two types of recovery beacon with the presence or absence of the Priroda designation in the Tass announcement were not successful. However, the Kettering Group eventually showed that TK was characteristic of missions with a photographic arc at 220 kilometers whereas TFs were received at the close of missions with photographic arcs at 275 kilometers.[213]

The Tass announcement for Kosmos 912 was the first to employ the phrases quoted in the opening paragraph of this section. The reference to the involvement of the Priroda Center is omitted in some instances and this may not be without significance.

In 1979, there was a large increase in the number of announced Earth resources flights. This was sustained during 1980, coinciding with a change of inclination to 82.3° which could be due to the introduction of a new launch vehicle, provisionally designated F-2.

No photographs from such missions have been published and this may point to a dual military-economic role. However, their mode of operation was confirmed in an article by Kiyenko. He writes,

> The Kosmos series satellites, which are used to study the natural resources of the Earth, are equipped with various gear and are designed for returning photographic materials to Earth by means of descent vehicles. The satellites of this type make it possible, for example, to take multispectral photographs. The function of such satellites consists in the systematic support of the national economy with space photographic materials of a high spatial resolution for the solution of production and scientific problems of a long term nature in the interests of studying the Earth's surface, its interior, the vegetative cover, seas and oceans, shelf waters, etc.[214]

In the figure illustrating the article, such satellites are depicted as having a cylindrical instrument and engine section supporting, in front, a capsule formed from two cones joined base to base with the one attached to the cylinder being truncated at approximately half its height. While this is obviously schematic and should be accepted with circumspection, it must be pointed out that the representations of Salyut and Meteor in the same illustration are good representations of the actual spacecraft.

OCEAN RESOURCES NON-RECOVERABLE FLIGHTS

Writing on the main directions of Earth research from space in light of the decisions of the 26th Communist Party of the Soviet

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[213] Awaiting publication.

[214] Kiyenko, Yu. P. Issledovaniye Zemli iz Kosmosa. No. 2, 1980. pp. 5-10.

Union Congress for the 11th 5-year plan, the vice president of the U.S.S.R. Academy of Sciences specified investigations that would make it "possible to develop recommendations for determining zones of increased biological productivity, including fish, as well as scientific principles for the regional utilization of the ocean's biological and energy resources."[215] The importance of the ocean's resources is illustrated by the facts that 15 percent of the animal protein consumed as human food is provided by sea fisheries and about 20-25 percent of the world production of petroleum and gas already comes from the zone of the Continental Shelf.[216] Konovalov also makes the point that fish frequently seek shallow waters and that the introduction of the 200-mile economic zone by coastal countries has removed the most productive part of the waters of the world oceans from the free zone of fishing. The Soviet fishing fleet has been forced to move into the open ocean which, for the most part, constitute sea "deserts" and must now rely on cosmonautics to help to detect "oases" of fish life in those areas.[217] The Mediterranean Sea, which is poor in life is very transparent and has a blue-violet color whereas the Atlantic, which is biologically productive in its shallow-water areas, is turbid and had a greenish hue due to the presence of tiny algae and photoplankton, which contain chlorophyll. The interpretation of space photographs of coastal waters revealing subsurface structure makes it possible to detect regions promising for petroleum and gas.

A leading expert in Soviet oceanographic research is the director of the Marine Hydrophysical Institute, Ukrainian Academy of Sciences, at Katsiveli in the Crimea, Boris A. Nelepo. For a detailed exposition on space oceanography the reader is directed to his article on its problems and prospects, published in 1979.[218] Some of these problems are listed in the abstract to another of Nelepo's articles and include investigation of the patterns of spatial distribution of minerals on the floor of the world ocean, and especially in shelf zones; prediction of biological productivity of various specific regions and the ocean as a whole for efficient use of its food resources; detection of areas of interest for the commercial extraction of mineral resources; monitoring of ocean contamination and development of methods of contending with contaminants; prediction of earthquakes and tsunamis. He comments that "such an enormous program can be implemented only by the use of artificial Earth satellites alone or in a ship-buoy-satellite system." [219]

The meteorological use of oceanographic satellites has been mentioned above. The oceanographic aspects will be discussed below.

INTERKOSMOS 20

Launched by a C-1 vehicle from Plesetsk, on November 1, 1979, into an orbit with period 94.4 min., 74° inclination, and heights between 523 and 467 km, Interkosmos 20 was the first Interkosmos

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[215] Sidorenko, A V Issledovaniye Zemli iz Kosmosa, No. 2, March-April 1981, pp. 5-8.

[216] Konovalov, B. Izevestiya, July 29, 1981, p. 3.

[217] Idem

[218] Nelepo, B A. Leningrad, Problemy Issledovaniya i Osovoyeniya Microvogo Okeana, 1979, pp 111-133 Translated in JPRS L/9526. U.S.S.R report. Space (FOUO 1/81), Feb. 5, 1981, with 23 references in bibliography (16 Russian).

[219] Nelepo, B.A. Issledovaniye Zemli iz Kosmosa. No 1, 1980, pp. 55-63.

mission for oceanographic research. The principal objective of the mission was to test an experimental system for the collection of information from buoys and its transmission via a central ground reception station to users. The equipment was developed by specialists from Hungary, East Germany, Czechoslovakia and the U.S.S.R.

KOSMOS 1025

Launched by an F-2 vehicle from Plesetsk, on June 28, 1978, into an orbit with period 97.8 min., 82.5° inclination, and heights between 680 and 649 km, Kosmos 1025 was the first satellite in the Kosmos series to have such orbital parameters. It may be considered as a development flight for the two oceanographic satellites which followed, a systems failure, or unrelated to them and performing an electronic intelligence [ELINT] gathering mission of some kind.

KOSMOS 1076

Launched on February 12, 1979, into an orbit similar to that of Kosmos 1025, Kosmos 1076 was announced as performing an oceanographic mission. Its research equipment was comprised of four instruments:

1. A visible-band spectrometer, used to determine the characteristics of sea water according to the spectrum of the emitted radiation. It had six channels in the 455-675 nanommeter band, with a bandwidth of 3-8 nm in each channel and local resolution of about 20 km;
2. A multichannel infrared radiometer, used to determine the ocean's surface temperature and the atmosphere's parameters and transfer function. It had 10 channels in the 9.04-18.4 micron band, with an individual channel pass band of 135-325 nm and spatial resolution of the order of 25 km;
3. A multichannel superhigh-frequency radiometer, used to determine the ocean's surface temperature, wave action intensity and wind force, ice cover characteristics, atmospheric humidity, water reserves in clouds and intensity of precipitation. It had four working wavelengths: 8, 13.5, 32, and 85 mm. The 32 mm channel consisted of two semicomplexes. The antenna of one of them was oriented at an angle of 56° from the nadir, along the direction of the satellite's flight and operates in two orthogonal polarizations. The field of view of the superhigh-frequency radiometer semicomplex on the 32 mm band, as is the case for all other wavelengths, is oriented on the nadir. Spatial resolution on the Earth's surface ranges from 18 km in the 8 mm band to 85 km on the 85 mm band; and
4. Equipment for collecting data from automatic buoy stations and transmitting them to reception centers.[220]

The visible band equipment clearly detected the cloudy and cloudless sections along the satellite's ground-track. When determining the color of the ocean, however, significant difficulties related to the strong back-scattering of sunlight from the Earth's atmosphere were encountered, less than 20 percent of the radiation

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[220] Nelepo, B.A., et al., Issledovaniye Zemli iz Kosmosa, No. 3, May-June 1982, pp. 5-12.

received coming from the ocean's surface. Only in rare, favorable cases was it possible to evaluate variations in chlorophyll concentration in the sea water by this technique.[221]

KOSMOS 1151

This satellite, launched from Plesetsk on January 23, 1980, was also announced as performing oceanographic research. Its orbital parameters were similar to those of Kosmos 1025 and 1076. Observations by Sven Grahn, of the Kettering Group, showed that it transmitted weak c/w signals on frequencies of 153 and 204 MHz, the third and fourth harmonics of 51 MHz presumably for Doppler tracking. Instrumentation was as for Kosmos 1076.

Ocean surface temperature maps were compiled for the North Atlantic on the basis of the results of the superhigh-frequency radiometric measurements made by Kosmos 1151. In the absence of heavy wave action and severe cloudiness, the mean-square error in the temperature determination is estimated to be of the order of 2 K. Results of spectral and polarization measurements made over the Arctic Ocean confirmed the possibility of obtaining information about the state of the ice cover. Measurements made on January 25, 1980, reproduced graphically, clearly delineate four discrete areas: the Greenland Sea, where brightness temperature variations are related to changes in the ice's solidity and thickness; the northern part of the Greenland Sea, where the ice cover's solidity is approximately constant but its thickness increases; zones of open water to the northwest of Spitzbergen; and the solid ice zone of the Arctic Ocean where changes in brightness temperature at 85 mm wave-length indicate the ice cover's temperature pattern.[222]

THE PRIRODA CENTER

The word "Priroda" (Nature) has appeared frequently in recent years in a number of different connections. The writer's first recollection was a reference to the 25th Meteor as "Meteor-Priroda." Later, certain satellites in the Kosmos series were announced as reporting to the Priroda Center. These were those with recoverable payloads in near-polar orbits which had been identified as performing ice reconnaissance during the period of breakup of ice along the northern sea route across the Soviet Union.[223] As time went by, these satellites flew at other times of the year and some, but by no means all, were given the Priroda designation in the launch announcement.

The Salyut 6 cosmonauts were directed primarily in their visual observation program by specialists of the State Nature Center who were located, for the duration of the flights, at the Kaliningrad Flight Control Center.[224]

Priroda is also the name given to a special mobile laboratory designed for ground truth measurements in conjunction with remote sensing by satellites and aircraft. The laboratory is built onto a

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[221] Idem.

[222] Ibid., figs. 3 and 4.

[223] Soviet Space Programs, 1971-75. Washington, U.S. Government Printing Office, 1976, p. 447.

[224] Spaceflight, London, vol. 21, No. 2, 1979, p. 74.

large truck equipped with a cherry-picker arm on whose platforms is mounted the sensor instrumentation. The program was coordinated by the Nature Resources Space Research Institute of the Academy of Sciences of Azerbaidzhan.[225]

In the Soviet Union there are more than 1,200 scientific research, planning and production organizations, higher and intermediate special educational institutions which are interested in the use of the data on Earth sensing from space. Steps were taken to evolve a statewide system of economic and efficient design with optimized information capability, precision, timeliness and reliability to satisfy as completely as possible the needs of the national economy.[226] There was a need to develop two closely interrelated, yet at the same time, rather independent approaches obtaining and using the remote sensing data, of a quick-look and a long-term nature. Consequently, two specialized centers were established: the State Scientific Research Center for the Study of Natural Resources [GOSNITs IPR] of the State Committee of Hydrometeorology and Environmental Protection and the State Scientific-Research and Production Center "Priroda" of the Chief Administration of Geodesy and Cartography at the Council of Ministers of the U.S.S.R. These were assigned the tasks of obtaining, intersectoral processing, storage and dissemination of space information for the quick-look and long-term purposes respectively.[227]

An automated information retrieval complex is under development at the Priroda Center. The first section of the complex has been operational for some time and performs the following functions:

1. Stores blocks of data about quantitative and qualitative parameters of pictures taken from space;
2. Informs users on a regular basis or upon request about availability and nature of information about any part of the Soviet Union contained on film taken from space;
3. Synthesizes information; and
4. Checks accuracy and completeness of data furnished to clients.

This first section was estimated to have saved 280,000 rubles and relieved 80 persons of manual processing work in its first year of operation.[228]

It will be seen that, in some respects the Priroda Center fills a role analogous to that of the U.S. EROS Data Center in Sioux Falls, SD, where Landsat data is collected, stored, and sold. Soviet technical papers on remote sensing include Landsat data from time to time and, for a while, it appeared that the Soviet Union was pursuing plans to build a ground station for direct reception of Landsat data. State Department approval would have been required before the high-technology transfer of U.S. equipment could take place and the Soviets would have had to agree to make available any data that the United States might require under the

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[225] Spaceflight, London, vol 22, No. 4, 1980, p. 166.

[226] Kiyenko, Yu P. Issledovaniye Zemli iz Kosmosa, No. 2, 1980, pp. 5–10.

[227] Idem

[228] Krasnov, V.I., Ye. A. Reshetov, and I.N. Fadeyev. Geodeziya i Kartografiya, No. 11, 1980, pp 51–55

terms of a Landsat agreement.[229] An account of Soviet participation in the Landsat system is to be found in part 1 of this study.[230]

GEODESY AND MAPPING

Prior to 1957, geodesy, the study of the shape and size of the Earth and the determination of geocentric coordinates of points on its surface, was dependent only on ground measurements over small areas limited by the borders of states and continents. It was mainly due to this that there were discrepancies between geodetic networks determined in different parts of the globe and relatively large degrees of uncertainty in the connection between different continents. The availability of artificial satellites as objects for geodetic measurements greatly increased the scope of geodesy and satellite geodesy is now an important applied science. Satellite geodesy is being successfully applied to the studies of geodynamics, practical and theoretical geodesy, and geophysics. To solve most of the problems, in addition to improvements in equipment and observational techniques, effective scientific cooperation, unification of processing methods, continuing information exchange, and rational distribution of labor between participants are necessary. International cooperation started soon after the first techniques of satellite geodesy were developed, first on the basis of bilateral agreements and regional programs, and afterwards within the framework of the International Committee on Space Research [COSPAR]. The Soviet Union works through the Interkosmos program and certain developing countries, including Mozambique, Angola, Seychelles, Mali, India, and Egypt. In 1981, the Interkosmos network included 25 photographic and 12 laser-ranging stations (10–7 in Europe, 6–1 in Asia, 6–1 in Africa, and 3–3 in South America). The geometric method of space triangulation—the simultaneous observation of a satellite from two or more stations—provides a simple technique for developing basic geodetic networks for mapping unsurveyed territories and for developing natural resources comparatively quickly and inexpensively.[231]

The Soviet Union's National Paper to the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space devotes a complete section to the utilization of satellite tracking data for geodetic and geophysical problems in the interests of developing countries. It reports that, from 1970 to 1980, as part of international programs of satellite tracking, more than 98,000 positions of satellites have been photographed and 66,000 laser-ranging distance measurements have been made. As a result of this the directions and coordinates of the European and North African parts of the network have been reduced to a single reference system to within 10–20 meters.[232]

Besides triangulation methods it has become possible to determine a position on the Earth's surface using the Doppler navigational satellite system described earlier in this chapter. By comput-

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[229] Aviation Week & Space Technology, vol. 106, No. 8, Feb. 21, 1977, p. 19.

[230] Soviet Space Programs: 1976–80. Washington, U.S. Government Printing Office, December 1982, pp. 235–240.

[231] National Paper: U.S.S.R., Sept. 2, 1981, pp. 55–62.

[232] Idem.

er-processing the results of some 20 or more determinations made in a 2 or 3 day period it is possible to establish a fixed position to within 1 or 2 meters. It might be noted that Western experts at a recent conference were talking in terms of decimeter accuracy by such techniques before long.[233] Such precision is necessary for locating caps of oil wells beneath the surface of the sea and defining interstate borders at sea. Most satellite observatories operating within the Interkosmos program are equipped with the Doppler installations and carry out regular observations as part of the international programs.

As reported in the previous section of this chapter, the Priroda Center is part of the Chief Administration of Geodesy and Cartography of the Council of Minister of the U.S.S.R. An article by I.A. Kutuzov, of the administration, and Yu. P. Kiyenko, of the Priroda Center, describes space cartography in the U.S.S.R. The following quotations are taken from the abstract of their article.

> Space surveys of the Earth have significant advantages over other methods for obtaining information for map compilation. The most important of these advantages is the areal coverage of space images. From satellites of the "Meteor" type the width of the surveyed zone is thousands of kilometers, whereas from stations of the "Salyut" type the photographed zone has a width of 450 km. In a short time an enormous area can be photographed; for example, in 5 minutes a survey of a million square kilometers can be made from an orbital station. Due to the high position of the center of projection, the central projection in which the image is constructed becomes close to orthogonal and this makes it possible to simplify a number of processes in photogrammetric work in map production. . . . The inaccessibility of areas has lost its importance and remote, unpopulated areas can now be surveyed safely, quickly and inexpensively without the organization of time-consuming, arduous expeditions. in the U.S.S.R., such areas include the Pamir and Tien Shan, Chukotka and Novaya Zemlya, the Kurile Islands and deserts of Central Asia.[234]

GEODETIC KOSMOS FLIGHTS WITH THE C-1

With the exception of a few flights, such as Interkosmos 10, and general references to "Meteor" and "Salyut" types the Russians have not identified geodetic or mapping flights specifically. This study, therefore, must limit itself to inferential candidate flights for these purposes and presumably these are buried within the Kosmos series. Such candidates would be those with near-circular orbits with sufficiently high periods to ensure mutual visibility between stations separated by large distances for a reasonable duration so that multiple observations can be made. Table 41 lists C-1 launched Kosmos payloads with such orbits. With two exceptions these will be seen to fly somewhat higher than the contemporary navigation satellites which have periods close to 105 minutes in

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[233] Strange, W E., and L D Hothem. Phil Trans R Soc. Lond. A, vol. 294, 1980, pp. 335-340.
[234] Kutuzov, I A., and Yu P. Kiyenko. Issledovaniye Zemli iz Kosmosa, No. 1, 1980, pp. 79-87.

near-circular orbits at approximately 1,000 km above the Earth's surface. The satellites with 74° inclination fall into two categories; those with periods close to 113 minutes at approximately 1,400 km, and those with periods close to 109 minutes at approximately 1,200 km. Flights at 83° show no such dichotomy being all at approximately 1,200 km. The two exceptions, Kosmos 842 and 911 had parameters indistinguishable from those of navigation satellites but Kettering Group analysis based on orbital-plane spacing, lack of signals on 150 MHz and no obvious gaps in the series of identity numbers at the relevant times, make the net balance of evidence that they are more likely geodetic rather than navigation flights.

TABLE 41.—POSSIBLE GEODETIC MISSIONS FOR KOSMOS C-1 PAYLOADS

Launch date	Kosmos number	Apogee	Perigee	Inclination	Period	Remarks
1968:						
Feb 20	203	1,200	1,200	74.1	109.4	
Nov. 30	256	1,234	1,168	74.1	109.3	
1969:						
Mar. 17	272	1,220	1,195	74	109.4	
Nov. 24	312	1,187	1,145	74	108.6	
1971						
Apr 28	409	1,222	1,185	74	109.4	
Nov. 20	457	1,229	1,192	74	109.5	
1972:						
Mar. 25	480	1,212	1,183	83	109.2	
Dec. 21	539	1,353	1,302	74	113	
1973						
Sept. 8	585	1,416	1,385	74	113.6	
1974						
Apr. 29	650	1,413	1,380	74	113.5	
Aug. 29	675	1,429	1,370	74	113.7	
1975						
Feb 12	708	1,423	1,387	69.2	113.6	
Sept 24	770	1,222	1,138	83	109.2	
1976						
July 21	842	1,023	987	83	105	Possible navigation satellite.
1977						
May 25	911	1,018	984	82.9	104.9	Do.
Nov 24	963	1,220	1,190	82.9	109.3	
1978						
Oct 26	1045	1,724	1,688	82.6	120.4	Possible use of the F-2, mission perhaps obscure.
Dec. 26	1067	1,226	1,184	83	109.2	

Notes

1 The table arranges probable geodetic flights in the order of date of launch, giving the Kosmos number

2 Apogee and perigee are in kilometers, inclination in degrees, and period in minutes

3 Most of the flights, although in the pattern of contemporary navigation satellites, have tended to fly slightly higher, and hence can be quickly recognized as different. However, Kosmos 842 and 911 have elements indistinguishable from those of navigation satellites. Analysis by the Kettering Group, both as to orbital plane and to lack of designation within the navigation systems broadcasts, make the net balance of evidence that they are more likely geodetic flights than they are navigation flights

4 The Kosmos 1045 mission is distinctly different from the others in the table. The rest are all launched on the C-1, and may weigh about 600 kilograms. Kosmos 1045 may have been launched on the F-2, and could weigh as much as 3,400 kilograms. The principal reason for including this flight in the table is that the orbital elements put it closer to the geodetic family than to any other recognized grouping but this leaves obscure its actual function at least until the possible appearance of additional flights in the same category

5 The U.S.S.R. has not identified any specific flight as geodetic in purpose, but they have published a fair number of articles about the several techniques for using satellites for geodetic purposes, and have published the results of their geodetic studies in part. The overall nature of the program could be considered of the specific end uses and informational gathering activities are regarded as militarily sensitive

Sources: App. III of pt. 1, with all statistical data from Tass

POSSIBLE MAPPING MISSIONS WITHIN THE PHOTO RECONNAISSANCE FLIGHTS

A special subset of recoverable Kosmos satellites, transmitting the two-tone tracking beacon on 19.994 MHz, instead of the usual 19.989 MHz, exists within the third generation missions. These do not maneuver and have a TL recovery beacon instead of the usual TFs or TKs The nonmaneuvering feature led to their initially being classified as successors to the first-generation low resolution flights. As time passed and such flights appeared, in general, only two or three times a year at times close to the equinoxes and at different annual inclinations to the Equator, some other role was sought and it is now thought that they perform a geodetic survey and mapping function. With the Sun overhead close to the Equator, there will be average illumination in both Northern and Southern Hemispheres.[235] Table 42 lists Kosmos missions belonging to this subset.

TABLE 42 POSSIBLE MAPPING MISSIONS WITH THE PHOTO RECONNAISSANCE PROGRAM

Launch date	Kosmos number	Launch vehicle	Apogee	Perigee	Inclination	Period	Decay	Days life
1971								
Dec. 27	470	A 2	272	185	65.4	.1	Jan. 6, 1972	10
1972								
July 13	502	A-2	284	206	65.4	89 2	July 25, 1972	12
Dec 27	541	A-2	371	242	81 4	90 3	Jan. 8, 1973	12
1973								
June 27	576	A-2	358	212	72 9	89 9	July 9, 1973	12
Dec 17	616	A 2	355	214	72.9	89.9	Dec. 28, 1973	11
1974								
June 29	664	A 2	364	212	72.9	90	July 11, 1974	12
Nov 4	693	A-2	271	215	81 3	89.1	Nov. 16, 1974	12
1975								
Mar 21	720	A 2	283	223	62 8	89 4	Apr 1, 1975	12
Sept 12	759	A 2	281	234	62.8	89 6	Sept. 23, 1975	12
1976								
Mar 31	811	A 2	361	212	72.9	89 9	Apr. 12, 1976	12
Sept 21	855	A 2	356	212	72.9	89 9	Oct. 3, 1976	12
1977								
June 10	916	A 2	307	250	62 8	89 9	June 21, 1977	12
1978								
Feb 8	988	A 2	363	210	72 8	89.9	Feb 20, 1978	12
Nov 1	1045	A 2	353	212	72 9	89.9	Nov 13, 1978	12
Dec 28	1069	A 2	290	244	62 8	89.8	Jan. 10, 1979	13
1979								
Aug 3	1119	A 2	267	222	81 3	89 1	Aug 15, 1979	12
Oct 5	1139	A 2	357	212	72.9	89 9	Oct 18, 1979	13
1980								
May 15	1180	A-2	296	240	62 8	89 8	May 26, 1980	12
Sept 23	1211	F-2	261	215	82 4	89 1	Oct 4, 1980	11

Notes

1 The table lists in order of date of launch by Kosmos number all flights related to a possible class of mapping, geodesy, and resources study missions. Apogee and perigee are in kilometers, inclination in degrees, and period in minutes

2 Most were launched on the A-2 at various inclinations. The last one may have been launched on a new F-2 vehicle as the inclination is 82 4 close to other flights probably using the new vehicle

3 All of these are recoverable missions, and all probably carry a separable pickaback, though such a pickaback was not tracked in every instance by Western sensors

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[235] Perry, G.E., in "Outer Space—A New Dimension of the Arms Race," ed. Jasani, B., S I P R I London, Taylor and Francis, 1982, p. 141.

4 Identification of members of this family has been performed by the Kettering Group The signal format is "two-tone, no telemetry," but instead of being 19 989 MHz like others of that group, broadcasts on 19 994 MHz The recovery beacon is unique a Morse code TL

5 Setting on the exact mission is a more difficult task, and is open to some question In most respects, the missions are generally indistinguishable from other military photographic recoverable missions. The U.S.S.R. says it has mapping missions which combine a simultaneous view of a star field outward, and a view of the Earth downward. These flights also seem to have an approximate 6 months seasonal pattern. The absence of maneuver seems to put them into the low resolution category.

Source App. III of pt I, Tass announcements, the Royal Aircraft Establishment and the Kettering Group.

The Soviet Union has the need to be able to correlate the international mapping grids for precise targeting of its missiles with MIRVed warheads and it has been suggested that this is achieved by taking simultaneous photographs in opposite directions of ground targets and star backgrounds using laser technology.[236]

KOSMOS 1045

This satellite is also included in table 39 on the grounds that, although distinctly different from all others in the table, having been launched by the F-2 instead of the C-1, its orbital parameters put it closer to the geodetic subset than to any other recognized grouping. Even so, it is higher than any of those having a period close to 120 minutes at approximately 1,700 km. Its mass has been estimated as a possible 3,400 kilograms which, with the two amateur radio satellites launched with it, each of mass 40 kg, is well within the capability of the F-2 at that height and the 82.5° inclination.

SPACE MANUFACTURING

In 1978, a popular book with the title "Industry in Space" was published in Moscow. Among the chapter titles are "Foundry above the Earth," "Other materials which did not exist before," and "Biology and pharmacology in space." The book highlighted the problems of using the conditions of high vacuum and microgravity and considered various uses such as obtaining materials with unusual physical-mechanical properties, large single crystals, and superpure materials, including medicines.[237]

In a Pravda article published in 1980, cosmonaut Valeriy Kubasov defined space technology as encompassing a set of technological processes conducted in orbit utilizing the physical factors of outer space—primarily weightlessness[238] and vacuum. He named the two most important areas of space technology as the repair and assembly of equipment in near-Earth space and the production of materials and articles with new or greatly improved properties.[239]

SOYUZ 6

Launched on October 11, 1969, as the first in the "troika" mission, this flight was commanded by Lt. Col. Georgiy Shonin with Kubasov as his flight engineer. It carried, in the orbital module, a specialized research unit, "Vulkan," developed at the Ukrainian

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[236] Aviation Week & Space Technology, vol. 113, No. 12, Sept. 22, 1980, pp. 14-15.

[237] Yevich, A F Industriya v kosmose, Moskovskiy rabochiy, 1978.

[238] The traditional terms "weightlessness" or "zero-g" are not strictly accurate. A body experiencing an acceleration is acted upon by an external force. In an orbiting spacecraft, such forces arise as results of drag, thruster action, and crew movement. Even a rotation demands a centripetal acceleration for all points of the body distant from the center of rotation. Consequently, the term "microgravity" is currently used to encompass the variety of small accelerations experienced in orbit.

[239] Kubasov, V. Pravda, Apr. 26, 1980, p. 3.

S.S.R. Academy of Sciences' Electric Welding Institute, to investigate alternative methods for welding in conditions of high vacuum and microgravity. The Vulkan unit was remotely controlled by electric cable from the command module after the communicating hatch had been sealed and the orbital module depressurized and opened to the high vacuum conditions of space. Three methods were tested:

1. A low pressure compressed arc,
2. An electron beam, and
3. Arc welding with a consumable electrode.

Only the electron beam experiment was reported as completely successful in initial accounts. However, more recently, Kubasov claimed that, on October 16, the final day of the mission, metals were cut and welded by several methods. He comments that at the time it was difficult to evaluate the entire significance of the experiments without some hesitation but that they can now be seen as impetus to the practical development of space technology. They demonstrated the possibility of manipulating molten metal under conditions of microgravity and high vacuum. It had been possible to ensure the directional transfer of molten metal into the welding bath, form a weld seam, and localize the crystallizing metal along the edges of the cut exactly as is done on Earth. He also points out the psychological importance of successfully demonstrating the ability to cope safely with molten metal, sparks, and high voltages on board the spacecraft.[240] The article concludes with discussion of related experiments conducted on board Skylab in 1973, during the joint Apollo-Soyuz mission of 1975, when Kubasov was a member of the two-man Soyuz crew, and in Salyut orbital stations.

THE APOLLO-SOYUZ TEST PROJECT

The ASTP experiments package comprised 28 separate experiments. Five of these were joint U.S.-U.S.S.R. experiments. One of 18 approved on August 16, 1973, was MA-010, the multipurpose electric furnace with A. Boese, of the Marshall Space Flight Center, as principal investigator. Based upon a similar furnace (M-518) flown on Skylab, this furnace was used to heat and cool material samples in space, thereby taking advantage of the lack of thermal convection and sedimentation during the liquid or gaseous phase of the material being processed. Seven experiments were performed. The guiding design requirement for the multipurpose electric furnace system was to produce an apparatus that provided the widest possible flexibility in applying predetermined temperature distributions and temperature/time sequences within the constraints imposed by existing interfaces. Although the Skylab multipurpose furnace met all expectations of performance and reliability, it was apparent that improvement in function could be obtained with some specific modifications for ASTP. The system consisted of three essential parts:

1. The furnace,
2. A programmable electronic temperature controller that provided the desired temperatures, and

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[240] Idem

3. A helium rapid cooldown system.[241]

Joint experiment MA-150 was designed by the Soviet Principal Investigator, I. Ivanov, and used the American MA-010 furnace in the docking module. There were three identical cartridges, each containing three ampules, and all three cartridges were returned to the Soviet Union on Soyuz. One ampule contained aluminum powder that was melted (at 700 °C) in an attempt to produce perfect spheres when the melt cooled. Spheres were produced, but aluminum oxide influenced their formation and they were not perfect; they were about the same as spheres produced in 1-g.

During the first 3 hours after the furnace was switched on, the temperature rose linearly from 0 °C to 1150 °C. This temperature was maintained for 1 hour and was then reduced in an active cooling phase at a rate of 0.6 K/min for nearly 4 hours. For the remainder of the 10-hour duration of the experiment, the temperature fell with passive cooling, following the switch-off of the heating current to 46 °C, at which temperature the cartridges were removed from the furnace.

The ampule that received the full 1150 °C temperature for the hour-long soak contained tungsten spheres and aluminum. In 1-g, the unmelted tungsten spheres would sink to the bottom. In microgravity, they remained in place, and the Soviet scientists measured the rate of formation of tungsten-aluminum alloys during the 1-hour soak.

The middle ampule reached a somewhat lower temperature. It contained germanium "doped" with 2 percent of silicon atoms—a semiconductor used in electronic circuits. The melt solidified directionally, from the cool end toward the hot end of the cartridge. The Soviets considered these germanium silicon crystals to be better than those made in 1-g.[242]

The multipurpose electric furnace and its experiments undoubtedly had some influence on the design and research programs of the Splav (Alloy) and Kristall furnaces which were later flown on Salyut 6.

SALYUT STATIONS

Experiments in space technology and studies of the behavior of materials are now a permanent component part of the flight program of Salyut orbital stations.

The electric furnace Splav-01 had a mass of 23 kg. The problem of heat insulation was solved by designing the furnace to fit into the waste-disposal air lock.

Splav had three heating areas—one that could maintain temperatures of up to 1100 °C, a "cold" area that could maintain 600–700 °C, and a "gradient" area along which there was a linear temperature gradient between the maximum and minimum furnace heating capabilities. The furnace was controlled by a computer which ensured an accuracy of plus or minus 5 K of the required temperature. The material samples were in capsules, and each capsule contained three crystal ampules that fused when subjected to

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[241] Ezell, E.C., and Linda N. Ezell. "The Partnership," NASA SP-4209, Washington, DC, 1978, app. E, pp. 533-535.

[242] "Zero-G Technology," NASA EP-140, Washington, DC, Oct. 1977, pp. 21-22.

heating. This was intended to permit formation of mono-crystals in the "gradient" area, while three-dimensional crystallization would occur in the hot and cold sections of the furnace.[243]

The first experiment, which lasted some 14 hours, was made to study diffusion processes in molten metals in microgravity. A capsule containing ampules of copper and indium, aluminum and magnesium, and indium antimonide was placed in the furnace. After the airlock was depressurized, the furnace was switched on and the computer monitored the process of crystallization.

During the experiment, the complex was put into the "drift regime," with all its orientation engines switched off, to reduce dynamic disturbances on the experiment.[244]

Splav was later used to investigate the possibilities of obtaining immiscibility-gap alloys—alloys of materials having substantially different densities, such as an alloy based on aluminum and tungsten. Such experiments are not possible on Earth since a uniform alloy does not form due to the different densities of aluminum (2,700 kg/cubic meter) and tungsten (19,300 kg/cubic meter). In microgravity, however, they form an alloy which is stronger than steel. Another experiment, said to be of practical interest, was that of impregnating porous molybdenum with gallium to form a superconductor.[245]

On board Progress 2, which docked with Salyut 6 on July 9, 1978, was a new electric furnace, an improved version of the Splav furnace already on board. The new furnace, known as Kristall (Crystal), had a mass of 28 kg and the process of crystallization took place in a different manner.

The substance from which the crystal was to be formed was first placed in a zone where the temperature was reduced; a seeding technique was used which kept one side cold and the other hot. The cold side acted as a seed. The temperature curve was kept constant in space. The sample in the capsule then stretched slowly across the zone, with the same result as in Splav, but temperature control was better, giving crystals that were more regular and homogeneous.

Kristall was said to be highly automated. It incorporated many kinds of electronic devices enabling the cosmonauts to select various work programs without interfering in the processes. Whereas Splav was in the airlock chamber, so that heat could be discharged into open space, Kristall had better heat protection and was placed inside the station's transfer section. There was a certain amount of heat from it but the temperature control system was able to cope.[246]

The first experiment with Kristall was used to produce a pure monocrystal of gallium arsenide from a high temperature solution by a zone-melting technique.[247]

The scientific director of the Kristall experiment, V.T. Khryapov, said the distinguishing feature of the Kristall apparatus was that, in the first place, it could operate inside the orbital station, with-

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[243] Grishin S D , Moscow Home Service. Feb 21, 1978, 0800 G m t
[244] Tass. Moscow. Feb 15, 1978, 1234 G m t
[245] Grishin. S D . op cit
[246] Grishin. S D Moscow Home Service. July 9. 1978 1700 G.m t
[247] Tass. Moscow. July 17, 1978, 1242 G m t

out having direct connection to the space vacuum. Second, the fact that the apparatus enabled technological processes to be conducted by four methods in distinction from apparatuses which were used previously.

The first method was that of obtaining monocrystals from the gaseous phase by sublimation; the second was obtaining films of monocrystals by the chemical gas-transportation method; the third method was obtaining monocrystals by what is called the moving solvent method to obtain a high-temperature solution; and the fourth was the traditional method of volumetric-directed crystallization—the method used earlier. He went on,

> It is necessary to conduct pure experiments when the interference which occurs on Earth in the form of convection, heat distribution is absent; and therefore this research produces materials which, having been obtained in this installation, can be used in instruments. The quantity used in the instruments is very small, measured in milligrammes. But in this installation we can obtain grammes of it.[248]

Temperature distribution along the axis of the Kristall furnace was measured by experiments with the code name "Imitator." The Imitator-1 experiment employed shaped meltable wires with different melting points for control panel settings of 1,100, 900, 800, 600, and 400 °C. In the Imitator-2 experiment, temperature profiles in both steady-state and dynamic modes were measured with 10 nickel-chromium nickel microthermocouples attached to a simulated ampule. The thermoelectric e.m.f.'s were measured with a digital electronic voltmeter. Good correlation was obtained between results from both experiments.[249]

Kovalyonok and Ivanchenkov performed an experiment to produce optical glass using the furnace delivered by Progress 2. The absence of gravity was expected to improve the microstructure of the glass and provide a surface that required no further treatment. Whereas difficulties were caused in manufacture on Earth by the molten glass touching the walls of the furnace, in space it was possible to carry out the melt and solidification in a state of suspension.[250]

Experiments with the furnaces have been a main feature of manned spaceflight operations under the Interkosmos program. During the Soyuz 31 visit to Salyut 6, in August 1978, the Berolina experiment was performed as part of the joint flight program with the G.D.R. At the time, it was said to be likely to have a big influence on semiconductor technology and component manufacture and thus on the development of electronics in the G.D.R. Lead telluride, which serves as a base material in opto-electronics and laser technology, was obtained under conditions of microgravity.[251]

Two experiments were performed using both the Splav and Kristall furnaces. The Berolina S-1 experiment boiled beryllium-thori-

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[248] Khryapov, V T Moscow Home Service, Aug 1, 1978, 0800 G.m t.

[249] Gorbatko, V V, et al Kosmicheskiye Issledovaniya, vol 20, No. 2, March-April 1982, pp 310-312

[250] Tass, Moscow, July 14, 1978 1700 G m t

[251] Herrmaan, R. ADN, Aug. 28, 1978, 1743 G.m t.

um glass. A more uniform and higher quality glass could be obtained in space conditions and it was hoped to use this in optical devices such as telescopes, microscopes, cameras, and so on. The second Splav experiment, Berolina S-2, differed from previous experiments in that semiconductor crystals of bismuth-antimony were produced using a special programmed temperature reduction process.

The Kristall experiments used a different crystallization method, employing a computer-controlled mechanical retraction device which slowly withdrew the ampule from the high-temperature zone of the furnace during the cooling process. In the Berolina K-1 experiment, lead telluride crystals were grown by sublimation. The Berolina K-2 experiment grew bismuth-antimony crystals of the same composition as in the S-2 experiment so that the results of both processes of crystallization could be compared afterwards and the best crystal-growing method ascertained.[252]

Photographs of the Kristall furnace and the ampules used in the Berolina experiments carried out by V. Bykovskiy and S. Jahn on board Salyut 6 were published in Spaceflight.[253] A picture of the Splav-01 appeared in the previous issue.[254]

In the March to May 1979 period, a cycle of 10 experiments in space material science, under the general name "El'ma," was carried out by cosmonauts Lyakhov and Ryumin using Splav and the new Kristall furnace, which had been ferried up in Progress 5.

The El'ma experiments, in cooperation with French scientists, who had supplied the sample materials, were devoted to the study of crystallization of aluminum (with copper added) and tin (with lead added) under conditions of microgravitation. The experiments were also devoted to obtaining new magnetic materials; in this work neodymium-cobalt was used, which can be obtained in principle under Earth conditions, but its structure would be very heterogeneous; manganese-caesium, which cannot be obtained under Earth conditions, was also used.

A subsequent group of El'ma experiments was devoted to studying crystallization from a gaseous state (vanadium oxides and germanium were used). Also studied was the influence of spaceflight factors on the crystallization of semiconductor materials from the liquid state in samples of bismuth, tellurium and bismuth-tellurium and indium-antimony alloys. Finally, crystallization from gallium-arsenic and gallium-indium-antimony solutions was investigated in two El'ma experiments.[255]

The "Khalong" series of experiments devised by specialists of the U.S.S.R., the Socialist Republic of Vietnam, and the German Democratic Republic, used the Kristall and Splav-01 furnaces to grow crystals of semiconducting compounds. The first three investigated direct crystallization from solid solutions of $Bi_2Te_{2.7}SE_{0.3}$, $BiSbTe_3$, and $Bi_{0.5}Sb_{1.5}Te_3$. The fourth and fifth experiments, also conducted in the Kristall furnace, concerned the growing of gallium phosphide crystals from a melt bath by the moving solvent method. In

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[252] Grishin, S. D., Moscow Home Service, Aug. 30, 1978, 1530 G.m.t.

[253] Spaceflight, London, vol. 21, 1979, p. 131.

[254] Spaceflight, London, vol. 21, 1979, p. 56.

[255] Kotel'nikov, V., Izvestiya, June 28, 1982, p. 2.

the latter experiment the gallium phosphide was alloyed with zinc and oxygen. The sixth experiment, using the Splav-01 furnace, grew lead telluride and $Bi_2Te_{2.7}Se_{0.3}$ crystals, with an excess of tellurium, in separate ampules in a single capsule.[256] The selection of these materials was based on their having been studied extensively on Earth and possessing electrophysical properties which are extremely structurally sensitive and growth-condition dependent, their extensive employment in electronics technology, and their suitability for growth in conditions available in the furnaces.

During the Salyut 4 mission it became necessary to resurface the 25 cm-diameter main mirror of the solar telescope. The cosmonauts sprayed a new reflective layer onto it. The process worked well and this was a deciding factor in Soviet plans for future space stations since there would be no point in sending up other telescopes for long duration missions if mirror surfaces could not be recoated.

On Salyut 6, experiments involving the vacuum deposition of coatings were performed using the "Isparitel" (vaporizer) unit. Electrons emitted by an electron gun situated in a vacuum bombard the molten metal located in a refractory crucible. The metal is vaporized and deposited on a plate. The window through which the metal vapors fall on the plate is opened and closed by a blind. The thickness of the deposited metal layer, which is proportional to the time for which the window is open, can be regulated. Developed by the same Institute as the Vulkan unit, Isparitel consisted of the working unit with two electron guns and a manipulator for changing the deposited plates installed in one of the air locks. These were electrically connected to the remote control panel. Two cosmonauts were needed to perform the experiment. One monitored the instrument readings and operated the controls while the other kept a precise time count of the vapor deposition using a stopwatch. Plates were coated on both sides and each one had its own exposure time.

Analysis back on Earth of the coatings of several samples showed that the film did not lose its mirror quality at thicknesses greater than the designed value. Thus it would appear that, in microgravity, it is possible to obtain a stronger mirror coating than under ground conditions.[257]

Following the final series of coating experiments, the cosmonauts removed the Isparitel unit from the airlock and installed the Splav electrical furnace in its place.

FUTURE OUTLOOK

At the end of 1979, the Director of the Space Research Institute [IKI], Sagdeyev, interviewed during a seminar sponsored by the Znaniye (knowledge) Society in Tallin on "The Latest Achievements in Space Research and Problems of Propaganda" said, "I am certain that in the next 5-10 years a vast amount of industrial activity will begin in orbit. Toward that end we must prepare not only technology but men as well." [258]

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[256] Idem

[257] Kalinin, A. Aviatsiya i Kosmonavtika, No. 12, Dec 1980, pp 44-45.

[258] Sagdeyev, R. Sovetskaya Estoniya, Tallin, Dec 7, 1979, p 1

Writing on the occasion of the 25th anniversary of the first satellite launching, Academician Glushko commented that satellite methods enable monitoring of the degree of pollution of the Earth and the effectiveness of means used to protect its biosphere. He went on to add that among radical measures for protecting the Earth from contamination, depletion and overheating is putting major industry and energy facilities beyond its confines in outer space. He wrote,

> In the first instance, industrial production should be organized in space making use of the unique properties such as weightlessness, clean vacuum, low temperature and solar energy, and production of unique materials that would be impossible or unprofitable to organize under terrestrial conditions. This pertains primarily to the manufacture of crystalline, optical and semiconductor materials, and some medicines.
>
> Processes are being worked out under space conditions for soldering, welding, melting, assembly installation, applying coatings; automatic machines are being designed that are capable of constructing standard components of large-scale structures. These are but the first steps on the road to the inevitable industrialization of space.[259]

These two quotations are indicative of Soviet thought as to the manner in which space processing should develop. Already there is evidence from the Salyut 7 missions that some of these measures are in hand. Electrophoretic techniques have been employed for the separation of tissue cells in the Tavriya experiment.

In the distant future one might expect the Soviets to take steps to establish a permanent space station in geosynchronous orbit for the purposes of industrial production under conditions of microgravity and also for the collection of solar energy, its conversion to electrical energy and transmission to Earth by microwaves, but these introduce difficulties several orders of magnitude greater than those solved to date.

At the beginning of this chapter, it was reported that the Russians were initially slow to exploit space although their writers had been quick to recognize the potential applications for a wide variety of purposes. However, from ~~what has~~ been recorded above, it can be seen that the Soviet space program has made great strides during the period under review and now appears to be totally committed to maintaining a steady and purposeful advance toward the exploitation of its results for the benefit of the Soviet system.

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[259] Glushko, V.P. Zemlya i Vselennaya, No. 5, September-October 1982, pp. 4-10

Chapter 4 Annex 1

Channel Frequencies and Utilization in the Soviet Communications Satellite Systems, With Particular Reference to the Television Traffic

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CHANNEL FREQUENCIES

FREQUENCIES IN THE UHF RANGE

MOLNIYA 1

The first Soviet announcements of communications satellite frequency bands came shortly after the Orbita system entered operational service, quoting a television downlink frequency "close to 1 GHz" for the Molniya 1 satellites, with a transponder RF output of 40W, giving global beam coverage via a parabolic antenna. Later reports quoted the downlink as "800-1,000 MHz".

Since the transfer of TV traffic to the higher frequency bands of the Molniya 2 and subsequent Molniya 3 series, the Molniya 1 downlinks have carried other forms of modulation. Observations at Sheffield, England, since 1976 have revealed the presence of signals between 974 and 998 MHz approximately, suggesting a transponder band with on the order of 30 MHz, adequate for FM television, extending perhaps from 970 to 1,000 MHz. This 30 MHz seems a more likely value of bandwidth than the quoted 200 MHz, and leads us to speculate whether the mention of an 800 MHz frequency may have referred in fact to the region of the Molniya 1 uplink channel, a frequency not otherwise announced. Prior to 1972, the capacity of Orbita for other services, for instance newspaper facsimile transmission, in addition to TV, could be explained on the basis of timesharing outside TV program hours.

Received signal levels in this channel are consistent with multiple carrier occupancy at the claimed level of effective isotropic radiated power [EIRP]. Polarization is right-hand circular.

UHF DIRECT BROADCAST SYSTEM: EKRAN

The downlink frequency adopted for the U.S.S.R.'s first direct-broadcast TV satellite system falls within the lowest frequency band allocated to this service at WARC-ST.[260] Twenty-four MHz wide, centered on 714 MHz, the channel accommodates an FM TV signal of broadcast specification, beamed from the Statsionar-T lo-

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[260] World Administrative Radio Conference for Space Telecommunications, Geneva, 1971.

cation of 99° E to the northern and eastern regions of the Soviet Union, with a maximum EIRP of some 56 dBW. Uplink is at 6,200 MHz, from Gus'Khrustal'nyi, east of Moscow. Unconfirmed reports suggest than an additional television program may be provided in the future, by means of a second Ekran satellite, also at 99° E, downlinking in an adjacent channel, possibly centered on 754 MHz.

FREQUENCIES IN THE 6 GHz (UPLINK) AND 4 GHz (DOWNLINK) BANDS

The precise nature of the now obsolete Molniya 2's use of the microwave spectrum remains unclear. Early Soviet announcements spoke of the 3.4–4.2 GHz bands for downlinks, though with the limited capacity of the Orbita 2 system it seems unlikely that more than a small portion of that allocation was used. Certainly the Russians made use from an early stage of a TV channel centered on 3,875 MHz. The corresponding uplink was at 6,200 MHz, the translation frequency of the Molniya transponders being 2,325 MHz, compared with the 2,225 MHz standard for the 3.7–4.2 GHz downlink subband of Western systems. The frequency 3,875 MHz has been retained as the primary television downlink channel, for geostationary as well as inclined orbit satellites in the SHF bands.

At one stage a channel spacing of 90 MHz seems to have been favored, possibly with digital TV or time division multiple access [TDMA] telephony in mind, but the plan now in use throughout the Soviet 6/4 GHz satellites is based on 50 MHz channel spacing, with a usable channel width of perhaps 40 MHz. Observations below the Western band edge of 3.7 GHz are less than satisfactory at the Sheffield station,[261] but it appears that 11 channels may be available, on 50 MHz centers from 3,425 to 3,925 MHz inclusive. Figure 49 shows the uplink and downlink frequencies for each channel. Arbitrary channel numbers have been assigned here for reference only, and differ from the numberings I have used elsewhere.[262]

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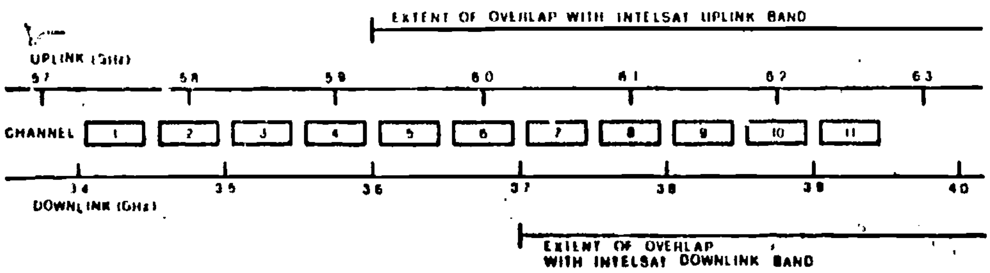
[261] Birkill, S.J. Development of a Satellite Terminal: Experimental System for TV Reception. Wireless World, vol 86, London, September 1980, pp 67–70

[262] Birkill, S.J. 4 GHz Downlink Band: Transponder Frequencies in Existing and Planned Systems. Worldwide Community Antenna Television Journal, vol 7, Oklahoma, September 1980, pp 42–43

FIGURE 49.—Channel Frequencies Used by Soviet Communications Satellites in the 6/4 GHz Bands



Use of the lower frequency channels brings the advantage of avoiding cochannel interference with the established international (Intelsat) and various domestic and regional systems sharing the 6 and 4 GHz bands. Since the limits of current Western occupancy are 5,925–6,425 MHz and 3,700–4,200 MHz for uplinks and downlinks respectively, Soviet channels 1–6 are clear of potential interference on downlink and 1–4 are clear on both uplink and downlink. Confining operations to these channels would permit a Soviet satellite to share a geostationary "slot" with a satellite of another system, without mutual interference.

The allocation of SHF channels to the various satellite systems to date is as follows. In all cases, the channel numbers quoted refer to figure 49. Downlink polarization is right-hand circular.

MOLNIYA 3

Three channels have been observed, corresponding to numbers, 6, 8, and 10 in figure 49. Only two of the three appear to be occupied to any one time. Received signal levels are consistent with an RF power of some 15W to the global beam horn antenna, giving a beam edge EIRP in the region of 29 dBW. The constancy of signal strength with change of up and down path lengths during the active loop of the highly elliptical orbit, suggests a closed-loop control of EIRP, involving the uplink terminal.

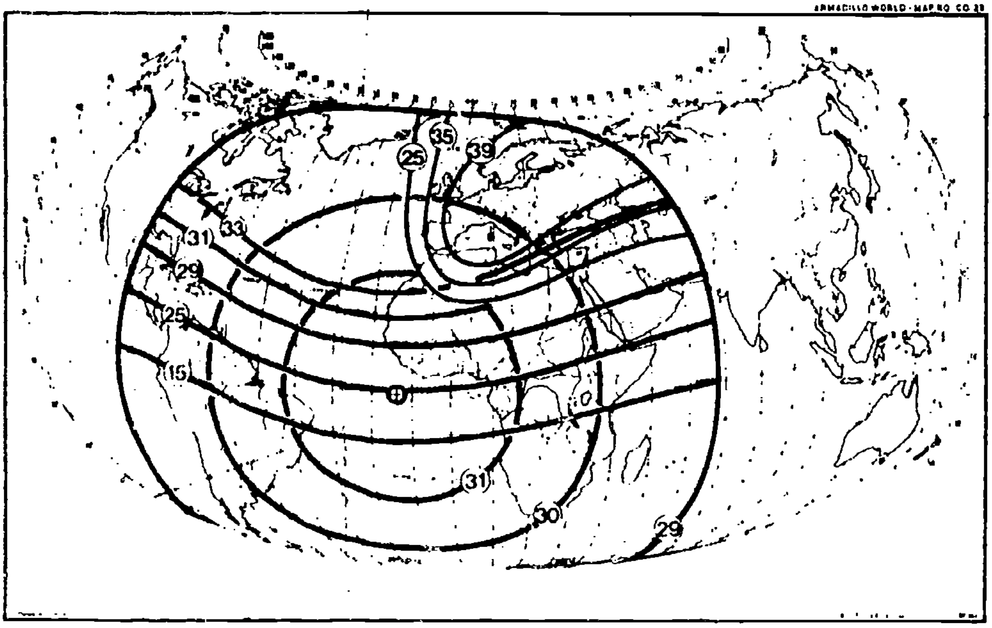
RADUGA

A series of these satellites have been observed, at the Statsionar-2 geostationary location of 35° E., over Africa. Signals are simultaneously present in the even-numbered channels 2, 4, 6, 8, and 10. Signal strength is comparable to that from Molniya 3, though it is possible that some transponders serve a "northern hemisphere" beam while others are global in coverage.

GORIZONT

These spacecraft have been observed both at 14° W. (Statsionar-4) and 53° E. (near to Statsionar-5). Channels carried are in each case 6, 7, 8, 9, 10, and 11, all capable of simultaneous operation. The Gorizont satellities have revealed some flexibility in beam switching, the Atlantic satellite apparently having the capability to switch at least some of its transponders to European spot-beam pattern, in addition to global and northern hemispheric beams. In the spot-beam mode, an EIRP as high as 36 dBW (beam edge) has been estimated, some 7 dB above the global beam power. Again, these values would be achieved with a transponder RF output power in the region of 15° W. Figure 50 shows the estimated EIRP contours for the Atlantic Gorizont. These have been derived from published contours for this type of satellite, combined with signal level measurements made on both sides of the Atlantic. The diagram shows the global beam pattern with the northern hemispheric and European spot beams overlaid.

FIGURE 50.—Composite Map of Statsionar-4 Estimated Beam Patterns. Contour Values are in dBW, Decibels Above 1 Watt EIRP



CHANNEL UTILIZATION

MOLNIYA 1

Current usage of this UHF channel is divided between two independent used sets of Molniya-1 satellites. The four active spacecraft falling into the standard orbital plane groupings A through D carry a series of FM carriers, some of which are frequency-division multiplexed [FDM] between 974 and 985 MHz approximately, for 3 hours each side of apogee on the Asian loop of the orbit, over the Soviet Union. They are also used in their North American loop, over Canada, though with fewer carriers, also grouped around 980 MHz.

The second set of four satellites, those with orbital planes intermediate between the four standard groups, appears to operate only on the Asian loop, and carries an estimated 12.5 kilobits per second digital frequency-shift keyed [FSK] signal of 140 kHz deviation, close to 998 MHz. No detailed analysis of modulation parameters or information content of these signals has been attempted.

The Molniya 1 satellites are duel-fed at changeover, the "incoming" and "outgoing" spacecraft simultaneously carrying the same traffic for a period of up to 5 minutes.

MOLNIYA 3

The North American loop of the orbit is the one employed for internal TV distribution from Moscow, on channel 10, to the Orbita rebroadcast stations serving the far northern and eastern regions of the U.S.S.R. National TV programs are repeated at intervals appropriate to feed the range of time zones of the Soviet Union, though Moscow time (G.m.t.+3 hours) is quoted throughout. Between the program transmissions an electronically generated test pattern is radiated, keeping the channel occupied with television signals almost 24 hours per day. TV programs audio is carried by a two-channel time-division multiplex method employing two analog width-modulated pulses transmitted in the horizontal blanking interval of the modified TV waveform. A separate audio channel utilizes a 7.5 MHz subcarrier added to the baseband video signal. The program content of this channel is unrelated to the TV picture.

Also on the Molniya 3 North American loop, channel 8 is active in a single channel per carrier [SCPC] mode. (See figure 51.) Among the carriers in this transponder are believed to be those of the Washington, DC, to Moscow Direct Communication Link ("Hot-Line"),[263] with terminals at Fort Dietrick, MD, and Vladimir, 180 km east of Moscow.

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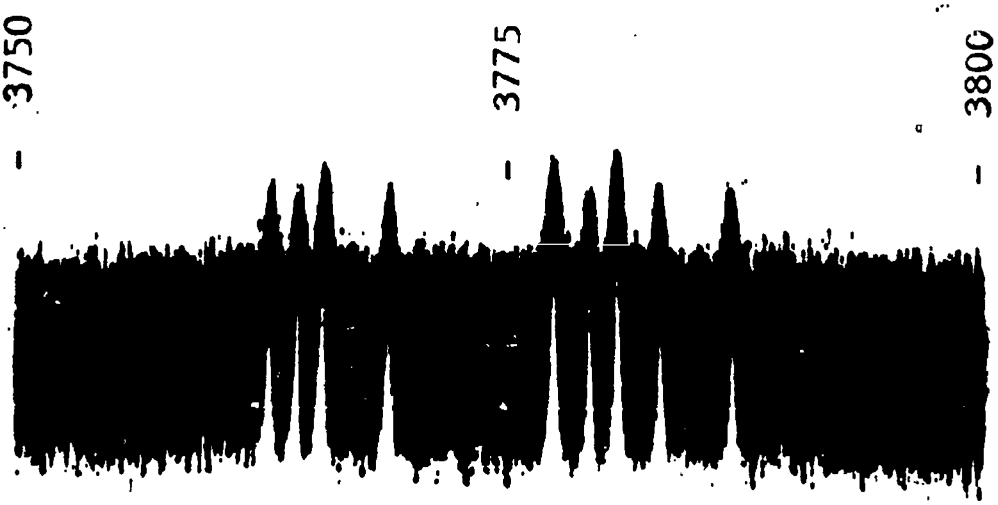
[263] Hooper, Rogers, and Whitman. The U.S.A.-U.S.S.R. Direct Communications Link Terminal, AIAA 5th Communications Satellite Systems Conference, Los Angeles, CA, 1974

FIGURE 51.—SCPC Carriers in a Molniya 3 "Channel 8" Transponder, While Over Canada; Frequencies, Given in Megahertz. Received Sheffield, England, August 1980



Observations around change over on this loop reveal that the uplink is not dual fed. The "incoming" satellite is activated approximately 1 minute before handover. At this time transponder noise can be seen in the downlink channels 8 and 10. Acquisition of the "incoming" satellite by the antenna of the uplink terminal, is accomplished in less than 1 second, immediately after which the transponders on the "outgoing" satellite are deactivated.

On Molniya 3's Asian loop, the satellites carry multiple carrier FDM/FM and FM/SCPC traffic in the channel 6 and channel 8 transponders. Channel 10 TV signals have very occasionally been seen on the Asian loop, transmitting test waveforms only. It is probable that, during the period of interest, the Raduga geostationary satellites have taken over TV distribution service to Orbita stations in those regions south of the limit of full-time visibility from the active portion of the North American loop. In this sense, the Molniya 3 and Raduga satellite systems are seen to be complementary.

RADUGA

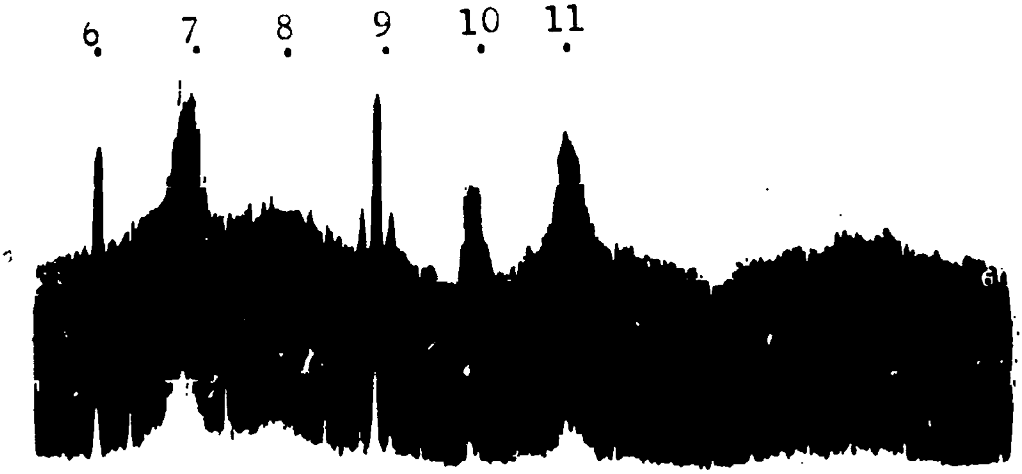
The Statsionar-2 satellite carries the "Orbita-IV Vostok" version of Moscow TV in channel 10. The same type of audio pulses are transmitted, but in this case it is the 7.5 MHz subcarrier which is modulated with TV program audio, the pulse-width modulation [PWM] bearing an unrelated feed. Channel 6 is apparently occupied by a lightly loaded FDM/FM carrier, while the remaining channels transmit multiple carrier SCPC-type signals. The channel occupany of the Statsionar-1/Statsionar-3 Raduga is not known.

GORIZONT

The Gorizant satellites' primary function would appear to be the provision of international TV circuits for Intersputnik. The Atlantic satellite stationed at Statsionar-4 (14° W approximately) has carried up to five independent TV feeds simultaneously. Gorizont 2 began operation at this location in time to cover the Non-Aligned Nations Summit in Havana, Cuba in September 1979. Initially all six transponders operated, channel 8 being reserved for FDM/FM or TDMA telephony traffic, while channels 6, 7, 9, 10, and 11 were available for TV. Feeds have been seen from a number of Intersputnik members, including Czechoslovakia, Poland, Hungary, and the German Democratic Republic, as well as the U.S.S.R.

By the beginning of 1980, only the channel 8 and channel 10 transponders remained operational, but this situation was remedied in July of that year, when Gorizont 4 took over at the Statsionar-4 location with six channels, five of which were to provide Intersputnik and European TV coverage of the Moscow Olympic Games.[264] (See figure 52.) Channel 8 remained dedicated to telephony.

FIGURE 52.—RF Spectrum 3,650-4,150 MHz, Showing Gorizont 4 Channels 6-11 Inclusive. Received Sheffield, England, August 1980



Various transmitting antenna beams were in use over this period, but by October 1980 utilization had fallen to three channels, 6, 8, and 10, with TV on 6 and 10, channel 6 being selected to the European spot beam, as with Gorizont 2. In this mode, an

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[264] Douglas, J N EBU Coverage of the 1980 Summer Olympic Games. EBU Review Technical. Brussels, June 1980, No 181, pp. 130-132.

energy-dispersal [ED] triangular waveform of 2 Hz, with a peak-to-peak deviation of 5 MHz, was added to the TV signal (nominal peak deviation 15 MHz). Otherwise, no ED is used in the Soviet systems. In early 1981, the satellite resumed 6-channel operation, with channel 6 carrying Moscow Central TV's "channel 1" programs, channels 7 and 11 the "II Orbita" feed and channel 10 being reserved for Intersputnik.

Gorizont 3, in the Indian Ocean Statsionar-5 location, has a similar TV usage of channels 6 and 10, the "Orbita III Vostok" variant of Moscow TV, with additionally FDM/FM telephony in channel 11.

All TV is 625-line, 25 frames/second with SECAM color. Even when taking a PAL-coded Eurovision source, the color is converted to SECAM before the feed is uplinked. The PWM "sound-in-vision" technique does not appear to have a place in Intersputnik exchanges. Standard audio subcarrier frequency is 7.5 MHz, though 8.2 MHz is also used. During Moscow Olympics coverage, further subcarriers were added for additional language feeds, down to a frequency of 5.5 MHz.[265]

EKRAN

The Ekran satellites at Statsionar-T (99° E) cannot be observed from the Sheffield location but the TV transmissions have been resolved experimentally in Malawi and South Africa,[266] some 13 degrees off beam, a direction in which the EIRP is estimated as 30 bdW. It is understood that the Peking (China) authorities have made a formal complaint to Moscow over the high level of 714 MHz signals reaching China, and their potential for interference to other services.

The programs transmitted are a version of Orbita TV, between 1200 and 1800 Moscow time. Audio is believed to be via a 6.5 MHz subcarrier, for compatibility with the intercarrier audio of Soviet domestic TV receivers. The signals, though of adequate strength for direct home reception within the target area, are also relayed by attended and unattended rebroadcast stations, in terrestrial AM TV format.

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[265] Cooper, R.B., Jr. Russian Olympics via Molniya and Gorizont. Coop's Satellite Digest, Satellite Television Technology, Arcadia, OK. September 1980, pp. 5-8.

[266] Bunney, R. Long-Distance Television. Television, vol. 30, December 1979, London, pp. 90-91.

Chapter 4 Annex 2

Radio Transmissions From Soviet Navigation Satellites

This is an updated extract from a paper by C.D. Wood and G.E. Perry presented at a Royal Society Discussion on Satellite Doppler Tracking and its Geodetic Applications held in London, England, on October 10 and 11, 1978, and subsequently published in the Philosophical Transactions of the Royal Society, London, by whose permission this is reprinted here.[267]

TRANSMISSION FREQUENCIES

Like the U.S. Transit satellites, the Kosmos navigation satellites transmit simultaneously in the v.h.f. and u.h.f. bands. Frequencies of 150.00 and 400.00 MHz were used initially. As the number of operational satellites increased, channels above and below 150 MHz were brought into operation, the 3:8 frequency ratio of VHF and UHF channels being maintained. Signals, when received, have indicated an effective radiated power in the order of 10 W. The UHF carrier is unmodulated.

CARRIER MODULATION

Fifty bits/second modulation is employed. The data to be transmitted selects a low frequency and the resulting sequence amplitude modulates the VHF carrier. The frequency spectrum is shown in figure 53.

The data to be transmitted select either 3, 5, or 7 kHz producing side bands a, b, or c after modulating the carrier. Only the 3 and 5 kHz convey the binary information. Transitional encoding is employed, binary 1 being represented by a change from 3 to 5 kHz or vice versa. Binary 0 produces no frequency shift. The 7 kHz provides time synchronization every second. The low amplitude odd and even harmonics of sidebands a and b that are normally present are not shown in figure 53.

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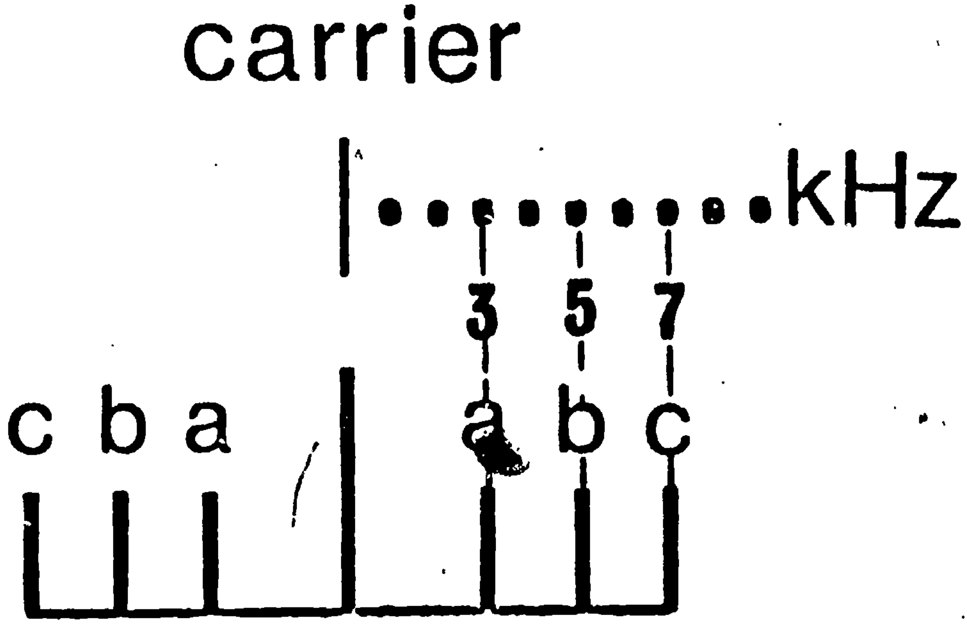
[267] Wood, C.D. and G.E. Perry. Philosophical Transactions of the Royal Society. London, A 294, 1980, pp 307-315.

FIGURE 53.—Signal Spectrum



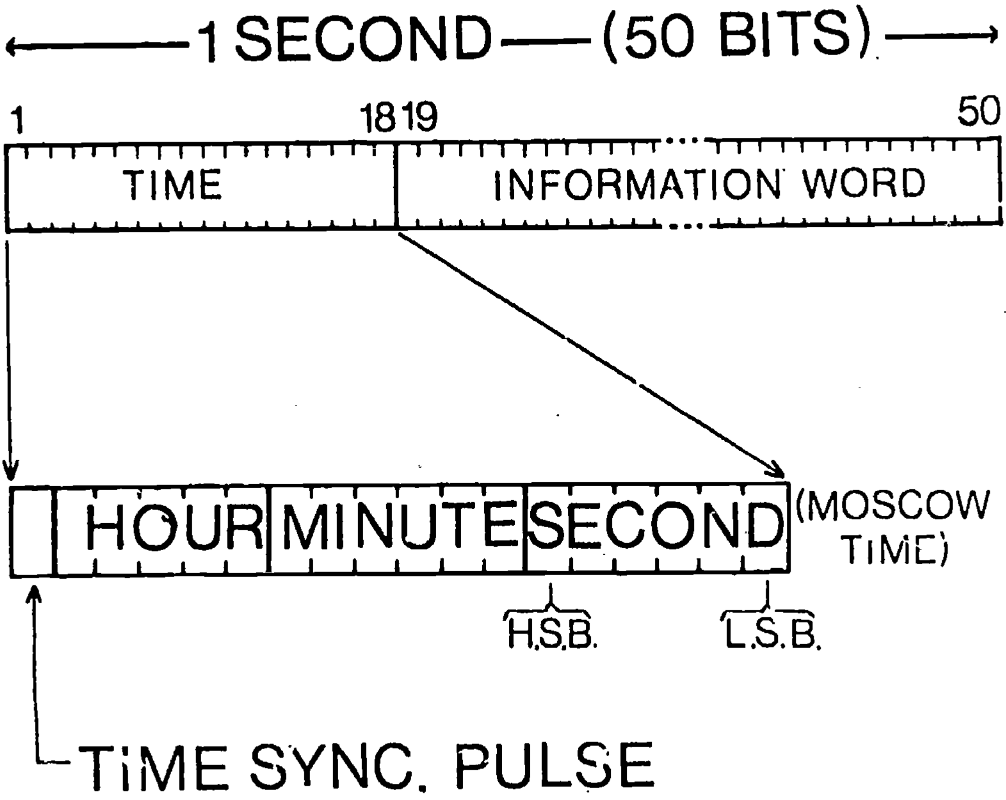
DATA FORMAT

Every second of the VHF transmission is punctuated by the time synchronization pulse shown in figure 54; 17 binary bits are used to give a statement of real time in hours, minutes and seconds (Moscow time) referred to the start of the pulse. (See figure 54.)

This pulse can extend its minimum 20 ms length up to the first binary 1 of the time statement, occupying the full 17 bits at midnight.

The last 32 bits of each second form an information word.

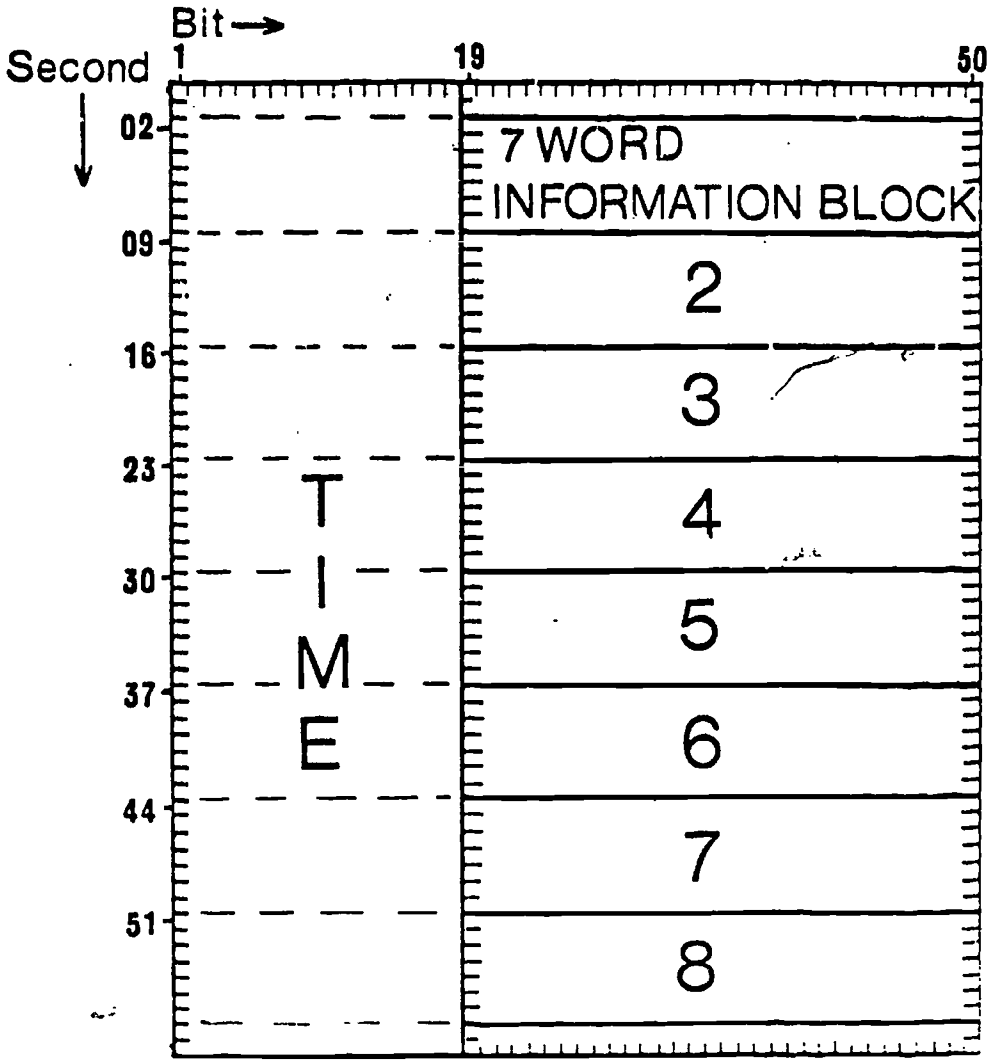
FIGURE 54.—Position of Encoded Time Information within Each Second



THE 1 MINUTE FRAME AND INFORMATION BLOCKS

Sixty-one second lines of data produce a 1-minute data frame. The seven information words starting from second 02 contain related data. Similarly, 7 other words of related data begin during seconds 09, 16, 23, 30, 37, 44, and 51. It is convenient to consider the 1 minute frame as having eight information blocks, as illustrated in figure 55.

FIGURE 55.—Composition of One Minute Time Frame



When a word is received, the block, its position within the block, and hence its purpose, are defined by the preceding seconds value of the time count.

The first two words of the frame each have 32 bits of binary 0 and hence contain no information. Binary values in the last two words of each frame are also 0 with the exception of bit 35.

UTILIZATION OF INFORMATION BLOCKS

The first four information blocks define the transmitting satellite's position in geocentric Cartesian coordinates; blocks 1 and 3 are identical, as are blocks 2 and 4. Even numbered blocks define the position 3 minutes after that given by the odd blocks.

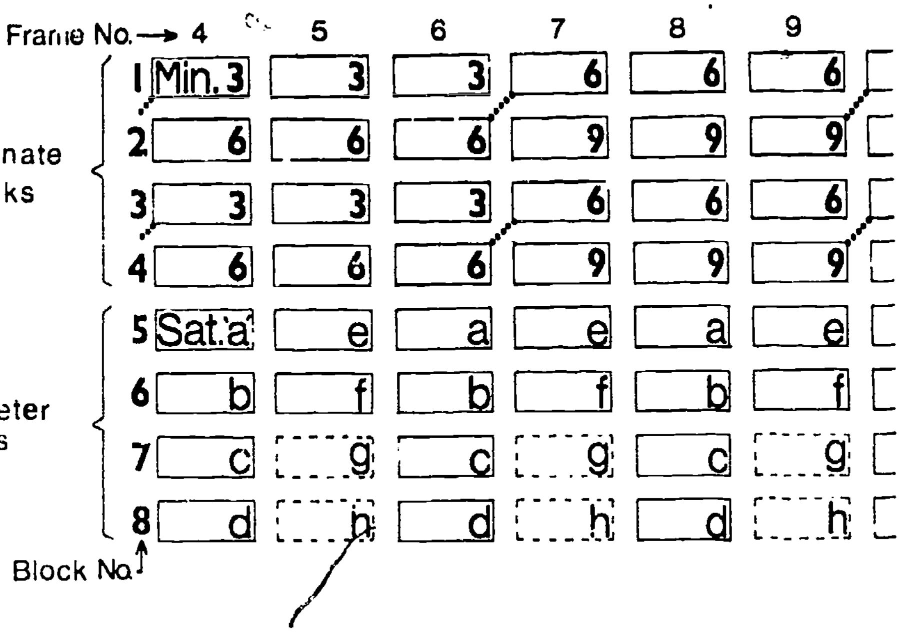
On the basis of one block per satellite, the remaining four blocks in the frame contain the orbital parameters of the satellites in the system. The parameters of the transmitting satellite always appear in block 5.

PROGRESSION OF INFORMATION BLOCKS

The coordinate blocks for *t* and *t*+3 min are repeated for three frames. In the next three frames the information for *t*+3, previously occupying blocks 2 and 4, move up to blocks 1 and 3, with *t*+6 minutes being inserted into blocks 2 and 4. Three frames later, coordinates are inserted for *t*+9. Thus coordinates of the satellite at intervals of 3 minutes are given in any frame and are updated every 3 minutes.

A system employing a 30° orbital plane spacing involves six satellites requiring six parameter blocks. Since only four blocks are available in each frame, parameter blocks are repeated every 2 minutes, making eight available. The use of seven or eight parameter blocks is not unusual, occurring when replacements are launched before the withdrawal of older satellites. These progressions are shown in figure 56.

FIGURE 56.—Block Progression, Frame by Frame



Block No.	Frame 4	5	6	7	8	9
1	Min. 3	3	3	6	6	6
2	6	6	6	9	9	9
3	3	3	3	6	6	6
4	6	6	6	9	9	9
5	Sat.'a'	e	a	e	a	e
6	b	f	b	f	b	f
7	c	g	c	g	c	g
8	d	h	d	h	d	h

SATELLITE IDENTITY NUMBERS

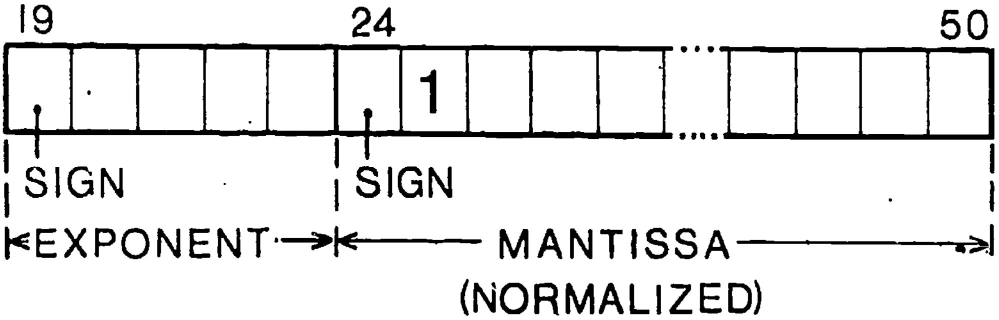
To avoid confusion, particularly in the parameter blocks, each satellite has an identity number. These numbers are not unique, and are reallocated, as necessary.

Identity numbers for the 30° system are in the range 1–8. The system with 45° spacing uses identity numbers 11–14.

INFORMATION DECODING

Generally, information words employ normalized binary floating point notation. The allocation of the 32 bits to the mantissa and exponent is shown in figure 57. The arrangement caters for decimal values ranging from +32768 to --32768 but excludes values smaller than $\pm 1.52587 \times 10^{-6}$. (See figure 57.)

FIGURE 57.—Allocation of Bits in Floating-Point Words



Words not using the above technique are split into two or more subwords and employ normal binary notation with the highest significant bit being transmitted first.

COORDINATE BLOCK DETAILS

As indicated above, the satellite's position in space is defined at a given time, in terms of *X*, *Y*, and *Z* coordinates. *X* is in the direction from the origin through 00° latitude—00° longitude, *Y* from origin through 00° latitude—90° E, and *Z* through 90° N. To enable the satellite's intermediate positions to be computed, each block also contains the rates of change of the coordinates (see table 43).

Words 1-6 use floating point notation and relate to the time *t* derived from a subword (bits 27-27) of the seventh word; the remaining subwords are described later.

SATELLITE PARAMETER BLOCK DETAILS

The orbital parameters are contained in words and subwords as shown in table 44. The transmitted values remain constant for a week and in the 30° system normally refer to the first ascending node occurring after Friday midnight Moscow time. Direct comparison, where possible, with values given in NORAD two-line orbital elements shows good positive correlation between both data sets.

The plot of $e \sin \omega$ against $e \cos \omega$ normally produces a circle with the centre slightly offset from the origin. Word 4 plotted against word 5 also produces a circle but with greater offsets than those obtained from NORAD figures. Constants K_1 and K_2 represent the difference between the two offsets having typical values of $+1.04$ by 10^{-3} and $+4.5$ by 10^{-4} respectively.

PARITY AND ERROR CHECKS

PARAMETER BLOCKS

Binary 1 occurs an odd number of times in each of the seven words of a parameter block. While the normal position for a parity bit would be at the end of the word, there is strong evidence to suggest that its position may be elsewhere. Such positions are indicated in table 44 and are those normally allocated to the exponent or mantissa sign. There is no conflict as such signs are redundant in the particular words. For example, the inclination given in word 2 is naturally positive, irrespective of the bit preceding the mantissa. Similarly the exponent of lines 4 and 5 should always be considered negative, irrespective of the sign derived from bit 19.

In view of the repetition rate of parameter blocks, more sophisticated error checking is probably unnecessary.

COORDINATE BLOCKS

Parity bits are not included in the coordinate block words. In view of the importance of these words in defining the satellite's position, it is probable that more sophisticated error checking techniques are employed. Word 7 has two undefined subwords, each of eight bits, whose values follow no logical sequence. It is possible that cyclic coding of the block is employed with the remainder, after modulo 2 division, being contained in one or both subwords. The most suitable generating polynomial is dependent on the number of bits included in the block before the addition of the remainder and is still undetermined.

TABLE 43.—ALLOCATION OF COORDINATE BLOCK WORDS

Word	Quantity	Unit
1	X coordinate	Kilometers.
2	Y coordinate	Do
3	Z coordinate	Do
4	dx/dt	Kilometers per second.
5	dy/dt	Do
6	dz/dt	Do
7	(a) bits 27-37, time t	Minute of day
	(b) remaining bits, see text	

TABLE 44.—ALLOCATION OF PARAMETER BLOCK WORDS

Word	Quantity	Unit	Parity bit
1	Ascending node longitude (east)	Radians	50
2	Inclination of orbit	do	24
3	(a) bits 19-23 identity number		24
	(b) bits 25-50 semi-major axis	kilometers	
4	Constant, K_1, $+e \sin \omega$		19
5	Constant, K_2, $+e \cos \omega$		19
6	Orbital period	minutes	19

TABLE 44.—ALLOCATION OF PARAMETER BLOCK WORDS—Continued

Word	Quantity	Unit	Parity bit
7	(a) bits 20-23 month		
	(b) bits 24-28 day	Time of ascending node 19	
	(c) bits 29-33 hour		
	(d) bits 34-39 minute		
	(e) bits 40-50 part minute		

Chapter 5

Soviet Military Space Activities

INTRODUCTION

DEFINITIONAL UNDERPINNINGS OF MILITARY SPACE ACTIVITIES

More than half of Soviet space launchings to date have been in direct support of military missions. Table 10 of part 1 of this report summarizes trends in this regard. While that table shows the great importance of military applications in the Soviet space program, it also shows that the program is not wholly military in its objectives. Other chapters discussing the organization, the goals and the hardware of the Soviet program show the many elements of the program used for scientific and civil or economic applications, which make the diversity of the total program abundantly clear.

There has always been an element of speculation about Soviet purposes in space because of their skillful use of information policies to combine a large flood of information about many aspects of space flight, including the quick identification of flight names and orbital parameters, and at the same time they have a policy of tight security and secrecy over the real purposes of most payloads and minimal information about the technology of Earth orbital flight. Other sections of this report have shown techniques for penetrating this obfuscation to provide fairly reliable indicators of real Soviet objectives, flight by flight. If this is not possible on the day of launch, particularly with new variations, this usually can be accomplished within a year or two by painstaking analysis of all the evidence which finally enters the public domain. It is partly a subjective judgment in the end, without Soviet cooperation, whether we have really explained all flights or whether there is a remnant where even our guestimates and intuitive feelings may be misleading us. In general, experience seems to demonstrate that our more conservative views about mysterious flights in the end find better support than the more speculative guesses that a particular new event is about to lead immediately to quantum jumps in ambitions and achievements.

The Russians have maintained they must pursue policies of secrecy over some aspects of their flight program because they do not want to boast in advance of concrete accomplishments—which is just another way of saying they hate to tarnish their contrived image of superiority by admitting to failures which inevitably occur in all space programs pushing into new technology. They also admit that most of their launch vehicles have also been used as military missiles, and hence, they reason, their characteristics must be protected against disclosure to their foreign rivals if their strategic deterrent against aggression by imperialists is to be preserved. This is hard to understand when Moscow parades have included the Shyster, Sandal, Skean, Sasin, Scarp, Scrag, and Savage, among others, while they have held back pictures of the complete D- and G-class vehicles, as well as details on some or all upper stages of A-, D-, and F-class launch vehicles. The Russians have routinely made clear that all their launches are conducted by the Soviet Strategic Rocket Forces, a military organization.

The Soviet claim is that all of their space flights are peaceful and scientific, while in earlier years it was common for them to attribute aggressive motives and see complete military domination in the U.S. program. Currently, Soviet propaganda is focusing upon the military potential of the shuttle. The problem of penetrating political semantics for scholars in a truly neutral setting, looking at claims and counterclaims, is not necessarily difficult, but is partly a matter of philosophy rather than absolutes. For some years, the United States has stated that its own space program is wholly peaceful—using space through NASA and other civilian departments to help us live better in peace, and using space through DOD to guarantee the peace. The United States seems at least as reticent as the Soviet Union in disclosing real details about military missions in space, although it acknowledges that it does withhold such information, while the Soviets pretend they have no military space program on which to withhold information. The Soviet claim that their space program is wholly scientific is valid only to the extent that science and technology can be treated as synonymous.

Perhaps the real tests of peacefulness or aggression lie not in labels or organizations but in intentions. Some specific acts in the space field are viewed as warlike. These include placing weapons of mass destruction in orbit—now banned by treaty—and direct interference with the flights of other nations. Beyond that, classifications become more nebulous. The bulk of space flights with military characteristics in both the programs of the United States and the Soviet Union are passive in character and neither violate any treaty nor pose any threat in themselves to other nations.

When one tries to sort out individual space flights into categories which are predominately civil or military, it quickly becomes apparent that it cannot be done by responsible agency alone because a simple administrative change in titles of government departments could upset classifications. The inherent peaceful or warlike character of flights is not easily answered by the hardware and flight path, because this depends partly on states of mind and intended end objectives, which are not always apparent. For example, when is a weather report just an economic fact for a farmer, and when is it a guide to the commander of a strategic bomber force? When is an observation flight one to gather economic data to raise the world standard of living, and when is it a safeguard against surprise attack to keep the world peaceful, and when is it a means for upgrading target information for future conflict? This chapter does not try to settle such philosophic issues nor does it offer judgments as to what is inherently good or bad.

Both the United States and the Soviet Union have been reasonably aware of trends in each other's military doctrine, hardware, and policies. They have developed whatever space systems they have from the same fountain of worldwide technology, although some parts of this knowledge and know-how have advanced at different rates depending upon the concentration of manpower and resources in particular areas. The DOD began its Discoverer flights as early as 1959, while the Soviet Union introduced the Kosmos label for many of its flights beginning in 1962, thus possibly signaling military activities. Even so, both countries must have started developing the technology for the military use of space long before these dates in order to be able to meet the lead time requirements of such flights. Whereas the Soviet Union was first into orbit with Sputnik 1 in 1957, the United States was first in orbiting satellites for military and civil applications as opposed to pure scientific research.

SOVIET STATEMENTS ON SPACE FOR MILITARY PURPOSES

This section reviews Soviet statements on military uses of space to a degree sufficient to supplement other analytical techniques in understanding the development of their military space program.

Not surprisingly, a primary journal for articles of analysis of the military aspects of the U.S. space program has been Red Star (Krasnaya Zvezda). In 1965, retired Maj. Gen. Teplinskiy wrote a long diatribe on U.S. activities, in which he claimed that the Apollo program aimed at prestige was a disappointment to Pentagon leaders, and then he developed the theme that most of the associated work of Mercury, Gemini, and Apollo really served military ends. He further attributed to the United States a long list of military missions ranging beyond military support work to space interceptors and orbital bombs.[1]

This was followed by a more detailed analysis of U.S. military space activities about 2 weeks later in the same paper. It traced work in geodesy, photographic observation, infrared detection of missile launchings, weather reporting, military communications, navigation—all reflecting a detailed familiarity with the spate of stories carried over the years in the American trade press. But the author went on to ascribe to U.S. planners schemes for stationing nuclear bombs in orbit, and armed interceptors for battle against other spacecraft. Dyna-Soar was discussed, with the Gemini-derived Manned Orbiting Laboratory [MOL] identified as an even more formidable successor. The article concluded that no matter how ambitious U.S. military plans were, they would always be exceeded in space by the combat might of the Soviet armed forces.[2]

Attacks on U.S policy were extended in October 1965, contrasting the purported scientific idealism of the Soviet Union with the claimed determination of the United States to pursue aggression by unleashing a new world war which would include war in outer space. Samos, Transit, and Secor (experiments related to observation, navigation, and geodesy respectively) were singled out for spe-

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[1] Teplinskiy, B. "The Pentagon, the Mad Men, and the Moon." Red Star, Jan. 10, 1965.

[2] Glazov, Col. V. "Cosmic Weapons." Red Star, Jan. 26 and 27, 1965.

cial criticism, together with experiments conducted by the crew of Gemini 5 of infrared observation of a missile launch, and especially the threat of the Manned Orbiting Laboratory [MOL].[3]

Although these quotations are illustrative of the general tone of Soviet pronouncements over the years, other quite interesting statements also have been made by Soviet authorities in other settings. Pravda quoted Party Chairman Brezhnev himself at a reception for Soviet military academy graduates at the Kremlin on July 1, 1966:

> A host of all kinds of fabulous stories is now in vogue in the United States—that it has the most "all-seeing" spy satellites, the "greatest possible number of rockets," the most "invulnerable submarines" and so forth and so on. But to put it mildly this does not agree with the facts, since the authors of such stories rely on those simpletons, who have never considered what rockets, sputniks, submarines, and other technical equipment the Soviet Union has.[4]

The text of a 1970 article on the intelligence services, which appeared in Moscow, seemed to give tacit approval for the use of reconnaissance satellites:

> Let us repeat, the division of labor within the intelligence service in no way signifies a desire on the part of its leaders to have clean hands; on the contrary they use secret agents to fulfill the most serious and profound tasks which cannot be solved by satellites, reconnaissance aircraft, or information centers using fast electronic equipment.[5]

The distinction was being drawn between human spies (necessary, but dirty) and modern technology (necessary and correct, if not applauded).

The advent of the U.S. Space Transportation System [STS] or space shuttle produced a steady flow of statements from the Soviets concentrating on military aspects of its proposed usage. This is an example from International Affairs.

> What alarms the world public most is the plans of the Pentagon strategists to use the Shuttle in implementing their new far-reaching military programs in outer space. In addition, it can put in orbit many "cheap" spy satellites as well as satellites concerned with military communication, navigation, weather and geodesy and other military purposes. The Shuttle provides the basis for a new anti-satellite system. It is believed that special devices will enable it to "inspect" space objects on orbit, and destroy them or take them down to Earth in the cargo compartment. The spaceship is supposed to be equipped with laser weapons. U.S. military experts are considering using it for placing nuclear devices in outer space. The Pentagon also

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[3] Golyshev, Col. M., "Military Review: The Pentagon Is Pushing."

[4] Pravda, Moscow, July 2, 1966

[5] Nedelya, Moscow, No. 46, Nov. 9-15, 1970, pp. 14-15

> pins great hopes on the Shuttle in the matter of deploying a space-based anti-missile defense system. With this aim in view it plans to build 10 permanent orbital stations over the next 15 years and arm them with powerful chemical lasers to destroy the warheads of the "enemy's" ICBMs in flight.[6]

An article contrasting the peaceful Soviet-French space programs, following the visit of Jean-Loup Chretien to Salyut 7, with American militarization of space made capital of the secrecy surrounding the Department of Defense's payloads on the STS-4 mission.

> Can one regard as a mere coincidence the fact that while the Soviet and French cosmonauts have been working for peaceful purposes aboard the orbital station (Salyut 7), the American space shuttle Columbia was completing its fourth consecutive test flight for the needs of the Pentagon? A military cargo aboard the Columbia has been labelled "top secret" by the Pentagon. According to available data, this applies to a telescope and scanning sensors for detecting "hostile" missiles and space devices. This is the Reagan administration's obvious step along the path of militarization of outer space.[7]

These selected quotations demonstrate the point that the Soviet Union has tried to make the United States look as bad as possible while keeping its own freedom of action in this regard. In the late 1950s and early 1960s, the Soviet charges were close to hysterical against the U.S. military involvement in space. In the middle 1960s, they continued to point with disapproval, and to charge that the United States would move beyond support work to space weapons. During the early 1970s, the general tone was more muted and there was more indirect acknowledgement that space defense work is useful to both nations. This even advanced to the point where SALT talks on limits to weapons referred to use of "national technical means" (unspecified, but not excluding space) as a method for each nation to verify the conformance of the other to whatever limits are agreed to in construction and deployment of weapons and defenses. Now, in the 1980s, the wheel has turned full circle.

DIVISION OR OVERLAP, CIVIL AND MILITARY ACTIVITIES

It is difficult to pinpoint military use of satellites when the same kinds of missions are normally carried out for civil purposes as well. Consequently, no attempt can be made here to quantify what part of the hardware or the usage of shared hardware is for military purposes. The primary purpose of this section is to discuss in more general terms what military uses do lie within some categories of flights.

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[6] Stashevsky, S. International Affairs in English, No. 7, July 1981, pp. 62-69.
[7] Dad'yants, G. Sotsialisticheskaya Industriya, July 1982, p. 3.

WEATHER REPORTING

A previous chapter explained the Meteor weather satellite system which is a general purpose activity serving many customers. Weather reports are important to agriculture, fisheries, water resource management, and many other economic users. Weather reports are especially important to aviation and shipping services of any description. Every military branch in any nation also requires weather information. In the United States, weather data from the satellites of the National Oceanic and Atmospheric Agency [NOAA] are coordinated with the Defense Meterological Satellite Program, and hence the flow of information from all these systems moves into the mainstream of shared weather reporting.

Similarly, it is reasonable to assume that data from the Soviet Meteor system is made available to both military and civilian users.

Philip J. Klass, the senior avionics editor of Aviation Week & Space Technology magazine, believed that the Soviet Union had a military weather satellite system as does the United States.[8] He credited the small satellites launched from Plesetsk by the B-1 as the carriers of such cameras, because he found some correlations of launch times of these with Soviet military observation recoverable flights. He suggested such military weather satellites guided the larger recoverables in their expenditure of photographic film. This hypothesis seems weak because it is believed that there would have been some direct evidence in signals from these craft if that had been the case. One can conceive of such signals being at frequencies and emitted over places in the interior of the Soviet Union to hide their function from Western listeners, but this represents a degree of security for a relatively passive mission which is out of proportion to Soviet security in other military space missions.

The Meteor satellites and certain seasonal flights of the military photographic recoverable series at high latitudes provide weather coverage of the Soviet Northern Seas Route across the top of Eurasia. Soviet naval vessels are moved between such ports as Murmansk or Archangel and Petropavlovsk or Vladivostok through this route, when ice conditions permit, saving the long trip around Africa (or through the Suez Canal, now open once more).

COMMUNICATIONS

The earlier chapter also discussed communications by satellite, using Molniya and geosynchronous satellites. It is impossible to say what proportion of total traffic handled through these systems is of a military nature. The Soviets have announced that the satellites not only handle television broadcasts, but also telephone, telegraph, and other data transmissions. It is known that the Molniya is used as a relay for space-related data transmitted between satellites and ocean tracking ships, extending this link on to Yevpatoria and Kaliningrad, among other points.

There are now more Molniya satellites active than are required for likely civil purposes. For example, the Molniya 1 satellites oper-

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[8] Klass, P.J. "Secret Sentries in Space." New York, Random House, 1971, pp. 157-8.

ate in one frequency band, while the Molniya 3 series operates at higher international frequencies, both in support of the Orbita ground station system. As described earlier, each of these Molniya systems provides a 24-hour communications coverage for the whole of the Soviet Union with four Molniya 3's in orbital planes spaced at 90° intervals accompanied by four Molniya 1's in the same planes and four more Molniya 1's in planes midway between these.

The introduction of operational geosynchronous satellite systems in the 1970s provided a further opportunity for continuous communications coverage worldwide. While the Ekran direct-broadcast TV satellites are, in all probability, mainly or entirely devoted to civilian traffic it would be naive to pretend that the military cannot or does not make use of transponders on satellites of the Raduga and Gorizont series. However, no direct evidence of such use has come to light.

GEODESY AND MAPPING

Geodesy is both of civilian and military interest. Military-operations use large volume of maps, and their grids must provide an accurate link and reference to places marked on the maps. Maps which might be accurate for one part of the world might not always be related to those in other parts of the world, especially across oceans and polar regions because the Earth is anything but a perfectly regular sphere. Defining the geoid (the Earth's surface) is a long-range task requiring many observations and much computer time. As soon as ICBM's were developed, the military need for this data became urgent to locate potential targets with a high degree of accuracy.

The Soviet Union says it performs geodesy from space, but it has not identified specific flights relating to this mission and has released very few satellite pictures of any description taken of Earth—mostly shots of general terrain and clouds, taken from their manned flights, some global views from Zond payloads, plus weather satellite imagery.

NAVIGATION

It was shown in the previous chapter that two distinct programs, one civil and the other military, exist within the subset of Kosmos satellites flown as navigation satellites. The civil, or Tsikada, system takes identity numbers from 11 through 14 whereas the military system of 6 operational satellites with orbital planes spaced at 30° intervals take identity Nos. 1 through 8 with Nos. 7 and 8 given to satellites which have been replaced towards the end of their active lives but which are still operational.

Although the Soviets have castigated the United States for its development of the Global Positioning System [GPS], or Navstar satellites, having an openly acknowledged military function with, in addition to the coarse/acquisition or C/A signal available for universal use, a precise or P-code signal which is an order of magnitude better in precision and resistant to electronic countermeasures and multipath interference,[9] they have, nevertheless, announced their intention of establishing a system, GLONASS, having similar orbital parameters.

MANNED FLIGHTS

Even before Project Mercury received its go-ahead in the early days of NASA, there was a proposal for MISS (Man in Space Soonest) which the U.S. Air Force sponsored. Later, Dr. Walter Dornbeger's concept which perhaps had its ancestry in the Eugen Sanger antipodal bomber was translated into the X-20 Dyna-Soar project. This evolved over some time into a reusable space glider to be launched by a Titan 3 launch vehicle as a demonstration of reusable ships handling the heat load of reentry by radiation rather than ablation or heat sinks, methods which had been used earlier. But in 1963, Dyna-Soar was cancelled, and replaced by the Manned Orbiting Laboratory [MOL]. This was also to be launched by a variant of the Titan 3 using Gemini as the ferry craft. The MOL program was cancelled in 1969 because DOD could not justify the need for military man in space. Instead, the manned component of the U.S. military program became part of the space shuttle plan. Development of the shuttle is funded by NASA but design considerations such as cross-range maneuverability and cargo-bay dimensions were made with both civil and military requirements in mind. The U.S. Air Force is constructing a launch pad at Vandenberg Air Force Base for use beginning in late 1985.

As discussed in chapter 3, part 2 of this study ("Manned Programs") the Soviet Union appears to have gone a different route in the use of manned spaceflight for military purposes but, as stated there, the Soviets do not admit to military missions on Salyut.

Most of the missions which have been talked about as practical military space tasks are not that different technologically from civilian missions. They may directly support observation, with an emphasis on search and close study of man-made facilities and human activities, rather than a study of natural resources of farms, forests, minerals, water supply, and oceans.

Of the five Salyut space stations which had flown successfully by the end of 1980, only Salyuts 3 and 5 are presumed to have had purely military missions. Distinctions between civil and military-oriented experiments became less clear during the long Salyut 6 flight and the dividing line now falls within a distinctly gray region.

ENGINEERING TESTS

From time to time, flights are observed from which no results are announced but which are followed by a prolonged series to which definite missions can be ascribed. Satellites in the operational series have orbital parameters similar to one or more of the earlier flights so it is not unreasonable to presume that those earlier flights were engineering tests related to the research and development program associated with the eventual mission. Examples of

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[9] McDonald. K D., "In Outer Space—A New Dimension of the Arms Race," ed. Jasani. B., SIPRI London. Taylor and Francis. 1982. pp. 167-183.

Kosmos satellites having such roles in connection with the Molniya and Meteor programs were cited in the previous chapter.

When a missile is withdrawn from service and converted to a space launcher, similar examples are observed, as in the cases of the SS-5 (Skean) and SS-9 (Scarp) in the C-1 and F-2 configurations. In both cases, the resulting launch vehicle has been used for a variety of space missions.

Table 45 lists launch vehicle tests with the C-1 in the years 1964 through 1968 and with the presumed F-2 in 1977.

TABLE 45.—LAUNCH VEHICLE TESTS, C-1 AND F-2

Launch date	Kosmos number	Launch vehicle	Apogee (km)	Perigee (km)	Inclination (deg)	Period (min)	Eventual mission
1964							
Aug. 18	38–40	C-1	876	210	56.2	95.2	Tactical communications.
1965							
Feb 21	54–56	C-1	1,856	280	56.1	106.2	Tactical communications.
Mar 15	61–63	C-1	1,837	273	56	106	Tactical communications.
July 16	71–75	C-1	550	550	56.1	99.5	Tactical communications.
Dec. 28	103	C-1	600	600	56	97	ELINT ferret.
1967							
Mar 24	151	C-1	630	630	56	97.1	ELINT ferret.
May 15	158	C-1	850	850	74	100.6	Store-dump communications.
1968							
Aug. 27	236	C-1	655	600	56	96.9	ELINT ferret.
1977							
June 29	921	F-2	711	644	76	98	
Sept 24	956	F-2	865	358	75.8	96.9	
Dec. 27	972	F-2	1,189	722	75.8	104	

Note Kosmos 158 and the three F-2 launches originated from Plesetsk. All other C-1 launches originated from Tyuratam

The triple and quintuple C-1 launches at 56° inclination out of Tyuratam are considered to have been engineering tests leading to the development of the tactical communications satellites which appear as octuple launches at 74° from Plesetsk starting in 1970.

Three further launches from Tyuratam at 56° inclination producing single payloads in near-circular 600 km orbits with periods close to 97 min are thought to have been research and development flights for the ELINT ferret missions which were to follow from Plesetsk, again at 74° inclination.

The one C-1 vehicle test from Plesetsk, Kosmos 158 on May 15, 1967, was the forerunner of the store-dump series with 100.6 min periods which followed in 1970.

The three flights in 1977 with a 75.8° inclination signaled the introduction of what is presumed to be a new vehicle configuration at Plesetsk which Sheldon labelled F-2. The appearance on a new inclination within the Soviet program is indicative of the introduction of a new launch pad but not always of a new vehicle configuration although these sometimes go hand in hand. A discussion of the merits of assigning this label will be found in part 1, pages 111-113.

USES OF SPACE SYSTEMS FOR MILITARY PURPOSES

Observation Missions

OPTICAL COVERAGE

Photo reconnaissance, recoverable payloads

The announcement that Kosmos 4 had been recovered from orbit after a flight of only 3 days signaled the inauguration of a continuing program of recoverable satellites within the Kosmos program which accounts for approximately 50 percent of all Kosmos launches. Figure 58 is a plot of Kosmos launches by year together with a plot of recoverables.

It will be seen that the 50 percent figure has held good over the whole lifetime of the Kosmos program. Recently, the Soviet Union has identified some of these payloads as performing Earth resources missions, but their telemetry is indistinguishable from some of the military satellites in this category.

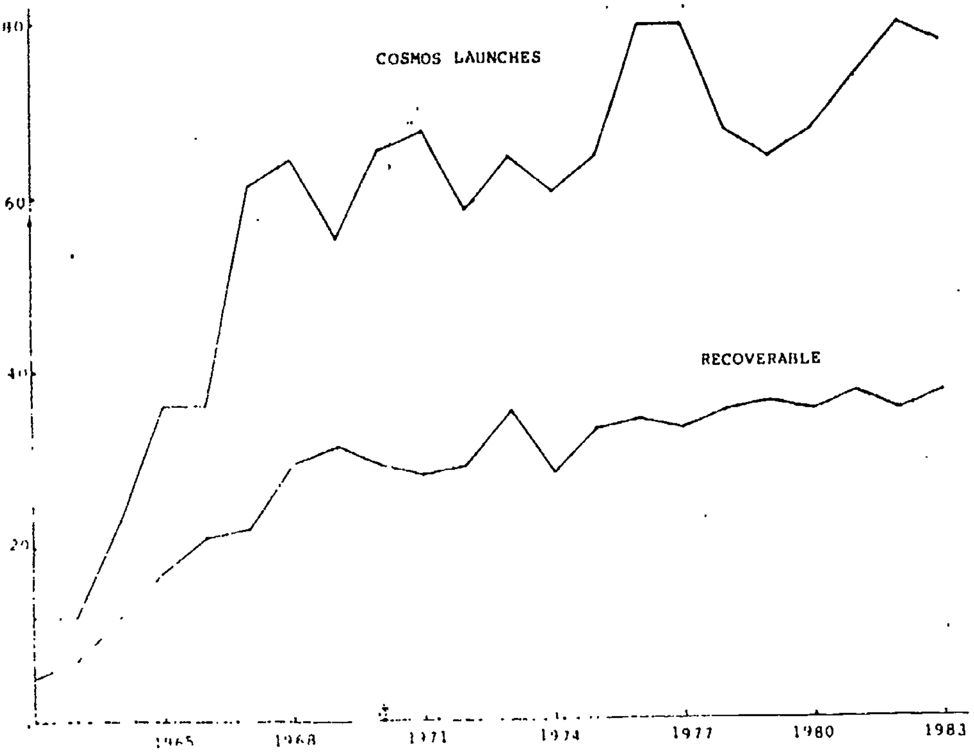

FIGURE 58—Approximately one half of all Cosmos launches produce recoverable payloads.

Launch vehicles

For many years the recoverable payloads were orbited by the A-vehicle, otherwise known as the SS-6. This was derived from Khrushchev's ICBM which made its first flight in August 1957. Two months later, in the A configuration, with a central core and four strap-ons, it was used to launch Sputnik 1. Addition of an upper stage produced the A-1 configuration used for the early lunar probes and the manned Vostok spacecraft. Twenty-five years after its introduction, it is still in use today with a more powerful upper stage as A-2 used for launching the manned Soyuz spacecraft. Until 1980 the A-vehicle had been responsible for the orbiting of all the recoverable Kosmos payloads, first as A-1 and then, following the introduction of a more powerful upper stage in 1963, solely as A-2 since 1968. With the introduction of flights at 82.3°, most of which are designated as performing Earth resources missions, the late Dr. Charles Sheldon hypothesized in 1980 that, as SS-9s became militarily obsolete, they redeployed as space launchers in an F-2 configuration. Just as the SS-4 derived B-vehicle was phased out and replaced by the SS-5 derived C-vehicle, it may well be that the F-vehicle will take over completely from the A, at least for all launches unconnected with the manned spaceflight program.

All launches from 1976-80 were made by the A-2 or the suspected F-2 vehicles. A-2 launches are summarized by mission category, launch site, inclination, shortwave telemetry transmissions and recovery beacons as identified by the Kettering Group, and mission duration in table 46 which follows. A-2 launches are dealt with in table 46 (a) through (e) and F-2 launches in table 46(f).

TABLE 46.—MILITARY PHOTOGRAPHIC RECOVERABLE MISSIONS

A. LOW RESOLUTION, NONMANEUVERING, A-2 LAUNCHED. PDM TRANSMISSIONS ON 19.994 MHz.

	Tyuratam		Plesetsk		
	65.0°	71.3°/71.4°	62.8°	72.9°	81.3°/81.4°
1976	809(12)G 819(12) 856(13)G*	799(12)	848.(13)*	840(12) 865(12)*	813(12) 834(12) 879(13)G
1977	914(13)* 966(12)*	889(12)G 904(14) 973(13)*	922(13)		898(13)G* 935(13)
1978		992(13)	984(13)F 1004(13)G*		995(13)

Notes

1 Kosmos launches subdivided by launch site and inclination. The Kosmos number is followed by the flight-duration in days shown in parentheses.
2 The letter G or F indicates that either a TG of TF recovery beacon was observed by the Kettering Group.
3 Flights shown with an asterisk carried a pickaback payload. With the exception of Kosmos 966, inflight telemetry indicated the presence of a scientific pickaback payload.

B. HIGH RESOLUTION, MANEUVERABLE, A-2 LAUNCHED. SIMPLE FSK TRANSMISSIONS ON 19.989 MHz.

	Tyuratam				Plesetsk			
	51.8°	65.0°/65.1°	70.3°/70.4°	71.4°	62.8°	67.1°/67.2°	72.8°/72.9°	81.3°/81.4°
1976		802(14)F 817(13) 835(13) 852(13) 859(11) ER 866(12) 844(12)		806(13)F 824(13)	788(13)F 810(13) 833(13) 847(13) 857(13) 863(11)		821(13)	815(13) 820(12) ER 854(13)

1977	908(14)F 888(13) 920(13)F 932(13) 957(13)			907(11) 915(13) 934(13)F 938(13)F 953(13)F 969(14)		829(13) 896(13)F 897(13)F 927(13)	902(13) 912(13) ER* 948(13) ER*
1978	986(14)F 989(14) 1021(13)F		999(13)F	974(13)F 987(14)F 1003(14)F 1029(10) 1031(13)F 1042(13)F 1050(14)F 1059(13)F 1068(13)		993(13) 1007(13)F ER 1022(13) 1047(13)F 1049(13)F	1010(13) 1033(13)K ER*
1979	1113(13)F	1120(13)F		1071(13) 1073(13) 1117(13)F 1128(13)F	1148(13)	1078(8) 1080(14)F 1098(13)F 1107(14)F	1099(13) ER 1105(13)K ER* 1108(13)K ER* 1115(13)K ER* 1123(13)K ER* 1127(13)F ER
1980		1170(11) 1173(11)F			1214(13)	1165(13)F 1187(14)F 1189(14)F 1200(14)F 1205(14)F 1213(14)F	

Notes.

1 Kosmos launches subdivided by launch and inclination. The Kosmos number is followed by the flight-duration in days shown in parens.

2. The letter F or K indicates that either a TF or a TK recovery beacon was observed by the Kettering Group.

3 Flights announced as performing Earth resources missions are followed by the letters ER.

4 Flights shown with an asterisk carried a pickaback payload

5 Inflight. maneuvers were not observed with the following Kosmos flights—912, 948, 1033, 1107, 1200, and 1202.

6 The inclination of Kosmos 1120 was announced as 70.6°.

7. A subset of flights which maneuvered to near-circular orbits with perigees above 300 km were not identified as separate missions by Dr. Sheldon but are shown together in table (c) which follows.

C MEDIUM RESOLUTION (?) A-2 LAUNCHED, MANEUVERING TO A HIGHER, NEAR-CIRCULAR ORBIT TOWARDS THE END OF THE FIRST DAY IN ORBIT. SIMPLE FSK TRANSMISSIONS ON 19.989 MHz.

	Plesetsk	
	62.8°	72.8°/72.9°
1976	867(13)F	
1977	958(13)	
1979	1103(14)F 1111(15)F	1095(14)F 1126(14)F 1138(14)F 1142(13)F 1147(14)F
1980		1149(14)F 1155(14) 1165(13)F 1166(14)F 1178(15) 1183(14)F 1216(14)F 1221(14)F 1224(14)F

Notes: As above

D. LOW RESOLUTION, A-2 LAUNCHED. SIMPLE FSK TRANSMISSIONS ON 19.994 MHz.

	Tyuratam		Plesetsk		
	51.8°	65.0°/65.1°	62.8°	72.9°	81.3°/81.4°
1976				811(12)* 855(12)*	
1977			916(12)* 950(14)	947(13)G	
1978	1026(4)	1002(13)G 1060(13)	1012(13) 1044(13)G 1061(13)G* 1069(13)L*	998(12)L* 1046(12)L*	1032(13)G

1979	1070(9)	1090(13)G **1139**(13)L*	1102(13) ER* 1106(13)G ER* 1118(13) ER* **1119**(12)L* 1122(13) ER*
1980	**1180**(12)L*		

Notes:

1. Kosmos launches subdivided by launch site and inclination. The Kosmos number is followed by the flight-duration in days shown in parantheses.
2. The letter G or L indicates that either a TG or a TL recovery beacon was observed by the Kettering Group.
3. Flights announced as performing Earth resources missions are followed by the letters ER.
4. Flights shown with an asterisk carried a pickaback payload.
5. Kosmos numbers in bold face flew missions with a presumed mapping and geodesy role
6. Failure to observe a recovery beacon following the unexpected recovery of Kosmos 1026 after only 4 days does not permit allocation of this flight to a mapping and geodesy mission with any certainty.

F FOURTH GENERATION WITH SOLAR PANELS. HIGH RESOLUTION. A-2 LAUNCHED. NO SHORTWAVE TELEMETRY DISCOVERED.

	Tyuratam	Plesetsk	
	64.9°	62.8°	67.1°/67.2°
1976			805(20) 844 exploded.
1977		949(30)	905(30)
1978			1028(30)
1979		1097(30)	1079(12) may have malfunctioned. 1121(30) 1144(32)
1980	1218(43)		1152(13) 1177(44) 1208(29) 1236(26)

Notes: As above

F POSSIBLE F-2 LAUNCHES. SIMPLE FSK TRANSMISSIONS ON 19 989 MHz. PLESETSK LAUNCHES AT 82 3°.

1980	1182(13)P	1203(14)F P	1210(14)F
	1185(14)F ER	1207(13)K ER	1211(11)L $
	1201(13)K P	1209(14)F P	1212(13)K P

Notes

1 The Kosmos number is followed by the flight-duration in days shown in parentheses.
2 The letter F, K or L indicates that either TF, TK or TL recovery beacons were observed by the Kettering Group.
3 Kosmos 1211, indicated by $, transmitted on 19 994 MHz and is presumed to have performed a mapping and geodesy role. This is supported by the TL recovery beacon.
4 The majority of flights in this subset were announced as performing Earth resources missions. Letters ER or P following the Kosmos number indicate such missions, the P denoting those which were announced as reporting results to the Priroda (Nature) Center

Flight durations

While during the first year, the average duration of flights was 4.6 days, this quickly stabilized for the next 7 years at about 8 days. From 1976–1980, flights were mainly of 12 to 14 days duration, but the introduction of a fourth generation spacecraft, presumably equipped with solar batteries, has seen the extension of some missions to periods of 4 to 6 weeks. Those brought back in shorter times, in a few cases may reflect malfunctioning equipment, but more often seem to be associated with crisis situations where a quick look for order of battle determinations makes it more important to have pictures in hand than to obtain maximum use from the payload. If it is impossible to orient the flight for recovery, or if retrofire fails, the payload is exploded to prevent its random decay in some place outside Soviet territory in nearly intact form.

A novel way of looking at mission durations is to plot, in terms of days of the week, launch against recovery. Such a plot is given in figure 59.

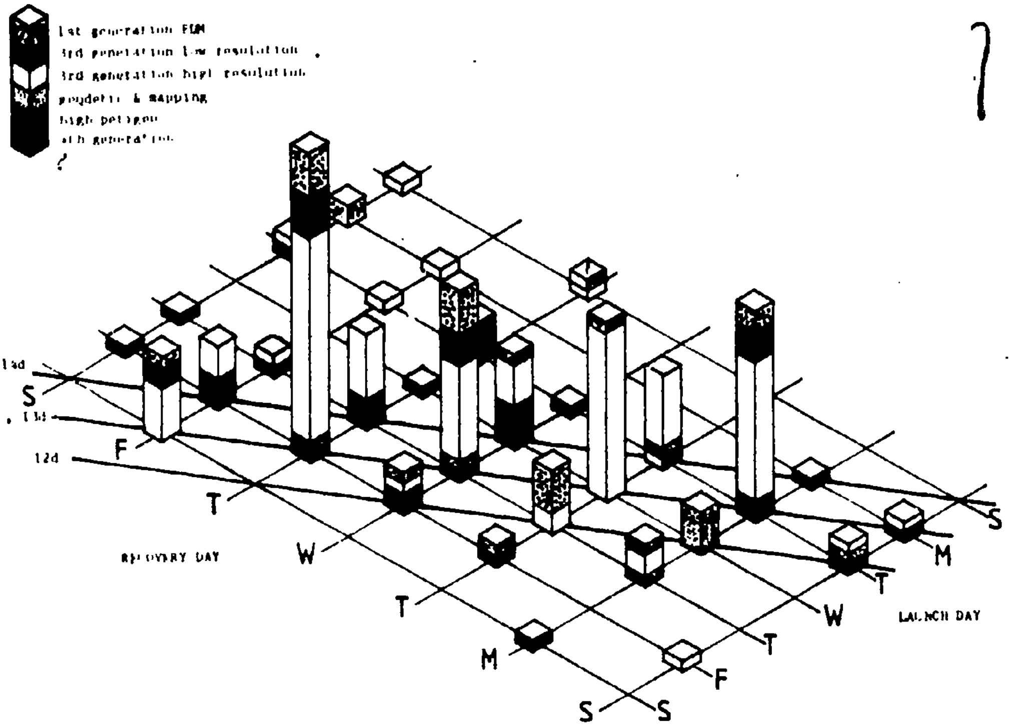

FIGURE 59.—RECOVERABLE PHOTO-RECONNAISSANCE COSMOS SATELLITES 1976–80

The 12-, 13- and 14-day missions are seen to lie on diagonal lines and to account for a preponderance of the missions. The only Sunday launch which was recovered on the following Saturday, Kosmos 964, was also a 13-day mission and, if translated to an adjacent grid, would be found to lie on the 13-day line. Also the two Monday launches with Saturday recoveries, Kosmos 865 and 966, were 12-day missions and, likewise translated, would be found to lie on the 12-day line. The reluctance to launch (three times only) and recover (six times only) on Sundays is clearly evident.

A later section shows how flight duration is usually constrained by considerations of complete photographic coverage over a given region.

Flight durations as integer numbers of days are given in parentheses following the Kosmos numbers in table 46.

Launch sites

Until 1966, all military recoverable launches were made from the Baikonur Cosmodrome, to the east of the Aral Sea. The launch pads are located much closer to the old town of Tyuratam and the new city of Leninsk, built to serve the needs of the manned spaceflight program, than to Baikonur itself, which is more than 350 km to the northeast. Consequently, Western analysts usually refer to the site as Tyuratam. This site, used for the launch of the first Sputnik and still the main site for R&D, can be considered as the Soviet counterpart to Cape Canaveral. All of the manned spaceflight missions, lunar and interplanetary probes, and geosynchronous satellites have been launched from here.

Use of the second launch site at Kapustin Yar, near Volgograd, has been restricted to small payloads, sometimes having announced scientific missions, launched as vertical sounding probes or placed into orbit by the smaller launch vehicles.

The launch of Kosmos 112 on March 17, 1966, marked the opening of the third cosmodrome near the town of Plesetsk, within the Arctic Circle to the south of Arkhangel'sk. Since that time, the majority of the recoverable Kosmos payloads have been launched from there. In 1979 and 1980, Tyuratam launched only two and three such payloads. Plesetsk is used for near-polar inclination orbits and is the Soviet equivalent of the USAF Western Test Range at Vandenberg Air Force Base. Although more launches have been conducted here than at any other site, Soviet or American, the existence of Plesetsk was not openly acknowledged by the Soviets until 1983.

Flight altitudes

Table 46 does not include information on the altitudes of the flights. That information is provided in the master log of all flights which appeared as appendix III of part 1 (p. 395) of this study.

Apogees have ranged between 200 and 450 km, with 300 to 350 probably most typical. Perigees have ranged from 147 km upwards. The maneuverable satellites often lower their perigees during flight to improve resolution or to stabilize their ground tracks. Further maneuvers, including a compensating raising of apogee, may be necessary to maintain the flight for its full duration.

Commencing with Kosmos 867 in 1976, some flights have raised their perigee to above 300 km during the early states of the mission to produce interlaced ground track coverage. These are listed separately in table 46(c).

Flight inclinations

Tyuratam alone has been used to send flights to inclinations around 52°. Plesetsk alone is still used to send flights to above 81°. Both sites come close to duplicating each other's coverage in the range from 65° to 73°.

Initially, a pair of flights was sent each spring to about 81° latitude, presumably to give coverage of the ice movement along the Northern Seas Route across the top of Eurasia. The Kettering Group also demonstrated that sending summer flights at about 52° would give twice-daily coverage of northern hemisphere target areas of interest, during good daylight hours.[10]

Some other reasons influencing choice of inclination are to obtain coverage of areas of interest, either as soon as possible after launch, or to coincide with favorable lighting conditions, or to be timed to match some ground event.

Introduction of the presumed F-2 vehicle increased the maximum value of the inclination to 82.3° and those flights have taken over the ice surveillance missions in addition to performing Earth resources missions.

Recovery procedure

Recovery procedure is based on Vostok technology in which attitude is determined by optical sensing of the horizon prior to retrofire. Following retrofire, the spherical pay load is detached from the service module and begins its ballistic re-entry. The transmitter in the service module continues to transmit until the module burns up in the lower layers of the atmosphere. Some 6 or 7 minutes later, when the recovery capsule is at a height of some 8 or 9 kilometers above the Earth's surface, a pressure-operated device deploys the parachute system and actuates a recovery beacon to assist the ground crews in its location and recovery. Descent on the parachute lasts some 7 minutes. The moment of touchdown is signaled by a marked reduction in the strength of the signals from the recovery beacon transmitter and the duration of the transmission thereafter is a measure of the accuracy of prediction of the recovery area.

Recovery beacons

Following the loss of the shortwave telemetry from Kosmos 114, as the instrument package burned up on reentry, a Swedish student, Sven Grahn, recorded a continuous sequence of Morse code TK groups on 19.995 MHz. Later in 1966, a similar transmission was recorded in Kettering following the recovery of Kosmos 126.[11] As time went by, it became clear that such signals originated from the recoverable capsule and were intended to assist recovery teams in locating the payload. The mean interval between loss of the PDM transmission and the onset of TK's was 6.75±0.5 minutes. The TK transmission begins at the instant the parachute is deployed. An abrupt decrease in strength some 7 minutes later indicates the time of touchdown. The length of time for which the

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[10] Perry, G E. "Spaceflight." London, May 14, 1972, p. 184.
[11] Perry, G E., and S. Grahn. "Spaceflight," London, vol. 10, 1968, pp. 142-143.

TK's persist after this is a measure of the precision of the recovery. There have been occasions when the signals have ceased abruptly in less than 7 minutes without a prior decrease in strength, raising the possibility of mid-air recoveries.

Pen-recordings reveal that the dash of the T has twice the duration of the dash in the K. Nevertheless, such signals have become known as TK's in the Western world. Horst Hewel, of West Berlin, pointed out that TK's were sometimes transmitted simultaneously on both 19.995 and 20.005 MHz.

As time went by, other recovery beacons were observed. TG's were transmitted on 20.005 MHz by first generation, low resolution satellites. These have not been used since the extended duration first generation satellites were phased out. TF's continued to be used by the third generation, high resolution satellites and some which have been designated as Earth resources missions. TL's are reserved for the special subset of satellites believed to have a mapping and geodesy role. The TV's are now believed to emanate from capsules jettisoned during the long-duration missions of the fourth generation satellites. The common factor of the "T" in all of these is justification for placing the T first in each pair of letters.

Figure 60 shows strip-chart representations of the various recovery beacons.

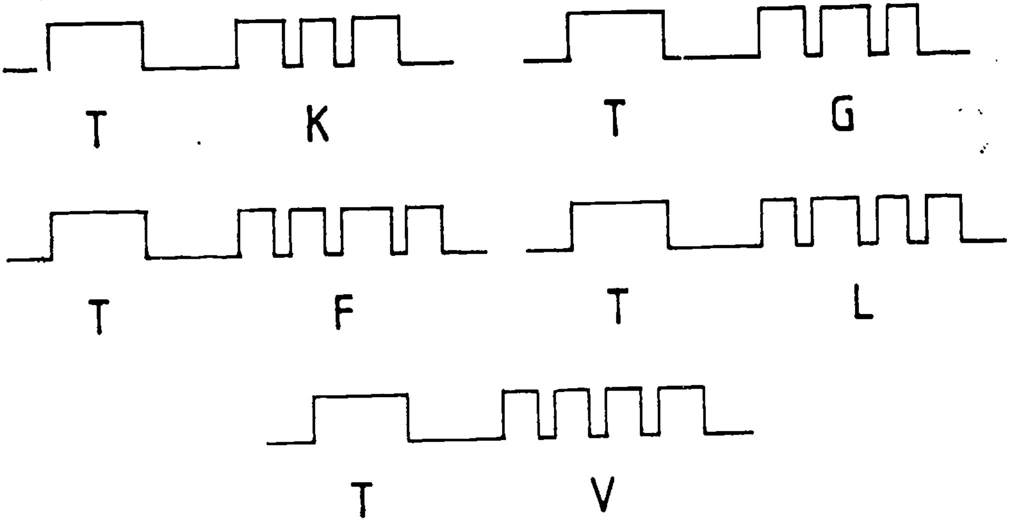

FIGURE 60.—Recovery beacons

Variants in payload types

Soviet Space Programs, 1971-75 combined changes in launch vehicle with observed changes in telemetry format. Separation of A-1 and A-2 launched payloads was possible because the final stage of the A-2 rocket is about 3 times as long as that of the A-1 when it is discarded in orbit. Optically, the difference in stellar magnitude makes it possible to distinguish the two sizes, and radar signature analysis provides more specific measurements.[12] The inference was

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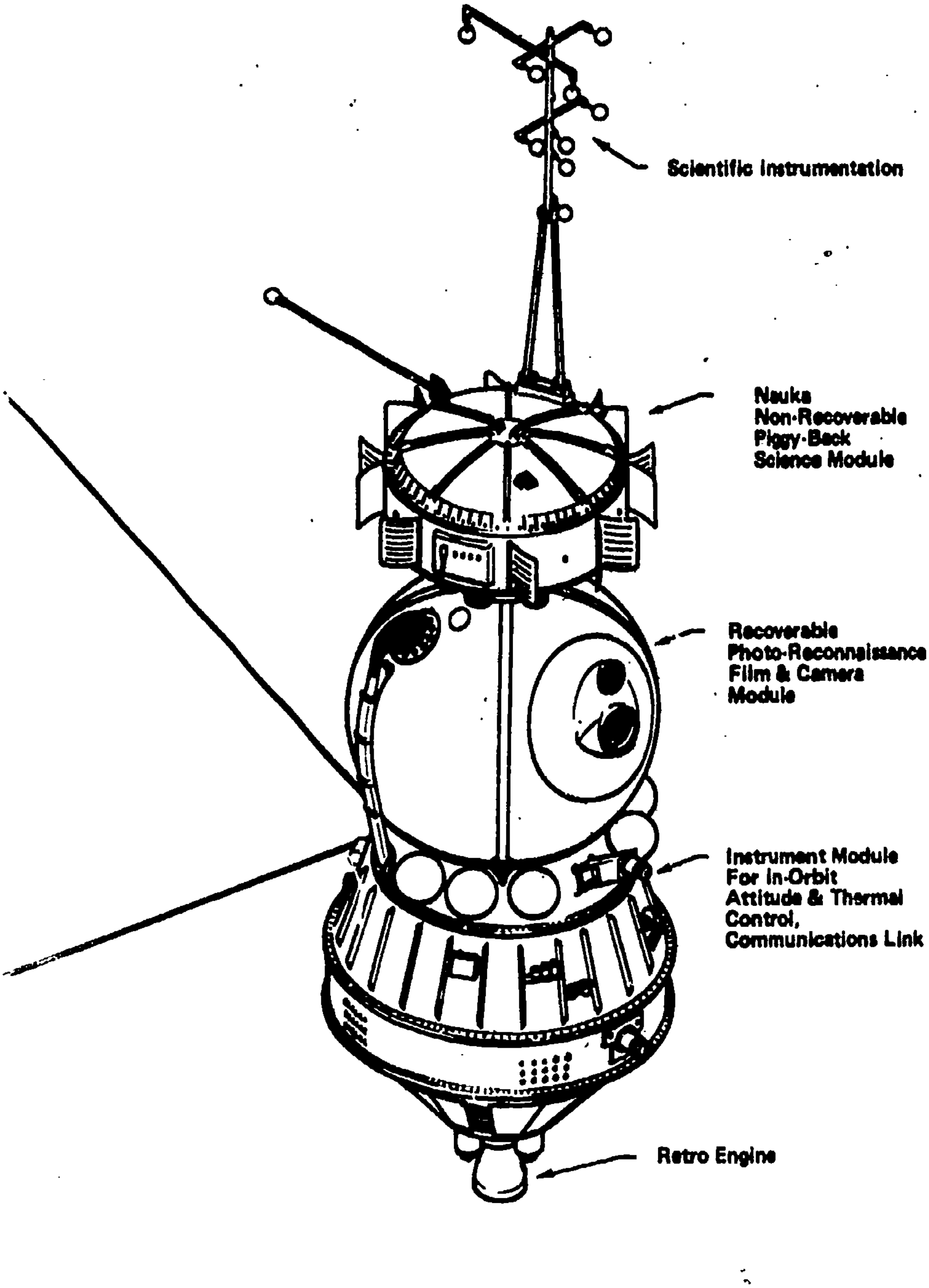
[12] Pilkington. J.A. Flight International. London, vol. 86, Oct. 1, 1964. pp. 605-607.

that payloads put up by a more powerful upper stage probably had an improved camera system that permitted higher resolution pictures. Two distinct telemetry modes appeared within the A-2 flights and, at times, both could be observed during the same mission. It was assumed that there might be more than 1 degree of resolution, with perhaps the simpler camera systems leaving sufficient weight and room to allow carrying other sensors to permit synoptic measurements of military interest. This hypothesis, which at first was hard to prove from public evidence, in time received added support when the later generation flights appeared. There were similar differences and cross links in telemetry patterns suggesting a continuity of function, and the later generation flights definitely could be sorted into maneuvering and nonmaneuvering payloads, strengthening the implication that fine maneuvers were to position high resolution cameras, while absence of maneuver was more likely to mean wider area coverage in search missions at lower resolution before the detailed study at high resolution.

The payloads themselves have not been put on display. From the general launch patterns and orbital behavior, the assumption has been that the first generations of military observation flights probably used essentially the same system as Vostok/Voskhod which, even though manned, operated either automatically or by ground control, so that a minimum change in the hardware for the vehicle bus and service module would be required to move from the manned program to the unmanned military flights. This view gains support from models of the international biological Kosmos satellites displayed in exhibitions. A drawing of such a model is given as figure 6-1. These biosatellites comprise a service module incorporating a retro-rocket and four swivelling maneuvering thrusters together with radio antennas and gas bottles, attached to a spherical capsule, something more than 2 meters in diameter, which carried white rats and other biological specimens. A flat cylindrical scientific package with shutters for active thermal control was mounted forward of this in the manner of the scientific pick-a-back payloads known to have been carried by some of the military recoverable satellites. In the reconnaissance version the spherical capsule would carry the cameras and film magazines. Figure 62 is a concept developed by Grant Thomson of the Kettering Group showing how Soviet-type photographic equipment might be accommodated in such a capsule.



© D.R.Woods 1984

FIGURE 61.—Kosmos Reconnaissance Spacecraft

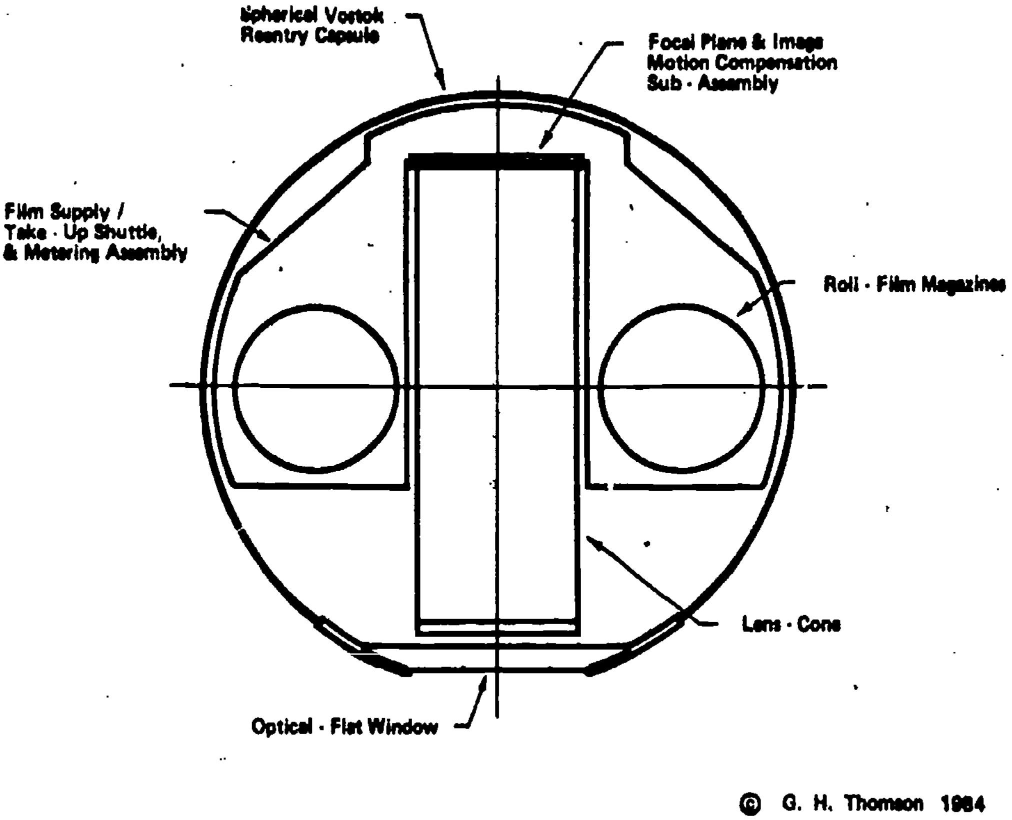


FIGURE 62.—Possible Vostok Capsule Used for Film Camera Housing for Photo-Recon Mission

Thomson assumes the use of an f/9, 3.8 meter focal length Cassegrain optical system. Access to the internal equipment and film magazines would necessitate the removal of the lens cone from the spherical capsule and ancillary items of equipment could be installed in the space available parallel to the section shown. The capacity of the film spools in this concept would be approximately 1,400 meters.

Some analysts suggest that the fourth generation satellites are derived from Soyuz technology employing solar batteries for power throughout their long-duration missions, but no evidence of solar panels is available from visual observations. The advantages of the Soyuz system would be greater ability to maneuver, and development of some lift during the reentry phase, because of the change of the shape of the reentry body.

Monitoring the in-flight radio transmissions as well as the recovery beacons has enabled four generations of recoverable satellites to be distinguished. Shortwave transmissions on 19.994 MHz and later on 19.989 MHz were frequency-shift keyed (f.s.k.) with the "off" periods being transmitted on the second frequency. The telemetry frame format consisted of a train of rapid synchronizing pulses followed by 15 words transmitted at a rate of approximately 1 word per second. These words were pulse-duration modulated [PDM].

It was found that, for the first generation satellites, the frame existed in two pairs of modes, one mode of each pair being associated with the post-retrofire phase of the mission. Three types of satellites were observed: mode 1-only, mode 2-only, and those which changed from mode 1 to mode 2 in midtransmisson. The first of these came to be associated with low resolution missions of the area surveillance category. These satellites had TG recovery beacons on 20.005 MHz. On occasions, TKs were observed simultaneously on both recovery beacon frequencies providing yet another type of classification. The introduction of extended duration missions from 8 to 12 days coincided with the repositioning of a very long duration word within the telemetry frame. Sometimes this word was not very long initially, but lengthened suddenly towards the end of the mission and this was shown to be related to the ejection of a scientific pick-a-back payload from which results were eventually reported.

A new type of transmission consisting of 12 groups, each of 3 Morse code characters, on 19.150 MHz signaled the appearance of a second generation satellite having a maneuverable capability. Each group was formed of characters giving seven pulses per group in a 2-3-2 configuration with the exception of one 3-1-3 group which served to denote the start of the frame. These represented 7-bit pulsecode modulation [PCM] binary code in which the first digit rather than the last was the least significant bit. The sixth group, which was invariably MWI throughout the main part of the mission, changed to MRI on the day prior to recovery at the same time as an additional piece was cataloged in orbit. The numerical value of the seventh group increased steadily during the flight and was shown to be a film exposure counter.

Third generation satellites, still used extensively today, employ a different type of f.s.k. transmission on 19.989 MHz which appears to be a tracking beacon lacking any telemetric information. Each tone is transmitted for equal durations and times for one complete cycle are typically between 1.5 and 1.75 seconds. Variations in cycle-duration serve to distinguish between different payloads in orbit simultaneously. Amplitude-modulated [AM] data is transmitted on command on 232 MHz in the VHF band.

Certain designated Earth resources missions have a TK recovery beacon, but most third generation satellites transmit TF on recovery. As reported in the previous chapter, the TK beacons originate from Earth resources payloads flying at a height of 220 km throughout the photographic arc, rather than at 270 km. The Earth resources missions had their origin in flights at 81.3° inclination timed to coincide with the break-up of Arctic ice along the northern seaboard of the Soviet Union. These have now been superseded by the F-launched flights at 82.3°. Some, but not all, are announced as reporting to the Priroda (Nature) Center.

A special sub-set of satellites, transmitting the two-tone tracking beacon on 19.994 MHz, exists within these third generation missions. These do not maneuver and have a TL recovery beacon instead of the usual TFs or TKs. They are thought to perform geodetic survey and mapping missions enabling correlation of international mapping grids for precision targeting of missiles with MIRVed warheads.

Recoverable Kosmos satellites which do not transmit on any shortwave frequency known to the Kettering Group first appeared in 1975 at the new inclination of 67.2°. Two of the first three fragmented in orbit, but these satellites are now seen to consititute a fourth generation. Frequency-modulated [FM] transmissions on 240 MHz have been observed at both low and high data-rates. Perigee heights are generally lower than for satellites of earlier generations, normally close to 175 km but occasionally falling below 160 km, necessitating regular boosting to overcome drag and maintain orbit. Imagery is probably returned digitally from orbit and film capsules are returned to Earth around the 9th and 18th days of the mission. Recovery beacon signals from these capsules take the form of a succession of TVs. These satellites are generally launched later in the day than those with 14-day missions to ensure suitable lighting conditions over the target area at the end of the flight and perigee is relocated to the southbound pass in the latter stages of those missions exceeding 4 weeks.

Photo coverage

Following an initial period of R&D, payloads were routinely recovered after flights of 8 days. Studies of the ground-tracks revealed that orbital periods were chosen so that the gradual daily drift of ground-track every 16 revolutions made those on the 8th day coincident with those on the 1st, thus ensuring complete coverage of the whole area of the Earth situated between northern and southern latitudes having the same value as the inclination of the orbit to the equator. Thus, a satellite with an orbital inclination of 65° could, within 8 days, photograph all the globe lying between 65 °N and 65 °S although it is not suggested that it would do so because a large fraction of the Earth's surface is covered by water. The rate of daily drift is a function of the cosine of the inclination and this was evident in the small differences in orbital periods chosen for the preferred inclinations of 81.3°, 72.9°, 65° and 51.8°. Even with the longer duration missions which were to follow as time went by, the criteria for complete coverage were still satisfied for the nonmaneuvering search-and-find missions.

The trend towards longer mission durations is direct corollary of a general improvement in photographic resolution. Use of longer focal length optics providing increased resolution on the same film format results in a narrower swath being recorded. Consequently, to obtain uninterrupted coverage with the requisite overlap, groundtracks must be more closely spaced. Since perigee heights have always been as low as practicable consistent with keeping drag to a minimum, the closer spacing and lower orbital period is obtained by lowering the apogee.

A maneuvering capability was introduced with the appearance of the second generation satellites in 1968. This enabled the orbit to be stabilized on reaching the desired location so that the satellite followed the same ground-track over the target on successive days providing a close-look capability. This was accompanied by the use of first generation satellites to fly area-surveillance missions with an extended duration. These extended duration first generation missions persisted even after third generation satellites replaced the second generation for the close-look missions in 1974 and were last flown in 1978. Since that time, area surveillance has been achieved by flying third generation satellites with much higher perigees and using the interlaced coverage. The 92.4 min period causes the second day's ground-tracks to fall almost exactly midway between those of the first day. Drift once again ensures complete coverage but each half of the target area is sampled on alternate days.

It is difficult to make estimates of the degree of resolution that is obtainable without access to the actual imagery. Claims that satellites can read newspaper headlines from orbit would seem to be wildly exaggerated. It has been suggested that photoscales of 1:3,000,000 for the search-and-find type of mission, 1:250,000 for quick-look coverage, and 1:50,000 for close-look missions represent reasonable estimates. With a moderate resolution of 35 to 50 cycles/mm for a low-contrast target it should be possible to make out the general outline of small vehicles such as cars or even smaller continuous features such as well-used footpaths.[13] [14]

The extended durations of a month or more for the fourth generation satellites require modifications to the flight patterns of the earlier generations. Generally, these fourth generation flights are launched later in the day to ensure useful lighting conditions over the target areas at the end of the mission. Peter Wakelin, of the Kettering Group, has evolved a formula for the calculation of the "longitude of local time," L degrees,

$$L = A - (T - 720)/4$$

corrected to lie between ±180° by adding or subtracting 360 if necessary, where A is the longitude of the ascending node of a given revolution measured in degrees West, and T is the time of this northbound equator-crossing expressed as minutes after midnight GMT. Calculations of L for these missions at times near to the launches and terminations reveal groupings by inclination and duration which can be used to decide whether or not a particular flight falls into a given category. As might be expected, the value of L increases in a westward direction throughout a mission and, for flights with durations in excess of 40 days, has a value close to 180° at the end. For these flights, maneuvers are made after 4 weeks to relocate the perigee to the southbound pass in order to ensure suitable lighting conditions at the time of the near-perigee pass over the target area.

Nicholas Johnson, of Teledyne-Brown Engineering, claims that there is a very tight constraint on the initial lighting conditions for all recoverable photographic reconnaissance flights, pointing out that, independent of the inclination, these satellites reach their southern apex at almost identical local solar times.[15]

Johnson also produced an algorithm for classifying these recoverable photo reconnaissance missions embodying long-established techniques based on orbital parameters and maneuverability, adding a further criterion relating the perigee velocity to an image-

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[13] Thomson, G H., British Journal of Photography, vol. 127, 1980, pp. 1164-1165.
[14] Thomson, G H., British Journal of Photography, vol. 126, 1979, pp. 774-775.
[15] Johnson, N.L. Air Force Magazine, March 1981, p. 92.

movement compensation process.[16] The high correlation between his classification and those of the Kettering Group based on criteria of transmission frequency, telemetry format and recovery beacon provides strong support for the contention that these missions have a photographic reconnaissance role.

Examples of the various mission profiles employed are given in the annex to this chapter.

Identification of possible targets

Soviet Space Programs, 1971–75 gave examples of various occasions on which the probable target for these missions could be identified with reasonable certainty, notably in the cases of the Indo-Pakistani and Arab-Israeli wars. The best current example is provided by observations for what was presumed to be an atmospheric test of a nuclear device by the Republic of South Africa in 1977. This was identified by Bhupendra Jasani, of the Stockholm International Peace Research Institute.[17] Kosmos 922, a low-resolution, area-surveillance type made passes over the test site on July 3 and 4. One week after it was recovered, a maneuverable, high-resolution, close-look satellite, Kosmos 932, was launched from Plesetsk. Two days later, just before passing over the test site. Its perigee was lowered to stabilize the ground-track and give four good passes over the test site between July 21 and 24. Its apogee was then raised to preserve its 13-day mission. Kosmos 932 was recovered on August 2. Some indication of the speed of processing data can be obtained from the fact that, only 4 days later, the Soviet Union informed the United States, France, the Federal German Republic, and the United Kingdom that South Africa was secretly preparing to detonate an atomic explosion in the Kalahari Desert. After considerable diplomatic activity, it was announced that South Africa had promised that "no nuclear explosive test will be taken * * * now or in the future."[18]

Berman and Baker[19] give a number of instances when, they claim, Soviet satellites have overflown certain targets prior to, or during, periods of military importance or crisis. Some of these connections have been made by other authors whose publications are cited in their book. These include the Indo-Pakistani conflict in 1971, the October War in the Middle East in 1973, and the potential detonation of a nuclear device by the Republic of South Africa just described.

Other examples are less convincing being based mainly on coincidences between particular events and Kosmos satellites listed in a comprehensive table of launches in the TRW Space Log. Great care must be taken when adopting such an approach, particularly in more recent times when something approaching continuous surveillance has been achieved. The claim that Kosmos satellites gave some forewarning of the first Chinese nuclear test in 1964, while

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[16] Johnson, N.L. Journal of British Interplanetary Society, vol. 34, 1981, pp. 197–199.

[17] SIPRI Yearbook 1978: World Armaments and Disarmament. London, Taylor and Francis, 1978, pp. 73–79.

[18] Marder, N., and D. Oberdorfer. Washington Post, Aug. 28, 1977.

[19] Berman, R.P., and J.C. Baker. Soviet Strategic Forces—Requirements Response (The Brookings Institution, 1982), app. E, pp. 155–164.

not totally disputed, does not stand up well to closer investigation. Berman and Baker write,

> They had launched two recoverable satellites in August and two in September 1964, including one whose orbital parameters would have taken it in over China. Two days before the Chinese nuclear detonation, in October, the U.S.S.R. launched a satellite that was recovered after only a 6-day flight (a normal mission was 8 days).

The two references cited were both to the TRW Space Log 1975, pages 49–50. Inspection of that publication shows, correctly, that one recoverable satellite only, Kosmos 37, an 8-day flight at 65° inclination, was launched during August. Of the two recoverable satellites launched in September, Kosmos 45, a 5-day flight, also at 65°, was announced as having carried a meteorological experiment. Kosmos 46 flew for 8 days at an inclination of 51.3°. Presumably this was the satellite whose "orbital parameters would have taken it over China." Since only a small part of China lies above 50 °N and no Soviet reconnaissance satellite has flown at inclinations of less than 51°, it will be seen that such a claim is meaningless because all Soviet recoverable reconnaissance satellites overfly China. Furthermore, if 51.3° was such a special inclination, why did Kosmos 48, launched 2 days before the detonation, fly at 65°?

Jasani's attempt to link the Otrag launches from Zaire to the satellites which observed the preparations for the South African incident is likewise subject to dispute.[20] Situated as it was, just south of the Equator, the Otrag site would have been overflown by all satellites in orbit at that time.

Photo-coverage, television relay

The question of whether or not the long-duration, fourth generation payloads are recovered at the termination of the mission has not yet been satisfactorily resolved. Rarely are fragments cataloged at the end of these flights whereas, in all other missions, one or more fragments appear in orbit immediately prior to or just after the payload is recovered. The Kettering Group has not observed recovery beacons from these satellites because the end of mission comes in the very early morning hours in Europe. Moreover, since Western Europe is in darkness at these times, it is extremely doubtful if such signals could be received if they did exist.

It has been reported earlier that TV recovery beacons have been observed during the early stages of these flights and are believed to originate from film capsules returned to Earth around the 9th and 18th days of the mission. It seems probable that the fourth generation spacecraft return imagery by television relay throughout the mission right up to its end in the manner of the U.S. KH-11 satellites,[21] but such transmissions have not been intercepted by the Kettering Group.

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[20] Ibid . SIPRI Yearbook 1978, pp. 79–82.

[21] Writing on "Satellite Photograph Interpretation" in Space flight, the British Interplanetary Society's magazine, in Apr. 1982, Curtis Peebles, described the KH-11 as a digital image satellite which could transmit imagery to a ground station almost instantly. Spaceflight, vol. 24, April 1982, p. 161.

MANNED OBSERVATION

It would be naïve to discount the probability of Soviet cosmonauts making observations from the Salyut space stations at the request of the military authorities. Indeed, as described in part 2 of this study, Salyuts 3 and 5, which flew in low orbits and employed telemetry of similar format to the first generation recoverable satellites, in addition to carrying all-military crews, are generally regarded by Western analysts to have been predominantly military in character. As mentioned earlier in this chapter, distinctions between civil and military-oriented experiments became less clear during the long Salyut 6 mission which commenced in 1979. Much time was devoted to the observation of the Earth from space and, by the end of the manned missions to Salyut 6 in 1982, some 13,000 photographs had been obtained using the KATE-140 and MKF-6M cameras.[22] Analysis of space photography returned from Salyut 6 provided much information about the nature of ocean currents and their boundaries revealing variations in the surface of the ocean ranging from 112 meters below mean sea level to 78 meters above.[23]

For a more detailed account of the Salyut missions the reader is referred to chapter 3 of part 2 of this study (Manned Programs).

RADAR RECONNAISSANCE

Ocean surveillance; RORSATS with the F-1-m

There are some frequencies of the electromagnetic spectrum which will penetrate cloud cover. In the Earth resources area, passive microwave affords one such opportunity. It is not clear whether resolutions are such as to give data beyond the level of climate and soil conditions to anything of military usefulness like order of battle.

One of the interesting exercises in which long range Soviet aircraft have engaged is that of locating U.S. carrier task forces at sea. The press has carried pictures of Bear turboprops with eight contrarotating propellers flying in mid-Atlantic or mid-Pacific, often with U.S. carrier aircraft or Royal Air Force planes flying alongside taking pictures in turn. In general, one assumes, the Soviet task of locating U.S. ships which may carry a nuclear strike capability is easier if the weather is good and if the U.S. ships are revealing their presence by carrying on regular radio communications, permitting radio direction finding. Acoustic signals from propellers in the water are used also for locating ships even over great distances, and are especially important in monitoring submarine activities since the latter, if nuclear powered, may not surface for long periods and may practice tight radio security.

Presumably the Soviets would have a strong motivation to develop technology for locating U.S. naval vessels at sea even when they maneuver to stay under cloud cover and when they keep their radio transmitters and radar sets turned off. An obvious approach would be to orbit radar equipment capable of making rapid, wide

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[22] Feoktistov, K. To Future Orbits. Pravda (Moscow, June 9, 1981), p. 3.
[23] Moscow Home Service, Feb. 13, 1980, 1530 G.m.t.

area searches, in any weather, from space. However, providing an adequate power supply and developing a system capable of both wide area searches and detailing what has been discovered with a signature which can be interpreted is no small feat.

Kosmos satellites with orbital periods of 89.5 minutes and inclinations of 65°, but differing from recoverable photographic reconnaissance satellites by having their perigees around 250 to 260 kilometers, appeared in 1967.

Commencing with Kosmos 651 and 654, these satellites operated in pairs and station-keeping was rigidly enforced. Orbital planes were coplanar and a 23-minute time difference was maintained during the operational phase so that ground tracks were displaced by some 6° from each other.

Table 47, compiled by the late Dr. Charles Sheldon, lists Kosmos satellites with RORSAT missions through the end of 1980.

TABLE 47.—SOVIET RADAR OCEAN SURVEILLANCE SATELLITES

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay date	Days life	Remarks
1967								
Dec. 27	198	281	265	65.1	89.8			Tass announcement.
		270	249	65.1	89.7			RAE original data.
		952	894	65.2	103.4			RAE, separated and moved up Dec. 29, 1967, after 2 days.
		239	224	65.1	89.1	Dec. 31, 1967	4	RAE, rocket, after separation.
		273	241	65.1	89.6	Jan. 21, 1968	25	RAE, platform, after separation.
1968								
Mar 22	209	282	250	65.1	89.6			Tass announcement.
		343	183.	65.0	89.7			RAE original data.
		944	871	65.3	103.1			RAE, separated and moved up Mar. 28, 1968, after 6 days.
		236	210	65.1	89.0	Mar. 25, 1968	3	RAE, rocket, after separation.
		267	227	65.1	89.5	Apr. 10, 1968	19	RAE, platform, after separation.
1970								
Oct 3	367	280	250	65.2	89.6			Estimated original orbit.
		1,030	932	65.3	104.5			Tass announcement.
		1,024	922	65.3	104.5			RAE, separated and moved up Oct. 3, 1970, after 0 day.
		246	226	65.2	89.2	Oct. 6, 1970	3	RAE, rocket, after separation.
		264	246	65.1	89.6	Oct. 31, 1970	28	RAE, platform, after separation.
1971								
Apr 1	402	279	261	65	89.7			Tass announcement.
		274	247	65.0	89.7			RAE original data.
		1,036	948	65.0	104.9			RAE, separated and moved up Apr. 9, 1971, after 8 days.
		258	239	65.0	89.5	Apr. 6, 1971	5	RAE, rocket, after separation.
		263	247	65.0	89.6	May 6, 1971	35	RAE, platform, after separation.
Dec 25	469	276	259	65	89.7			Tass announcement.
		262	249	65.0	89.6			RAE original data.
		1,023	941	64.5	104.7			RAE, separated and moved up Jan. 4, 1972, after 10 days.
		255	244	65.0	89.5	Jan. 7, 1972	13	RAE, rocket, after separation.
		261	247	65.0	89.6	Feb. 9, 1972	46	RAE, platform, after separation.
1972								
Aug 21	516	277	256	65	89.6			Tass announcement.
		263	251	65.0	89.6			RAE initial data.
		1,030	920	64.8	104.6			RAE, separated and moved up Sept. 21, 1972, after 31 days.

TABLE 47.—SOVIET RADAR OCEAN SURVEILLANCE SATELLITES—Continued

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay date	Days life	Remarks
		255	239	65.0	89.4	Sept. 25, 1972	35	RAE, rocket, after separation.
		259	243	65.0	89.5	Oct. 20, 1972	60	RAE, platform, after separation.
1973								
Dec. 27	626	280	257	65	89.7			Tass announcement.
		259	257	65.0	89.7			RAE original data.
		990	910	64.9	104.0			RAE, separated and moved up Feb. 11, 1974, after 46 days.
		296	234	65.0	89.8	Feb. 23, 1974	58	RAE, rocket, after separation.
		257	237	65.0	89.4	Mar. 22, 1974	85	RAE, platform, after separation.
1974								
May 15	651	276	256	65	89.6			Tass announcement.
		264	250	65.0	89.6			RAE original data.
		954	892	65.0	103.5			RAE, separated and moved up July 25, 1974, after 71 days.
		258	243	65.0	89.5	July 30, 1974	76	RAE, rocket, after separation.
		262	245	65.0	89.6	Sept. 5, 1974	113	RAE, platform, after separation.
May 17	654	277	261	65	89.7			Tass announcement.
		265	248	65.0	89.6			RAE original data.
		1,024	913	65.0	104.4			RAE, separated and moved up July 30, 1974, after 74 days.
		261	248	65.0	89.6	Aug. 4, 1974	79	RAE, rocket, after separation.
		226	203	65.0	88.8	Sept. 7, 1974	113	RAE, platform, after separation.
1975								
Apr. 2	723	277	256	65	[illegible]			Tass announcement.
		266	249	65.0	89.6			RAE original data.
		952	917	64.7	103.7			RAE, separated and moved up May 16, 1975, after 46 days.
		259	251	65.0	89.6	May 21, 1975	49	RAE, rocket, after separation.
		263	254	65.0	89.7	July 15, 1975	104	RAE, platform after separation.
1975								
Apr. 7	724	276	258	65	89.7			Tass announcement.
		266	248	65.0	89.6			RAE original data.
		937	869	65.0	104.3			RAE, separated and moved up June 12, 1975, after 65 days.
		255	245	65.0	89.5	June 17, 1975	71	RAE, rocket, after separation.
		262	248	65.0	89.6	Aug. 7, 1975	122	RAE, platform, after separation.
Dec. 12	785	278	259	65	89.7			Tass announcement.
		261	251	65.0	87.6			RAE original data.
		1,023	898	65.1	104.3			RAE, separated and moved up Dec. 13, 1975, after 1 day. Different frequency.
		283	241	65.0	89.7	Dec. 14, 1975	2	RAE, rocket, after separation.
		260	248	65.0	89.6	Feb. 5, 1976	55	RAE, platform, after separation.
1976								
Oct. 17	860	278	260	65	89.6			Tass announcement.
		265	252	65.0	89.7			RAE original data.
		1,008	919	64.7	104.7			RAE, separated and moved up Nov. 10, 1976, after 24 days.
		257	243	65.0	89.5	Nov. 15, 1976	29	RAE, rocket, after separation.
		261	244	65.0	89.5	Dec. 29, 1976	73	RAE, platform, after separation.
Oct. 21	861	280	256	65	89.6			Tass announcement.
		265	251	65.0	89.7			RAE original data.
		1,005	921	64.9	104.3			RAE, separated and moved up Dec. 20, 1976, after 60 days.
		253	226	65.0	89.3	Dec. 25, 1976	65	RAE, rocket, after separation.
		262	244	65.0	89.6	Feb. 4, 1977	107	RAE, platform, after separation.
1977								
Sept. 16	952	278	258	65	89.7			Tass announcement.
		265	251	65.0	89.7			RAE original data.

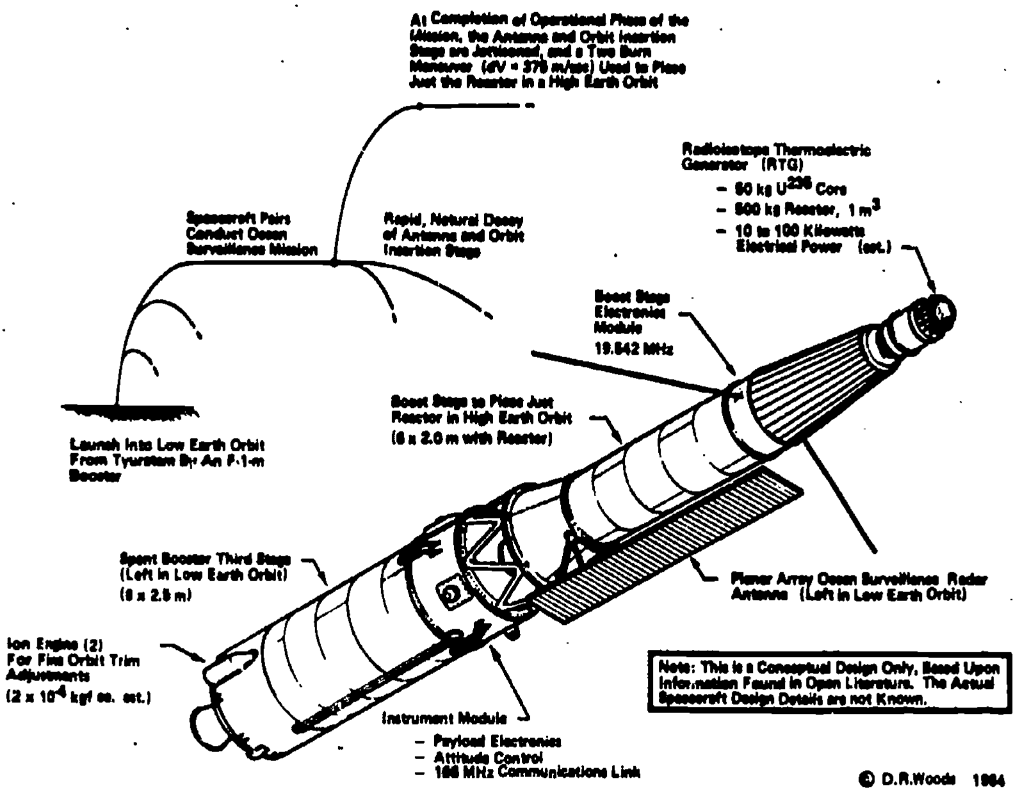
TABLE 47.—SOVIET RADAR OCEAN SURVEILLANCE SATELLITES—Continued

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay date	Days life	Remarks
		998	910	65.0	104.1			RAE, separated and moved up Oct. 8, 1977, after 22 days.
		233	224	65.0	89.1	Oct. 11 1977	25	RAE, rocket, after separation.
		253	235	65.0	89.4	Nov. 7, 1977	52	RAE, platform, after separation.
Sept. 18	954	277	259	65	89.6			Tass announcement.
		265	251	65.0	89.7	Jan. 24, 1978	128	RAE original data. Failed to separate and to ascend to higher orbit; decayed over northern Canada, leaving radio active residue.
1980								
Apr 29	1176	265	260	65	89.6			Tass announcement.
		266	250	65.0	89.7			RAE original data.
		966	870	64.8	103.4			RAE, separated and moved up Sept. 10, 1980, after 134 days.
		252	229	65.0	89.3	Sept. 12, 1980	136	RAE, rocket, after separation.
		264	244	65.0	89.6	Oct. 4, 1980	158	RAE, platform, after separation.

This type of satellite does not separate from the second stage of the launch vehicle on being placed into orbit. After an operational phase during which micromaneuvers maintain a circular orbit close to 260 km against the effects of drag, part of the payload separates from the second stage and is boosted into a much higher circular orbit from whence decay is of the order of several hundred years. It was deduced that this part contained a nuclear reactor for providing the power for a side-looking radar in the lower orbit using a slot-antenna built into the side of the second stage. Some confirmation of this was obtained following the uncontrolled reentry of Kosmos 954 in January 1987 when it was revealed that the reactor was fueled with 50 kg of enriched Uranium 235.

Kosmos 954 had worked with Kosmos 952 during its operational phase and was expected to follow Kosmos 952 into the "safe" orbit some time in November 1977. However, early in that month, it entered a regime of natural decay suggesting that it would reenter the Earth's atmosphere some time in the following March. On January 6 it lost attitude control and the decay accelerated, causing it to spread debris over a wide area of northern Canada on January 24. No further satellites in this series were launched following this catastrophe until Kosmos 1176 more than 2 years later.

Figure 63 is a conceptual drawing, based upon information found in open literature, of a possible configuration for such a spacecraft. The actual spacecraft design details are not publicly known and the artist has adopted a planar array antenna rather than the slot antenna mentioned above.



Note: This is a Conceptual Design Only, Based Upon Information Found in Open Literature. The Actual Spacecraft Design Details are not Known.

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FIGURE 63.—Conceptual Drawing of a RORSAT

At first it was believed that a Romashka (Camomile) reactor had been used to provide electrical power for Kosmos 954,[24] but it is now thought that the smaller Topaz reactor-converter, working on the thermionic rather than the thermoelectric principle, was employed.[25] The thermionic converter has two metallic elements, an emitter and a collector. When the emitter is heated to a temperature between 1,000° and 2,500° K, it emits electrons (thermionic emission). They are collected by a concentric electrode at a lower temperature separated from it by a few microns with cesium vapor in the gap to encourage the electron flow. Figure 64 is a sectioned drawing of the device, which maintained a power production of 10 kW for 1,600 hours in tests at the Physics and Power Engineering Scientific Research Institute, where it was designed, and was then maintained at another unspecified lower power level for a further 6,000 hours.[26]

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[24] Operation Morning Light. Canadian Northwest Territories, U.S. Department of Energy, 1978.

[25] Reese, R.T., and C.P. Vick. Journal of British Interplanetary Society, vol. 36, 1983, pp. 457–462.

[26] Petrov, B.N., ed. "Basis for Automatic Control of Nuclear Space Power Sources and Equipment," Machinostroyeniye, Moscow, 1974, p. 64.

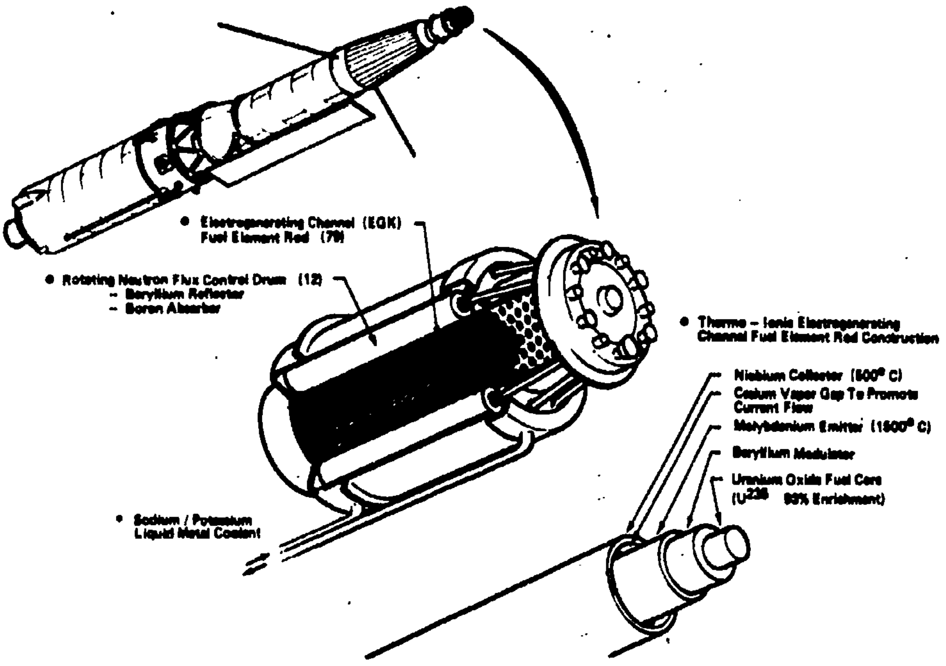

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FIGURE 64.—The "Topaz" Reactor-Powered Thermionic Converter

Cloud penetration on land

There is no evidence from open sources that synthetic aperture or any other type of radar has been used to penetrate cloud cover over land for military purposes. However, as was evident in imagery from the U.S. Seasat satellite, such a use is quite feasible and it is not beyond possibility that the Soviets could bring such a system into operation and might have already done so.

ELECTRONIC INTELLIGENCE; ELINT FERRETING

The Soviet Government has long had a reputation for giving special attention to the gathering of ELINT (electronic intelligence) data, also referred to as ferreting, or SIGINT (signal intelligence), COMINT (communications intelligence), and/or RADINT (radar intelligence). By definition, all spacecraft which receive and report on electromagnetic radiation are performing the same basic task, whether for solar studies, astronomy, weather reporting, Earth resources work, or communications.

It is still useful, however, to sort out categories of difference in origin and use of these signals. Some emissions are part of the natural environment and may obscure the receipt and recognition of those generated by man-made activities. These fall into two major subgroups: (a) those directed toward space deliberately to be picked up and relayed by satellite, and hence supporting the function of communications satellites, and (b) those not intended to be picked up by the receiving satellites, such as private messages or inadvertent leakages of signals, and hence supporting the function of ELINT, RADINT, COMINT and related categories.

Military interests extend to all natural phenomena, partly to understand the difference between natural signals and those which are man-made, and partly because many natural emissions, such as reflected light or radiated heat, translate into pictures and data defining ground, air, and space activity. Those emissions which were generated by electronic devices such as radio stations, radar equipment, microwave towers, and other spacecraft provide a general category of signals whose frequencies, power levels, locations, directions, and times of emission may answer questions of military interest. Although detection of the emissions presents technical challenges, understanding those emissions may be an even bigger challenge.

Soviet interest in ELINT is evident in such activities as the trawlers, with a forest of antennas, which follow NATO naval maneuvers, attend missile launchings and recovery areas, or cruise off the coasts of the United States. Since Soviet trawlers, naval vessels, embassies, and air and space defense systems all engage in signal gathering, it can be assumed that they also gather, by spacecraft, signals which are then relayed, either in real time or after taped-storage, to analytical centers in the Soviet Union.

EORSATS with the F-1-s

The terms EORSAT and RORSAT were introduced simultaneously by the U.S. Defense community to distinguish between the passive gathering of intelligence by monitoring the electromagnetic emanations of western navies (the EORSATs) and the active probing of the ocean surface to establish ship locations using radar techniques (the RORSATs). The EORSATs first appeared at the end of 1974. Equipped with microthrusters to overcome atmospheric drag, they make many small maneuvers to maintain their orbital period of 93.3 minutes in circular orbits at 65° inclination. This mode of operation has led to a revised designation of the launch vehicle as F-1-s, where the "s" indicates a sustaining engine rather than one capable of major maneuvers.

Table 48 lists flights in this category through the end of 1980.

Kosmos 1094 and 1096 operated together as a pair in the manner of the RORSATs following the Kosmos incident. Kosmos 1167 and Kosmos 1220, launched with an interval of 8 months between them in 1980 operated as a pair, rather than Kosmos 1220 being a replacement for the earlier satellite, and were in planes spaced such that the ground track of one satellite fell precisely midway between ground tracks of the other.[27]

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[27] Perry, G E., G P Sharpling, T A. Sharpling, and S. Grahn. Flight International, vol. 118, 1980, p 2278

TABLE 48.—SOVIET ELINT OCEAN SURVEILLANCE SATELLITES WITH ELECTRIC PROPULSION

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay	Days	Remarks
1974								
Dec. 24	699	454	436	65	93.2			Tass announcement.
		418	114	64.9	89.8			RAE initial data.
		440	428	65.0	93.3	Oct. 16, 1977	1,027	RAE adjusted orbit. Partially disintegrated Apr. 17, 1975.
		358	114	65.0	89.2	Dec. 25, 1974	1	RAE, rocket.
1975								
Oct. 29	777	456	437	65	93.3			Tass announcement.
		412	120	65.0	89.8			RAE initial data.
		442	425	65.0	93.3	June 3, 1976	218	RAE adjusted orbit. Partially disintegrated January 1976.
		373	118	65.0	89.4	Oct. 30, 1975	1	RAE, rocket.
1976								
July 2	838	456	438	65	93.3			Tass announcement.
								RAE initial data (missing).
		440	428	65.1	93.3	Aug. 23, 1977	371	RAE adjusted orbit. Disintegrated June/July 1977.
		382	117	65.0	89.5	July 3, 1976	1	RAE, rocket.
Nov. 26	868	457	438	65	93.3			Tass announcement.
		436	110	65.1	89.9			RAE initial data.
		444	422	65.0	93.3	July 8, 1978	589	RAE adjusted orbit.
		303	113	65.0	88.6	Nov. 27, 1976	1	RAE, rocket.
1977								
Aug. 24	937	457	438	65	93.3			Tass announcement.
		597	149	65.1	92.1			RAE initial data.
		444	424	65.0	93.3	Oct. 19, 1978	421	RAE adjusted orbit.
		379	100	65.0	89.3	Aug. 25, 1977	1	RAE, rocket.
1979								
Apr. 18	1094	457	437	65	93.3			Tass announcement.
								RAE initial data (missing).
		442	426	65.0	93.3	Nov. 7, 1979	203	RAE adjusted orbit.
		382	105	65.0	89.4	Apr. 18, 1979	0	RAE, rocket.
Apr. 25	1096	457	439	65	93.3			Tass announcement.
								RAE initial data (missing).
		442	428	65.1	93.3	Nov. 24, 1979	213	RAE adjusted orbit.
		370	113	65.0	89.3	Apr. 25, 1979	1	RAE, rocket.
1980								
Mar. 14	1167	457	433	65	93.3			Tass announcement.
								RAE initial data (missing).
		442	426	65.0	93.3			RAE adjusted orbit.
		280	98	65.0	88.3	Mar. 14, 1980	1	RAE, rocket.
Nov. 4	1220	454	432	65	93.3			Tass announcement.
								RAE initial (missing).
		440	427	65.0	93.3			RAE adjusted orbit.
		316	111	64.9	88.7	Nov. 5, 1980	1	RAE, rocket.

When natural decay takes over at the end of their active lives, some have been raised to higher orbits, removing them from the vicinity of their replacements and it is not unusual for fragmentation to occur at a later date.

Nicholas Johnson has pointed out that there appears to be an inter-group relationship for the RORSATs and EORSATs in that their orbital planes invariably differ by some 150°.[28]

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[28] Johnson, N.L. Spacecraft and Rockets, vol. 19, (1982), pp. 113-117.

ELINT with the C-1 and A-1

The Kettering Group has not intercepted transmissions from Soviet satellites which might be presumed to have an ELINT role, so it is only possible here to demonstrate that certain systems can provide the necessary global coverage with constellations of satellites deployed in orbital planes spaced at regular intervals around the Earth. Such systems include satellites at 74° inclination with periods of 95.2 min, and others at 81.2° with periods of 97.4 min, reminiscent of the early Meteor weather satellites. Both systems are launched from Plesetsk, the first by C-1 and the other by A-1. The smaller satellites, launched by the C-1, flew in operational groups of four with their orbital planes spaced at 45°.[29] The dramatic effect of the increased solar activity on the atmospheric density during 1980 caused the majority of these satellites to decay from orbit due to the increased drag and two only, Kosmos 1114 and Kosmos 1215 existed into 1981.[30]

Table 49 lists these satellites and was prepared by the late Dr. Charles Sheldon.

Table 50, in which adjacent columns represent orbital plane-spacings of 45° of longitude at the Equator, shows how these satellites were positioned in relation to the other members of the subset and reveals the sequence of replacement. Between the end of October 1968, and the launch of Kosmos 395 in February 1971, the system evolved into four satellites which were operational at any one time, with Kosmos 330 and 387 replacing Kosmos 250 and 269 respectively. The launches of Kosmos 425, 460, 479 and 536 in 1971 and 1972, suggested that the operational system was being extended to eight satellites. Such an interpretation implied that Kosmos 500, launched as a replacement for Kosmos 425 would have had an operational lifetime in excess of 4 years since it was not until December 1976 that another satellite, Kosmos 870, was placed in the same orbital plane as Kosmos 500, which had been launched in July 1972. In view of the usual rate of replacement of such payloads, such an interpretation seems untenable.

Furthermore, the failure to provide replacements for Kosmos 749, 781, 787, and 790, in their own orbital planes, during the period 1976-1980, lends support to the hypothesis that there never were more than four satellites operational at any one time, and that Kosmos 812 and its early replacement, Kosmos 845, merely provided a transition to planes in the opposite hemisphere.

Kosmos 358 and Kosmos 1186 are not considered as members of this subset since their orbital planes did not form part of the system. The very long life of Kosmos 358 in comparison with Kosmos 330 and 387 suggests that it was of a different configuration and density which resulted in a slower decay-rate.

The larger, A-1 launched, satellites fly in operational groups of six with their orbital planes spaced at 60°. Table 51, also prepared by the late Dr. Charles Sheldon, lists these satellites through the end of 1980.

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[29] Perry, G.E., and Sarah M. Mobbs. Spaceflight. vol. 22, 1980, pp. 38-39.

[30] Perry, G.E., in Outer Space—A New Dimension of the Arms Race, ed. B. Jasani, SIPRI, 1982, pp. 144-145

Table 52, prepared by Darren Conway of Kettering Boys School, shows the orbital plane-spacings of these satellites and the replacement sequence since mid-1975, with adjacent columns representing orbital plane-spacings of 60° of longitude at the Equator.

TABLE 49.—SOVIET ELINT FERRET MISSIONS WITH THE C-1 LAUNCH VEHICLE

Launch date	Kosmos number	Launch Site		Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay date	Days life	Remarks
		TT	PL							
1965										
Dec. 28	103	X		600	600	56	97.0			Vehicle test.
1967										
Mar. 24	151	X		630	630	56	97.1			Vehicle test.
Oct. 30	189		X	600	535	74	95.7	June 8, 1978	3,874	
1968										
Jan. 19	200		X	536	536	74	95.2	Feb. 24, 1973	1,863	
Aug 27	236	X		655	600	56	96.9			Vehicle test.
Oct. 30	250		X	556	523	74	95.3	Feb. 15, 1978	3,395	
1969										
Mar. 5	269		X	558	526	74	95.3	Oct. 21, 1978	3,517	
Dec. 20	315		X	556	521	74	95.3	Mar. 25, 1979	3,382	
1970										
Apr. 7	330		X	548	514	74	95.2	June 12, 1979	3,353	
Aug. 20	358		X	549	517	74	95.2			
Dec. 16	387		X	560	528	74	95.3	Jan. 19, 1980	3,321	
1971										
Feb 17	395		X	570	534	74	95.4	Apr. 6, 1980	3,336	
May 29	425		X	556	511	74	95.3	Jan. 15, 1980	3,153	
Sept. 7	436		X	550	514	74	95.2	Jan. 4, 1980	3,041	
Sept. 10	437		X	558	523	74	95.3	Mar. 29, 1980	3,123	
Nov 30	460		X	553	520	74	95.2	Mar. 5, 1980	3,018	
1972										
Mar 22	479		X	549	517	74	95.2	Apr. 13, 1980	2,944	
July 10	500		X	554	509	74	95.2	Mar. 29, 1980	2,819	
Nov. 3	536		X	555	514	74	95.2	July 20, 1980	2,816	
1973										
Jan 20	544		X	561	513	74	95.3	June 15, 1980	2,703	
Feb 28	549		X	556	513	74	95.2	June 29, 1980	2,678	
Aug 28	582		X	559	521	74	95.2	Sept. 5, 1980	2,565	
Nov 27	610		X	560	515	74	95.2	Sept. 15, 1980	2,484	
1974										
Feb 6	631		X	565	522	74	95.3	Oct. 4, 1980	2,431	
May 21	655		X	549	520	74	95.2	Nov. 19, 1980	2,374	
June 21	661		X	555	513	74	95.0	Aug. 27, 1980	2,259	
Dec 18	698		X	566	515	74	95.3	Dec. 9, 1980	2,183	
1975										
Feb 5	707		X	550	505	74	95.2	Sept. 7, 1980	2.041	
July 4	749		X	557	511	74	95.3	Sept 26, 1980	1.911	
Nov 21	781		X	557	508	74	95.2	Nov. 26, 1980	1.832	
1976										
Jan 6	787		X	564	519	74	95.3	Dec. 12, 1980	1.802	
Jan. 23	790		X	559	513	74	95.2	Nov. 12, 1980	1,756	
Apr 6	812		X	558	504	74	95.2	Oct. 30, 1980	1,668	
July 27	845		X	557	505	74	95.2	Nov. 15. 1980	1,572	
Dec 2	870		X	560	511	74	95.3	Dec. 20, 1980	1,479	

TABLE 49.—SOVIET ELINT FERRET MISSIONS WITH THE C-1 LAUNCH VEHICLE—Continued

Launch date	Kosmos number	Launch Site		Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay date	Days life	Remarks
		TT	PL							
1977										
Mar. 24	899		X	552	505	74.1	95.2	Oct. 19, 1980	1,305	
July 14	924		X	560	514	74	95.3	Feb. 10, 1981	1,317	
Oct. 25	960		X	549	505	74	95.1	Oct. 22, 1980	1,093	
1978										
May 17	1008		X	551	501	74	95.1	Jan. 8, 1981	967	
Dec. 15	1062		X	548	508	74	95.1			
1979										
July 11	1114		X	558	507	74	95.2			
1980										
Oct. 14	1215		X	550	498	74	95.1			

TABLE 50.—REPLACEMENT SEQUENCE OF KOSMOS "ELINT" SATELLITES

```
          250
     269 ....
315 .........
......... 330
.... 387 ....
............. 395
     ............. 425
     .... 436 .........
     ......... 437 ....
          ............. 460
               ............. 479
               .... 500 .........
                    ............. 536
                    .... 544 .........
                         ............. 549
                              ............. 610
                              631 .............
                              .... 655 .........
                                   ............. 661
                                   .... 698 .........
                                        ............. 707
                                        .... 749 .........
                                        781 .............
                                   787 .............
                              790 ..............
                         812 .............
                         845 .............
                    870 .............
               899 .............
          924 .............
          ......... 960 ....
          ............. 1008
          ... 1062 .........
         1114 .............
```

From: G. E. Perry and Sarah M. Mobbs, Spaceflight, 22, 1980. p. 38-39.

Orbital-plane spacings 45° between adjacent columns.

TABLE 51.—SOVIET ELINT FERRET MISSIONS WITH THE A-1 LAUNCH VEHICLE

Launch date	Kosmos numer	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)
1970					
Dec. 18	389	699	655	81	98.1
1971					
Apr. 7	405	706	676	81.3	98.3
1972					
Mar. 1	476	651	618	81.2	97.2
Dec. 28	542	653	554	81.2	96.4
1973					
Oct. 29	604	647	624	81.2	97.2
1974					
Aug. 16	673	648	620	81.2	97
1975					
June 20	744	650	612	81.2	97.1
Aug. 22	756	649	627	81.2	97.3
1976					
Mar. 16	808	647	618	81.3	97.1
Aug. 27	851	649	592	81	96.2
1977					
Feb. 27	895	648	613	81.2	97.2
July 7	925	645	622	81.2	97.2
Sept. 20	955	664	631	81.2	97.5
1978					
Jan. 10	975	680	637	81.2	97.6
May 12	1005	672	626	81.2	97.6
Oct. 10	1043	650	625	81.1	97.3
Dec. 19	1063	661	632	81.2	97.5
1979					
Feb 14	1077	651	629	81.2	97.2
Apr. 14	1093	650	625	81.3	97.3
July 20	1116	649	608	81.2	97.1
Oct. 26	1143	665	625	81.2	97.4
Nov. 27	1145	652	629	81.2	97.3
1980					
Jan 30	1154	671	634	81.3	97.3
Aug 15	1206	659	630	81.2	97.4
Nov. 21	1222	659	624	81.2	97.4

3

TABLE 52.—REPLACEMENT SEQUENCE OF A-1 LAUNCHED ELINT FERRET SATELLITES

				756	
			808		
		851			
				895	
					925
955					
	975				
			1005		
1043					
				1063	
					1077
			1093		
		1116			
	1143				
1145					
			1154		
1184					
		1206			
	1222				

NOTES:

1. Launches shown by Kosmos number.
2. Each column is separated from its neighbor by 60° in right ascension of the ascending nodes.

EARLY WARNING OF MISSILE AND SPACE LAUNCHES

Certain satellites in the Kosmos series have been placed into orbits with parameters suspiciously close to those of Molniya communications satellites. They have inclinations initially between 62° and 66°, eccentricities close to 0.74, and orbital periods approximately 12 hours.

Early Kosmos launches having such parameters were probably tests of the Molniya satellite or the Molniya orbit. Others came to be regarded as Molniya failures. Using the right ascensions of the ascending modes taken from NASA's Goddard Space Flight Center's two line orbital elements, Perkins and Perry[31] established that the Molniya satellites, from Molniya-1/11 on, fell into well-defined groups, spaced originally at 120° intervals and currently at 90° intervals, giving continuous communications coverage to the network of ground-stations in the Orbita system.

Kosmos 520, 606, 665 and 706 did not fit into these groups, however, and one orbital parameter, the argument of perigee, for each of these satellites differed significantly from that of the Molniyas, having values close to 315° rather than 280°. Clearly this was no mere coincidence and the Kettering Group concluded that a new mission category had been inaugurated.

Since then, analysis of groupings by orbital plane has shown that Kosmos 837, 853,[32] and 1175 have been Molniya failures and not early warning satellites.

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[31] Perkins, P.J., and G.E. Perry. Flight International, 107, 79, Jan. 16, 1975.

[32] Perry, G.E., R.A.F. Qy., vol. 17 (autumn 1977), p. 277.

Ground-track

Figures 65 and 66 show the ground-tracks of typical Molniya and Kosmos satellites with these semi-synchronous orbits. It will readily be seen that relocation of the perigee affects the shape of the ground-track considerably. The Northern Hemisphere loops near apogee are much broader than those of the Molniyas. However, it is the new position of the stabilized orbit which is more significant. A military early-warning satellite must be able to see into the Mid-western United States, to the Titan bases at Davis-Monthan, Mc-Connell and Little Rock, and the Minuteman bases at Malmstrom, Minot, Grand Forks, Ellsworth, Warren and Whiteman. Second, it must also be able to communicate directly with the Soviet Union.

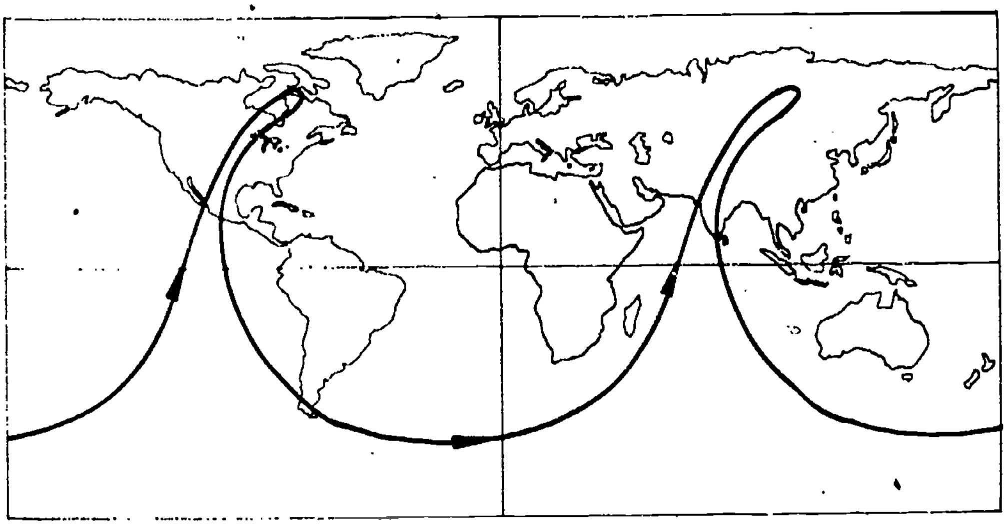

FIGURE 65.—Stabilized ground-track of the 45th Molniya 1.

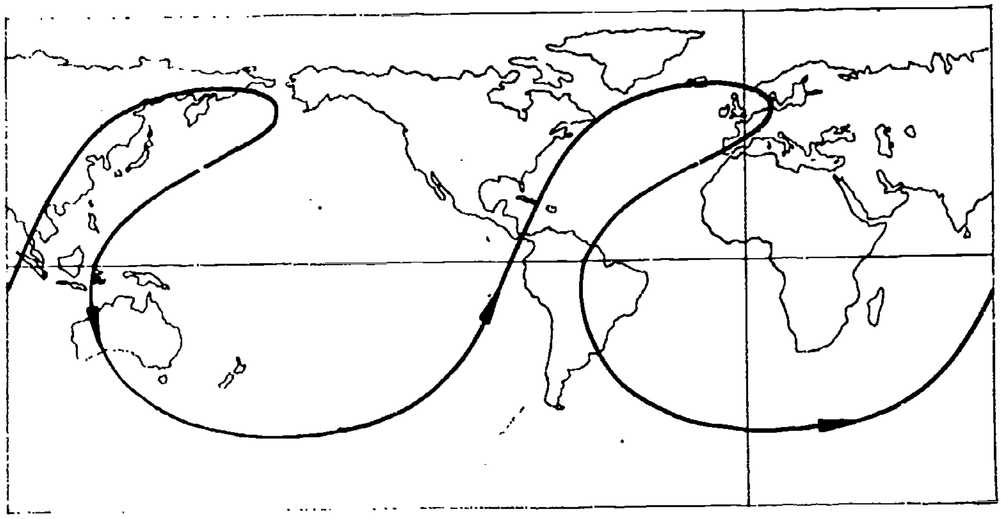

FIGURE 66.—Stabilized ground-track of Cosmos 1124.

The usual ascending node for Molniya satellites is chosen to be at 115° W and 65° E. By moving these ascending nodes 25° to the east the satellite can easily perform an early warning role for a considerable part of the orbit. After crossing the Equator near Panama, the satellite climbs steadily and 17 minutes later, at 40° N, comes into view of the Soviet Union [figure 67]. The whole of the United States will have been in view well before this time. An early warning role is possible until the satellite reaches 10° N when southbound some 9 hours later [figure 68].

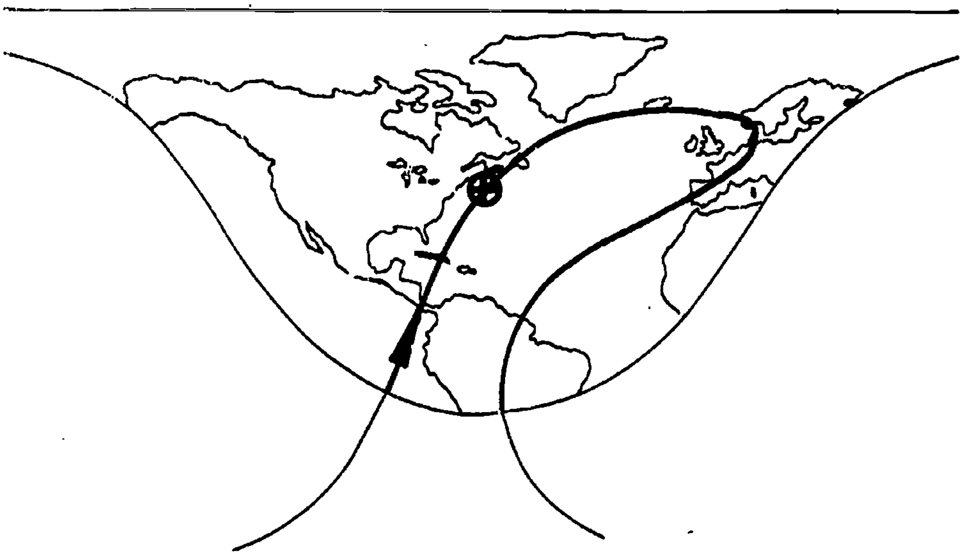

FIGURE 67.—40 °N, Equator+17 min, 5 380 km.

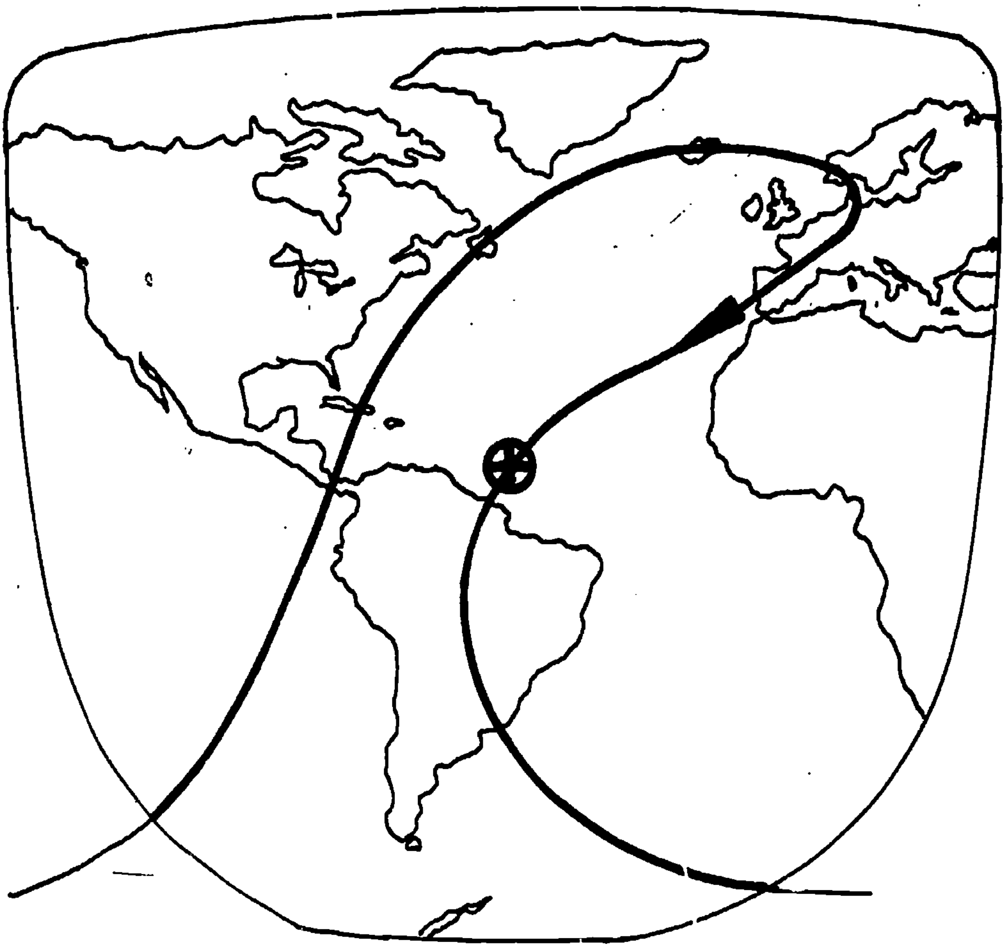

FIGURE 68.—10 °N, Equator+9 hr 26 min, 20 991 km.

The following orbit also permits early-warning coverage. Forty-five minutes after crossing the Equator west of Sumatra, the satellite is at 60 °N over the eastern part of the Soviet Union and has all the Minuteman bases, with the exception of Whiteman, in view. Soon, this and the Titan bases are also under surveillance [figure 69]. The Titan bases disappear at 40° N on the southbound portion, 4.5 hours later, and in just over another hour, at 30° N, the satellite is again unfavorably placed [figure 70]. However, it can be seen that for at least 14 hours each day early-warning surveillance is possible and a three, or perhaps only two, satellite system would give complete coverage.

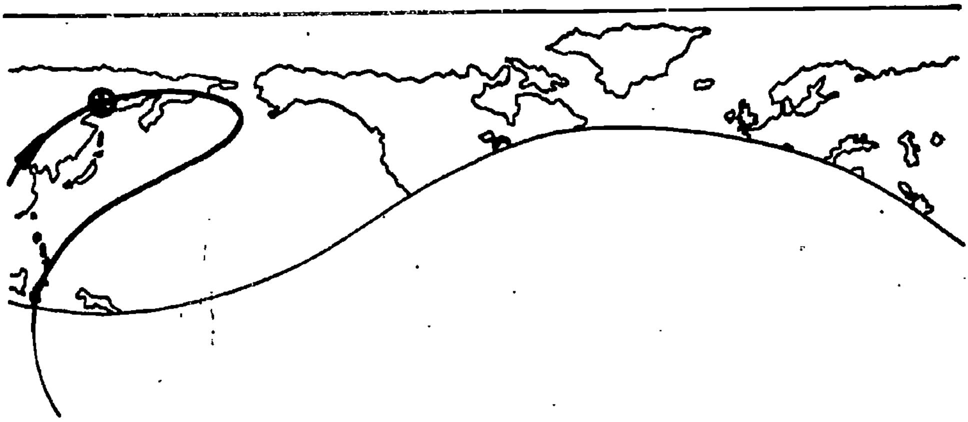

FIGURE 69.—60° N, Equator+45 min, 12 034 km.

FIGURE 70.—30° N, Equator+6 hr 54 min, 38 615 km.

Orbit stability

Allan[33] has shown that because the geopotential is slightly longitude-dependent there are two positions of the ascending node, 180° apart, for which the ground-track is stable. These positions depend, to some extent, on the value of the argument of perigee. Satellites placed elsewhere build up drift-motion which must be corrected at regular intervals. Orbits with semi-major axes of several Earth-radii can also be perturbed by luni-solar gravitational forces. For orbits of high eccentricity, the shape of the orbit can be appreciably affected and the lifetime depends critically on the initial conditions, particularly the right ascension of the ascending node.[34] This imposes a constraint on dates at which replacement satellites can be conveniently launched.

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[33] Allan, R.R. R.A.E. Tech. Rept. 69138. July 1969.
[34] Cook, C E., and Diana W. Scott. R.A.E. Technical Report 67189, August 1967.

Figure 71 shows how these periodical corrections maintained the longitudes of the ascending nodes of operational satellites close to 90° W during the latter part of 1980. Kosmos 1188 was replaced by Kosmos 1217 after only 4 months because it was no longer able to maintain station although only one correction had been performed following stabilization of the ground-track shortly after launch. It has been suggested that part of the difficulty in establishing an operational early-warning system has been due to stability problems, but whether this refers to attitude stability or ground-track stability is not clear.[35]

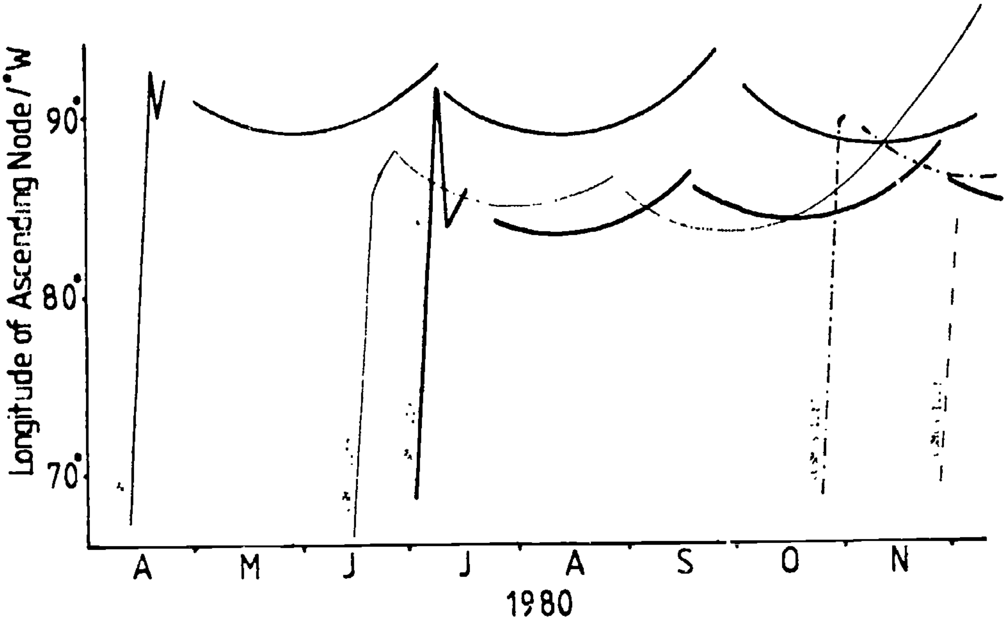

FIGURE 71.—Positional corrections of operational early warning satellites during 1980.

If the orbit is sufficiently commensurate with the ideal parameters, the ground-track librates about the stable position. The amplitude of libration should be as small as possible in an operational system. Figure 72 shows the locations of the ascending nodes of some of the operational satellites during 1978, 1979, and 1980. It will be seen that the amplitude of libration is much greater in the case of Kosmos 1030 than for Kosmos 1024. The orbit of Kosmos 1024 was corrected on four occasions before it was allowed to librate freely and it was not replaced by Kosmos 1188 until nearly 1 [illegible] after the last of those corrections, by which time it was drift-[illegible] back towards 90° W of its own accord. In some cases, as with Kosmos 1124, instead of librating, the ground-track circulates.

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[35] Soviet Aerospace, 30, Mar 2, 1981, pp 58-59

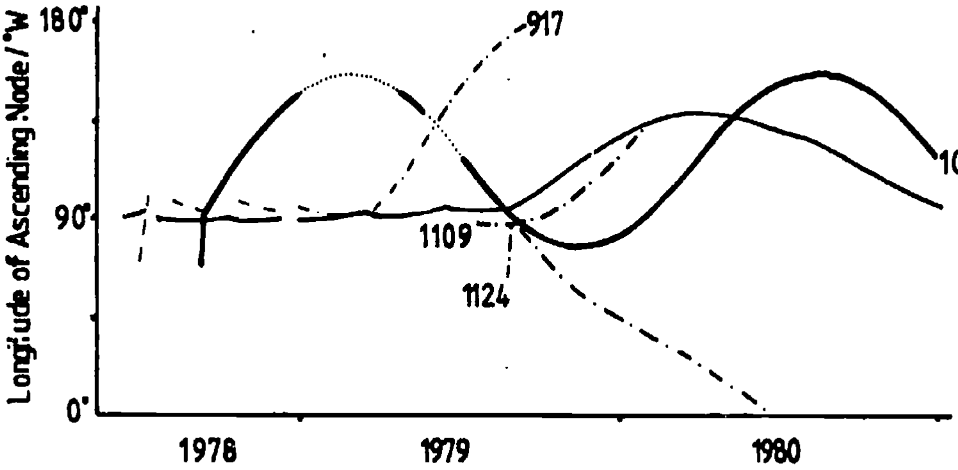

FIGURE 72.—Libration of ground-tracks of early warning satellites. Period of libration cycle for Cosmos 1030 is approximately 540 days.

On February 17, 1980, 5 days after the launch of Kosmos 1164, intended to replace Kosmos 1109, the final set of two-line elements for Kosmos 1109 were released. It is unlikely that the payload of Kosmos 1164 ever got out of the parking orbit, although NORAD issued one set of highly elliptical elements, typical of the prestabilization orbit, for what purported to be rev O. This same set of elements for Kosmos 1164, still for rev O, were reissued on March 19 and again on June 4. Ultimately, the payload was stated to have decayed on February 12, the launch date, in a decay note issued on January 26, 1981. From the outset the Russians announced a 640-220 km orbit with a period of 92.9 minutes. Since natural decay from such an orbit would be a matter of weeks it may well be presumed that the payload never separated from the launch platform, even though another object was cataloged more than 6 months after the launch by which time the launch platform and its rocket had both decayed.

Commencing with Kosmos 903 in 1977, the technique was adopted of placing the satellite in an orbit with a period in excess of 12 hours and allowing it to drift to the desired position before lowering the apogee to achieve ground-track stabilization. This is shown by the near-vertical sections at the beginning of the traces in figures 71 and 72. Kosmos 862 was stabilized much more to the east than later satellites in the series and probably could not have performed the early-warning role so effectively. Kosmos 862 is also unique in that it disintegrated in orbit. This is the only recorded disintegration in a Molniya-type orbit and raises the possibility of deliberate destruction by ground-command.

Development of an operational early warning system

Orbital plane spacing analysis by Mark Simmonds at Kettering Boys School established the development history of the early warning system.[36] Table 53 shows that following the initial development

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[36] Simmonds, M.R., unpublished.

flights an orbital plane spacing of 80° was adopted. At first the reason for this choice was obscure, but it now appears that a system of nine satellites at 40° spacings to give complete coverage is gradually being established. The 40° spacing hypothesis was reinforced by two launches in the first quarter of 1981. Kosmos 1247 was placed a further 80° away from Kosmos 1223, thus putting it only 40° away from Kosmos 1191. The placing of Kosmos 1261, launched on March 31, midway between the two most recent satellites gave six operational satellites with only three gaps remaining to be filled.

The first two satellites in the series, Kosmos 520 and 606, were placed, more or less, into the same orbital plane, the difference being only 7°. The third satellite was placed 47° away from Kosmos 606 and gave rise to speculation that a system of eight satellites at 45° spacings would evolve. This hypothesis gained support when Kosmos 706 was placed 182° away from Kosmos 606. However, Kosmos 862, the next in the series, was only 84° away from Kosmos 606 and thereafter three more satellites were added at 80° intervals. It is unlikely that more than three satellites were ever operational simultaneously. Kosmos 1024 replaced Kosmos 931 and was followed by Kosmos 1030 yet another 80° away, but only 40° from Kosmos 862 measuring in the opposite direction. The system settled down into a pattern of three satellites at 80° spacing until the appearance of Kosmos 1223, at the end of November 1980, which was placed in the same plane as Kosmos 903, 80° away from Kosmos 1172, the most elderly of the three satellites operational at that time. This suggested that there were four satellites operational.

Radio frequencies

A clue to the radio frequencies employed by the early warning satellites came when NASA's Charles Hall revealed that a loss of 45 minutes of critical data of a scan of Saturn's moon Titan by Pioneer 11 on September 3, 1979, might have been due to radio frequency interference from Kosmos 1124. Hall claimed that three satellites as well as Pioneer 11 were operating in a frequency range reserved internationally for scientific satellities, and reserved by the United States exclusively for interplanetary missions.[37]

Aviation Week & Space Technology gave the frequency band as 2.29 to 2.30 GHz.[38] Hall said that the signals from the Kosmos were 100 to 1,000 times stronger than the signals from the much more distant Pioneer. It turned out that the U.S.S.R. had complied with NASA's request to silence their satellites at the critical times on September 1 and 2, but that NASA officials had failed to realize early enough that conflict might also arise on September 3, and consequently had not requested a shut down for that period. It should be realized that Kosmos 1124 was not launched until August 28, only a few days prior to the encounter period. No trouble was experienced during the Voyager 1 encounter with Saturn in November 1980.

Launches through the end of 1980 are given in table 54 prepared by the late Dr. Charles Sheldon.

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[37] Soviet Aerospace. 16, Sept 10, 1979. pp 1-2

[38] Aviation Week & Space Technology. 113, No. 18, 32. November 1980.

TABLE 53.—REPLACEMENT SEQUENCE OF EARLY WARNING SATELLITES IN THE KOSMOS SERIES

```
          520 ....................................................................
          606 ....................................................................
665 ..............................................................................
.............................................................   706 ..........
.....................       862 ..............................................
.............................................     903 ..........................
.........................................................................    917
931 ..............................................................................
1024 .............................................................................
............      1030 ...........................................................
.........................................................................   1109
............      1124 ...........................................................
.........................................................................   1164
.........................................................................   1172
1188 .............................................................................
............      1191 ...........................................................
1217 .............................................................................
.............................................     1223 .........................
.....................       1247 .............................................
....................................      1261 ................................
```

NOTES:

1. Kosmos 1164 failed to leave the low, near-circular parking orbit and could never have become operational.
2. Main columns in the table are spaced at 40°-intervals of right ascension of ascending node.
3. Kosmos 665 and Kosmos 706 are deliberately displaced from these main columns (see text).

TABLE 54.—SOVIET EARLY WARNING SATELLITES

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
1967						
Aug. 31	174	39,750	500	64.5	715	Launched from Tyuratam, decayed Dec. 30, after 487 days.
1968						
Dec. 16	260	39,600	500	65	712	Launched from Tyuratam, decayed July 9, 1973, after 1,666 days.
1972						
Sept. 19	520	39,319	652	62.8	710	First of the Plesetsk launch series.
1973						
Nov. 2	606	39,360	626	62.8	710	
1974						
June 29	665	39,384	633	62.9	710	
1975						
Jan 30	706	39,812	625	62.8	719	
Oct. 8	775	35,900	35,900	.1	1,442	Possible use of geostationary orbit from Tyuratam for early warning test.
1976						
Oct. 22	862	39,300	610	62.8	709	Return to the Plesetsk launch series.
1977						
Apr. 11	903	40,170	630	62.8	726	

TABLE 54.—SOVIET EARLY WARNING SATELLITES—Continued

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
June 16	917	40,150	625	62.5	725	
July 20	931	40,180	600	62.8	726	
1978						
June 28	1024	40,000	630	62.8	726	
Sept. 6	1030	40,100	650	62.8	725.6	
1979						
June 27	1109	40,130	626	62.8	720	
Aug. 28	1124	40,070	620	62.8	724	
1980						
Feb. 12	1164	640	220	62.8	92.9	Probable failure in early warning program.
Apr. 12	1172	40,160	637	62.8	726	
June 14	1188	40,165	628	62.8	726	
July 2	1191	40,165	646	62.8	726	
Oct. 24	1217	40,165	642	62.8	726	
Nov. 27	1223	40,165	614	62.8	726	

A geosynchronous early warning satellite?

The mission of Kosmos 775, launched into a geosynchronous orbit by a D–1–e on October 8, 1975, has always been somewhat obscure. Thoughts that it might have been simple cover-up of a communications satellite failure received a jolt when Aviation Week & Space Technology reported its final positioning at 24° W longitude and declared it to be "the Soviet Union's first synchronous-orbit-early warning satellite." [39] It went on to say that the spacecraft had been slowing its drift-rate over to Atlantic near that location in December. It was never clear whether or not this was deliberate or a consequence of orbital dynamics and there was some uncertainty as to the authenticity of the identification of the object being tracked in that location.

Since no further launches having similar announced characteristics have appeared, one is inclined to classify this flight as some kind of engineering test.

COMMUNICATIONS, COMMAND, AND CONTROL

LONG DISTANCE LINKS: SYNCHRONOUS AND SEMISYNCHRONOUS

Semisynchronous

Early in 1976, the 32d Molniya 1 was placed into orbit with its orbital plane precisely mid-way between two of the Standard Molniya planes. Three more launches that year completed a set of four Molniya 1 satellites positioned mid-way between the standard locations. It was suggested that Molniya 1s had assumed a wholly military role, but no sooner had this been published [40] than four more Molniya 1s were replaced in the original groups. Currently, there

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[39] Aviation Week & Space Technology, vol. 104, Jan. 5, 1980, p. 9.
[40] Perry G.E. Royal Air Forces, Qy., vol. 17, summer 1977, pp. 154–162.

are eight Molniya 1s at 45° spacings with a Molniya 3 in each alternate position.

Birkhill has shown that the four inter-group Molniya 1s operate only on the Asian loop transmitting digital f.s.k. signals in what is presumed to be a military mode, whereas the other four and their accompanying Molniya 3s carry domestic traffic on both the Asian and North American loops of their ground-tracks.[41]

Molniya launches are listed in table 27 of this study.

Geosynchronous

With the introduction of communications satellites in geosynchronous orbit it is natural to presume that some military communications transponders are placed on them. Gals (Tack) satellites/transponders were planned for launch in 1979 to establish a four-satellite constellation for global military communications but no such launch has been announced by the Soviets. The uplink frequencies between 7.9 and 8.4 GHz and downlink frequencies between 7.25 and 7.75 MHz are in bands officially allocated for government service and internationally accepted as military communications bands. Further details are provided in chapter 4.

TACTICAL AND THEATER COMMUNICATIONS

The highest altitude flights of the C-1 launch vehicle are those that put eight payloads at a time into circular orbits at about 1,500 kilometers. The trade press believes them to be military communications satellites. If so, it would seem they are of the store-dump type because they do not fly high enough to permit real time communications among all Soviet forces. These launches come 2 or 3 times a year, meaning that probably 24 to 30 or more are active at any one time. These would seem to come closest to providing a system such as might be needed for some kinds of military communications and command and control. The store-dump feature would not allow real-time control of all missile forces, but it would allow passing of information to or from Soviet submarines and other organizations if time was not critical. They could also be used on a real-time basis for tactical communications within a given theater of operations. The fact that military communications systems may exist within the Kosmos program is strengthened by testimony before Congress by the Department of Defense that such systems exist beyond the Molniya system.

Table 55 lists launches in this series. It will be seen that vehicle and other test flights between 1964 and 1965 produced triple or quintuple payloads. The launch of Kosmos 41-43 at 49° used the B-1 rather than the C-1 but all other tests were at 56°.

It is a fact, for which no satisfactory explanation has yet appeared in the public domain, that new launches in this subset of Kosmos satellites are invariably made into the same orbital plane as that employed initially, although individual orbital planes drift relative to each other due to the small differences in orbital periods.

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[41] Annex to chapter 4

TABLE 55.—SOVIET TACTICAL THEATER COMMUNICATIONS WITH THE C-1 LAUNCH VEHICLE

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
1964						
Aug. 18	38-40	876	210	56.2	95.2	Vehicle test of triplet payloads, possible precursor to communications.
Aug. 22	41-43	1,099	232	49	97.8	Used B-1 launch vehicle instead, possible precursor to communications.
1965						
Feb. 21	54-56	1,856	280	56.1	106.2	Vehicle test of triplet payloads, possible precursor to communications.
May 15	61-63	1,837	273	56	106	Do.
July 16	71-75	550	550	56.1	99.5	Vehicle test of quintuplet payloads, possible precursor to either communications or ELINT ferret.
Sept. 3	80-84	1,500	1,500	56	116.6	Quintuplet payloads, one of which had RTG power source, probably communications.
Sept. 18	86-90	1,690	1,380	56	116.7	Quintuplet payloads, one of which had RTG power source, probably communications.
1970						
Apr. 25	336-343	1,500	1,400	74	115	First of a long series of octuplet payloads, tactical communications.
1971						
May 7	411-418	1,530	1,408	74.5	115	
Oct. 13	444-451	1,550	1,415	74	115	
1972						
July 20	504-511	1,540	1,425	74	115.2	
Nov. 1	528-535	1,495	1,375	74	114	
1973						
June 18	564-571	1,507	1,392	74	114.5	
Oct. 2	588-595	1,512	1,397	74	115	
Dec. 19	617-624	1,511	1,404	74	114.8	
1974						
Apr. 23	641-648	1,508	1,395	74	114.5	
Sept. 19	677-684	1,519	1,451	74	115.5	
1975						
Feb. 28	711-718	1,530	1,449	74	115.5	
[illegible]	732-739	1,532	1,475	74	115.8	
[illegible]	761-768	1,537	1,454	74	115.5	
1976						
Jan 28	791-798	1,538	1,453	74	115.6	
June 15	825-832	1,530	1,450	74	115.5	
Dec. 7	871-878	1,520	1,450	74	115.3	
1977						
Aug 24	939-946	1,518	1,448	74	115.2	
1978						
Jan. 10	976-983	1,520	1,452	74	115.3	
June 7	1013-1020	1,539	1,456	74	115.6	
Oct. 4	1034-1041	1,536	1,458	74	115.8	
Dec. 5	1051-1058	1,530	1,451	74	115.5	
1979						
Mar 15	1081-1088	1,526	1,455	74	115.4	
Sept. 25	1130-1137	1,515	1,446	74	115	
1980						
Feb. 11	1156-1163	1,528	1,450	74	115.4	

TABLE 55.—SOVIET TACTICAL THEATER COMMUNICATIONS WITH THE C–1 LAUNCH VEHICLE—Continued

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
July 2	1192–1199	1,522	1,451	74	115.3	
Dec. 24	1228–1235	1,491	1,415	74	114.6	

COVERT STORE-DUMP

Another subset of C–1 launched Kosmos satellites constituting a global system with a regular replacement policy is a constellation of three with orbital planes spaced at 120° having an inclination of 74° and orbital periods of just under 101 minutes. These are thought to perform clandestine store-dump missions in a COMINT role.

These satellites are listed in table 56.

Some evidence of the use of satellites for covert store-dump purposes appeared in the London Sunday Telegraph.[42] It reported the case of Ali-Naghi Rabbani, a high official of the Iranian education ministry, who was arrested in April 1977, by Savak, the Shah's security and intelligence service, as he was sitting beside an irrigation canal, in a deserted street manipulating what looked like a small calculating machine:

> He tried to make out that he was a bazaar merchant doing his sums.
>
> Rabbani's calculator turned out to be the most sophisticated spy gadget that Western intelligence has seen in the field up to this day. It enabled him to receive instructions directly from Moscow, via an orbital satellite. The KGB's coded messages were automatically converted into groups of 5 digits that Rabbani could rapidly decipher. It was easy for Savak to see how the system worked, since the KGB, apparently unaware that Rabbani had been captured, went on sending coded instructions to him for several days after his arrest.[43]

TABLE 56.—SOVIET STORE-DUMP COMMUNICATIONS FOR POSSIBLE CLANDESTINE USE, ON THE C–1 LAUNCH VEHICLE

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
1967						
May 15	158	850	850	74	100.6	Vehicle test.
1970						
Oct 16	372	828	786	74	100.8	

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[42] Moss, Robert. "How Russia Plots against the Shah." Sunday Telegraph, London, Nov. 5, 1978, p. 21

[43] Ibid.

TABLE 56.—SOVIET STORE-DUMP COMMUNICATIONS FOR POSSIBLE CLANDESTINE USE, ON THE C-1 LAUNCH VEHICLE—Continued

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
1971						
Apr. 23	407	844	799	74	101	
Dec. 17	468	830	788	74	100.8	
1972						
June 23	494	829	791	74	100.8	
Dec. 25	540	823	779	74	100.8	
1973						
Dec. 4	614	830	770	74	100.7	
1974						
Sept. 11	676	840	799	74	101	
1975						
Sept. 30	773	828	791	74.1	100.9	
Nov. 28	783	838	797	74	101	
1976						
June 29	836	843	796	74	101	
July 15	841	826	789	74	101	
Sept. 25	858	833	792	74	101	
1977						
July 1	923	842	804	74	101.4	
Dec. 16	968	822	783	74	101	
1978						
Feb. 17	990	824	783	74	101	
June 21	1023	822	784	74.1	101.8	
Nov. 16	1048	824	788	74	101	
1979						
June 28	1110	833	792	74	101	
Aug. 28	1125	834	795	74	101.9	
Oct. 11	1140	818	781	74	101	
1980						
July 1	1190	829	792	74	100.8	

The Kettering Group was unable to pursue this story due to the overthrow of the Shah, shortly after it appeared. Information as to the precise time of day at which the arrest was made would have permitted computation to demonstrate which, if any of this subset of Kosmos satellites had been above the Teheran horizon at the time.

NAVIGATION AND TRAFFIC CONTROL

The whole subject of the use of navigation satellites operating in a one-way mode is addressed in chapter 4 (p. 978).

Table 57, prepared by the late Dr. Charles Sheldon, lists flights in this subset through the end of 1980 and is placed here for convenience.

The GLONASS system of satellites in near semi-synchronous orbits, analagous to the U.S. Global Positioning System (Navstar) is described briefly in chapter 2.

TABLE 57.—SOVIET NAVIGATION MISSIONS WITH THE C–1 LAUNCH VEHICLE

Launch date	Kosmos number	Experimental program	Group 1st generation	2d generation	3d generation	4th generation	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
1967											
Nov. 23	192	X					760	760	74	99.9	
1968											
May 7	220	X					760	670	74	99.2	
1969											
Aug. 17	292	X					786	747	74	99.9	
Oct. 21	304	X					774	747	74	99.9	
1970											
Apr. 11	332	X					786	775	74.5	100	
Oct. 12	371	X					780	754	74	99.9	
Dec. 12	385		X				1,005	982	74	104.5	
1971											
May 22	422		X				1,020	994	74	105.1	
Dec. 15	465		X				1,023	984	74	105	
1972											
Feb. 25	475		X				1,013	977	74	105	
May 6	489		X				1,010	980	74	105	
Aug. 16	514			X			999	959	83	104.4	
1973											
June 20	574			X			1,026	996	83	105	
Sept. 14	586			X			1,020	986	83	105	
Dec. 29	627			X			1,032	991	83	105	
1974											
Jan. 17	628			X			1,026	975	83	105	
June 27	663			X			1,017	983	83	105	
Oct. 18	689			X			1,032	992	83	105.1	
Dec. 26	700				X		1,012	976	83	105	

1975									
Apr. 11	726		X		1,008	972	83	104.7	
Apr. 22	729	X			1,023	995	83	105	
Aug. 14	75[illegible]		X		1,025	991	82.9	105	
Nov. 4	778		X		1,018	989	83	104.9	
1976									
Jan. 20	789		X		1,029	993	83	105	
Feb. 3	800	X			1,027	1,000	83	105	
June 2	823	X			1,023	996	83	105	
July 29	846	X			1,025	967	83	105	
Oct. 29	864		X		1,021	980	83	104.9	
Dec. 15	883			X	1,023	975	83	105	
Dec. 28	887		X		1,030	973	83	104.8	
1977									
Jan. 20	890	X			1,032	1,000	83	105	
Feb. 21	894		X		1,026	988	83	105.1	
July 8	926			X	1,025	997	82.9	105.1	
July 13	928		X		1,022	977	83	104.8	
Sept. 13	951		X		1,029	989	83	105	
Oct. 28	962	X			1,022	983	83	104.9	
Dec. 23	971		X		1,021	993	83	105	
1978									
Jan. 17	985		X		1,032	960	83	105	
Feb. 28	991		X		1,022	972	83	104.8	
Mar. 15	994	X			1,023	996	82.9	105	
Mar. 28	996		X		1,020	970	82.9	104.8	
Mar. 31	1000			X	1,024	978	83	104.9	First specifically announced mission.
May 23	1011		X		1,026	978	82.9	104.9	
July 27	1027	X			1,015	979	82.9	104.8	
Dec. 20	1064		X		991	435	83	98.7	Failure.
1979									
Jan. 16	1072		X		1,030	983	83	105	
Mar. 21	1089		X		1,016	986	83	104.9	
Apr. 7	1091		X		1,024	985	83	105	
Apr. 11	1092			X	1,021	983	83	105	
May 31	1104		X		1,022	979	83	104.9	
Oct. 16	1141		X		1,014	976	82.9	104.7	

TABLE 57.—SOVIET NAVIGATION MISSIONS WITH THE C-1 LAUNCH VEHICLE—Continued

Launch date	Kosmos number	Experimental program	Group 1st generation	2d generation	3d generation	4th generation	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
1980											
Jan. 14	1150				X		1,028	998	83	105	
Jan. 25	1153				X		1,031	983	83	105	
Mar 17	1168				X		1,028	981	82.9	104.9	
May 20	1181				X		1,020	992	83	105	
Dec. 5	1225				X		1,041	967	82.9	105	
Dec. 11	1226					X	1,025	982	83	105	

GEODESY

The use of satellites for geodesy and map making has been described in chapter 4.

USE OF THE C-1

Table 58 lists C-1 launched Kosmos satellites which are thought to have had a geodetic role. These all originated from Plesetsk and were initially at 74° inclination in near-circular orbits at around 1,200 km, with periods close to 109 minutes. In 1972, Kosmos 480 marked the transition to 83° inclination for flights with these general orbital parameters and was followed, later that year, by Kosmos 539, once more at 74°, with a period of 113 minutes. Two flights at 74° in 1974 were in near-circular orbits at around 1,400 km with periods of 113.6 minutes and they were followed in 1975 by Kosmos 708 at the same height, but with the unique inclination of 69.2°.

Two satellites, Kosmos 842 and 911, are also included in table 58 as possible geodetic satellites. Although at a first glance, they appear to be navigation satellites, having the characteristic 105 min period at 83° inclination, their orbital planes, separated by 180° from each other, do not fit into any of the well-established navigation satellite constellations. Moreover, no transmissions on frequencies close to 150 MHz from this pair of satellites were intercepted by the Kettering Group.[44]

TABLE 58.—SOVIET GEODETIC MISSIONS WITH THE C-1 LAUNCH VEHICLE

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
1968						
Feb 20	203	1,200	1,200	74.1	109.4	
Nov. 30	256	1,234	1,168	74.1	109.3	
1969						
Mar 17	272	1,220	1,195	74	109.4	
Nov. 24	312	1,187	1,145	74	108.6	
1971						
Apr 28	409	1,222	1,185	74	109 4	
Nov 20	457	1,229	1,192	74	109.5	
1972						
Mar 25	480	1,212	1,183	83	109.2	First geodetic flight at 83°.
Dec. 21	539	1,3[illegible]3	1,302	74	113	First geodetic flight at this increased height.
1973						
Sept. 8	585	1,416	1,385	74	113.6	
1974						
Apr 29	650	1,413	1,380	74	113.5	
Aug. 29	675	1,429	1,370	74	113.7	
1975						
Feb 12	708	1,423	1,387	69.2	113 6	Unique use of this inclination.
Sept 24	770	1,222	1,188	83	109.2	

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[44] Wood, C.D., and G.E. Perry. Phil. Trans. R. Soc. Lond. A, vol. 294, 1980, p. 99.

TABLE 58.—SOVIET GEODETIC MISSIONS WITH THE C-1 LAUNCH VEHICLE—Continued

Launch date	Kosmos number	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Remarks
1976						
July 21	842	1,023	987	83	105	Did not belong to one of the NAVSAT constellations.
1977						
May 25	911	1,018	984	82.9	104.9	180° out of plane with Kosmos 842.
Nov 24	963	1,220	1,190	82.9	109.3	
1978						
Dec. 26	1067	1,226	1,184	83	109.2	

Notes

1 All of these launches originated from Plesetsk.

2 Kosmos 842 and Kosmos 911 did not fit the constellations of navigation satellites and were precisely spaced 180° apart to operate as a pair in approximately polar orbit with rotations in opposite senses. They are included in this table for convenience

USE OF THE F-2

As discussed in chapter 4, p. 1009, Kosmos 1045 which was launched by an F-2 on October 26, 1978, into a near-circular orbit at 82.6° inclination, 1,700 km altitude and 102.4 min period, is also tentatively classed as a possible geodetic flight although it was announced as also carrying the first two Soviet amateur radio satellites.

RECOVERABLE PAYLOADS

A subset of the recoverable observation payloads are also thought to have a geodetic role. These do not maneuver, transmit on 19.994 MHz rather than the 19.989 MHz employed by the majority of the recoverable Kosmos satellites, and transmit a TL beacon on recovery. Flights of this type are listed in table 44(d) and are described in this chapter.

WEAPONS USE

FRACTIONAL ORBITAL BOMBARDMENT SYSTEM (FOBS)

This study is not directly concerned with military missiles beyond their use as launch vehicles in the space program and as the use of their navigation, guidance and reentry technologies may be applied to space systems as well. But there is one area in which military missiles and spacecraft come together: that of the fractional orbital bombardment system satellites—known as FOBS.

Every long-range ballistic missile flight is really a space flight. The missile is given sufficient velocity during initial firing to carry it out of the atmosphere. The orbital path flown is one which intersects the Earth, thus terminating the flight. BMEWS (ballistic missile early warning system) was constructed in Clear, AK; Thule, Greenland; and Fylingdales, England to fan out radar signals which would intercept at the earliest practical time the flight of missiles from the Soviet Union against the United States, Canada, and parts of Western Europe.

It is also possible to send a missile the long way around the world on the other part of a great circle path to arrive at its target in exactly the opposite direction from which the principal defending radars have been pointed. For example, if the big defense radars are in the Arctic, and the missile comes to a U.S. target by way of Antarctica, that main defense system would miss it. Examination of the great circle path from Tyuratam to the United States via Antarctica may emphasize the strategic value of a base at Diego Garcia in the Indian Ocean.

Although there have been no FOBS flights during the period covered by this study, none in fact since 1971, they are described here for the sake of completeness.

The military parade through Red Square in May 1965 included a new, very large three-stage liquid fueled ICBM, the SS-10 Scrag. The Soviet radio announcer said:

> Three-stage intercontinental missiles are passing by. Their design is improved. They are very reliable in use. Their servicing is fully automated. The parade of awesome battle might is being crowned by the gigantic orbital missiles. They are akin to the carrier rockets which confidently put into space our remarkable spaceships like Voskhod 2. For these missiles there is no limit to range. The main property of missiles of this class is their ability to hit enemy objectives literally *from any direction*, which makes them virtually invulnerable to antimissile defense means.[45] (emphasis added)

The corresponding parade in November that same year included the same Scrag missiles, and the description given was:

> Now in front of the rostrum missiles are passing. These are orbital rockets. Warheads of orbital rockets are able to inflict sudden blows upon an aggressor on the *first* or any orbit around the Earth.[46] (emphasis added)

In 1967, there were new developments in the use of the F class vehicles. As flights occurred, they were promptly announced and given Kosmos names and numbers. All flew at 49.5° to 50° from Tyuratam. All were distinctive in that the orbital elements as announced included the inclination, apogee and perigee, but not the orbital period.

Typical was the Tass bulletin on the first of these flights:

> A routine launching of the artificial satellite Kosmos 139 took place in the U.S.S.R. Scientific apparatus intended for the continuation of research into outer space is installed on board.
>
> The satellite has been put into an orbit with the following parameters: maximum distance from the surface of the Earth—apogee—210 kilometers; minimum distance from the surface of the Earth—perigee—144 kilometers; inclination of orbit 50 degrees.[47]

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[45] Moscow Radio, May 9, 1965
[46] Ibid., Nov. 7, 1965
[47] Tass, Jan. 25, 1967. 1708 G m t

During 1967 alone there were nine of these flights. The public explanation came on the afternoon of November 3, 1967, from the U.S. Secretary of Defense, who tagged them as probable FOBS flights.

It was interesting that every one of the FOBS flights from 1967 until 1971 when they were terminated on that initial fractional orbit did not once cross the continental territory of the United States. The regular path at that inclination carried them mostly eastward and very slightly north from Tyuratam across Siberia, down through the central Pacific, across the lower part of South America, up the Atlantic, and across Africa and the Mediterranean to impact after retrofire on Soviet territory not far from the launch site. Some miscellaneous debris stayed up enough orbits that with the rotation of the Earth, the debris crossed over the United States.

After the nine flights of 1967, apparently the testing phase was complete, for only one or two flights a year continued in the next 4 years. In connection with the SALT talks, or perhaps coincidentally, all flights ceased in 1971.

The cessation of FOBS testing in 1971 left Western analysts in doubt as to whether the program had been so successful that the Soviets did not consider further tests necessary, or so unsuccessful that they had decided to scrap the system. The only clue in the open literature as to the status of the system is the fact that the never-ratified SALT II agreement calls for the dismantlement of 12 of the 18 launchers for fractional orbital missiles at Tyuratam, and the remaining 6 "may be converted to launchers for test missiles undergoing modernization" (Second Common Understanding to Paragraph 2(c)). Although the precise status of the FOBS system as of 1980 therefore continues to be uncertain, at least it is clear that it existed as late as 1979 and that the Soviets were willing to give it up.

Table 57 prepared by the late Dr. Sheldon, lists the F-1-r flights in the FOBS series together with three other flights which are discussed in the following section.

ORBITAL BOMBS AND SPACE MINES

Space writers and staff studies have explored the possibility of stationing bombs in orbit. Such an operation is not outlawed by treaty, so long as they are nonnuclear, and there is no real possibility that any weapons of mass destruction are currently in orbit. Although, technically, a bomb could be placed in orbit, that is not to say that it would be a practical proposition.

A somewhat related concept is that of the "space mine"—a small satellite based in orbit in peacetime, remaining always in lethal range of its quarry satellite and ready to explode on command.[48] Following precise stationing relative to its quarry, a maneuvering capability would be necessary to match orbital changes due to deliberate maneuver or natural decay. As with orbital bombs there is no evidence that such devices have yet been deployed.

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[48] Garwin, R.L., and J. Pike. Bulletin of the Atomic Scientists. May 1984, p. 75.

However, as reported in the previous section, three flights at 49.6° inclination and, for that reason, included in table 59, the two unannounced Kosmos flights of 1966, listed in the West as U-1 and U-2, and Kosmos 316 at the end of 1969 were by no means suborbital and deserve further consideration.

TABLE 59.—TESTS OF THE SOVIET FRACTIONAL ORBIT BOMBARDMENT SYSTEM

Launch date	Kosmos number	Eccentric orbit	Low orbit	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay date	Days life	Remarks
1966										
Sept 17	U-1 (no Tass announcement)	X		1,313	156	49.6	96.1	Nov. 11, 1966	54	Goddard information, payload.
				1,046	163	49.6	96.1			RAE information, payload.
				1,010	280	49.3	97.6	Mar. 4, 1967	168	RAE information, rocket body.
				245	193					Goddard information, rocket body, there were 159 pieces after one orbit.
Nov. 2	U-2 (no Tass announcement)	X		855	140	49.6	94.5	Nov. 17, 1966	15	RAE information, payload.
				1,513	123	49.2	101.3			Goddard information, rucket body, there were over 50 pieces after one orbit.
1967										
Jan. 25	139		X	210	144	50.0				Tass announcement.
				210	144	49.7	88.0	Jan. 25, 1967	0	RAE information, payload.
				~210	~144	~49.7	~88.0	do	0	RAE, rocket body.
				~210	~144	~49.7	~88.0	do	0	RAE, platform.
May 17	160		X	205	142	49.6				Tass announcement.
				177	137	49.7	87.6	May 18, 1967		RAE, disintegrated 1st rev., payload.
				~177	~137	~49.7	~87.6	do		RAE, rocket.
July 17	169		X	208	144	50				Tass announcement.
				200	135	49.7	87.8	July 17, 1967	0	RAE, payload.
				103?	102?	49.6	86.5	July 18, 1967	0	RAE, rocket body.
				129?	128?	49.6	87.0	do	0	RAE, platform.
1967										
July 31	170		X	208	145	50				Tass announcement.
				252	121	49.5	88.2	July 31, 1967	0	RAE, payload.
				263	126	49.4	88.3	Aug. 1, 1967	0	RAE, rocket.
				191	123	49.4	87.6	do	1	RAE, platform.
Aug. 8	171		X	220	145	50				Tass announcement.
				177	138	49.6	87.6	Aug. 8, 1967	0	RAE, payload.
				200	130	49.6	87.7	Aug. 9, 1967	1	RAE, platform.
				165	134	49.6	87.4	Aug. 8, 1967	0	RAE, rocket.
Sept. 19	178		X	205	145	50				Tass announcement.
				258	138	49.7	88.4	Sept. 19, 1967	0	RAE, payload.

				209	130	49.7	87.9	Sept. 20, 1967	0	RAE, platform.
				163	137	49.6	87.4	Sept. 19, 1967	0	RAE, rocket.
Sept 22	179		X	208	145	50				Tass announcement.
				107	139	49.6	87.9	Sept. 22, 1967	0	RAE, payload.
				212	120	49.5	87.7	Sept. 23, 1967	0	RAE, platform.
				156	141	49.4	87.4	Sept. 22, 1967	0	RAE, rocket.
Oct. 18	183		X	212	145	50				Tass announcement.
				315	130	49.6	88.9	Oct. 18, 1967	0	RAE, payload.
				179	127	49.7	87.5	Oct. 19, 1967	0	RAE, platform.
				211	151	49.3	88.1	Oct. 18, 1967	0	RAE, rocket.
Oct 28	187		X	210	145	50				Tass announcement.
				301	143	49.6	88.9	Oct. 28, 1967	0	RAE, payload.
				298	139	49.6	88.8	do	0	RAE, platform.
				240	139	49.6	88.2	do	0	RAE, rocket.
1968										
Apr 25	218		X	210	144	50				Tass announcement.
				162	123	49.6	87.3	Apr. 25, 1968	0	RAE, payload.
				167	131	49.6	87.4	do	0	RAE, rocket.
				172	133	49.6	87.5	do	0	RAE, platform.
Oct 2	244		X	212	140	50				Tass announcement.
				158	134	49.6	87.3	Oct. 2, 1968	0	RAE, payload.
				159	133	49.6	87.3	do	0	RAE, rocket.
				193	149	49.6	87.8	Oct. 3, 1968	1	RAE, platform.
1969										
Sept 15	298		X	212	140	50				Tass announcement.
				162	127	49.6	87.3	Sept. 15, 1969	0	RAE, payload.
				156	123	49.6	87.2	Sept. 16, 1969	0	RAE, rocket.
				169	134	49.6	87.5	do	1	RAE, platform.
Dec 23	316	X		1,650	154	49.5	102.7			Tass announcement.
				1,638	152	49.5	102.8	Aug 28, 1970	248	RAE, fell in Oklahoma, Kansas, Texas, payload.
				1,581	147	49.5	102.2	Jan. 28, 1970	36	RAE, rocket.
				920	130	49.5	95.1	Jan. 1, 1970	9	Goddard, rocket?
1970										
July 28	354		X	208	144	50				Tass announcement.
				~178	~134	~49.6	~87.5	July 28, 1970	0	RAE, payload.
				157	114	49.6	87.1	July 29, 1970	0	RAE, rocket.
				178	134	49.6	87.5	do	0	RAE, platform.
Sept 25	365		X	210	144	49.5				Tass announcement.
				~174	~133	~49.7	87.5	Sept. 25, 1970	0	RAE, payload.

TABLE 59.—TESTS OF THE SOVIET FRACTIONAL ORBIT BOMBARDMENT SYSTEM—Continued

Launch date	Kosmos number	Eccentric orbit	Low orbit	Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay date	Days life	Remarks
				174	133	49.7	87.5	Sept. 26, 1970	0	RAE, platform.
				161	117	49.7	87.2	Sept. 25, 1970	0	RAE, rocket.
1971										
Aug. 8	433		X	259	157	49.5				Tass announcement.
				299	112	49.4	88.5	Aug. 9, 1971	0	RAE, payload.
				300	112	49.4	88.6	Aug. 10, 1971	2	RAE, platform.
				174	142	49.5	87.6	do	1	RAE, rocket.

On September 17 and again on November 2, 1966, the Russians made space launchings which were the first since January 1963 to be totally unacknowledged. These flights came out of Tyuratam on a new inclination—49.6°, suggesting use of a new rocket or new launch pad or both. Debris or staging were left at several altitudes.

A third flight of the same kind came in 1969, but was announced as Kosmos 316. This time there was no evidence of wholesale explosions. Some kind of stage or platform was left with an apogee of 920 kilometers, while a final rocket stage had an apogee of 1,518 kilometers, and the payload reached 1,650 kilometers.

Most analysts seem to have classified these three flights as FOBS flights which in some fashion malfunctioned, and then were exploded. This analysis does not seem to stand up because the placement of the stages and debris are not that closely akin to the FOBS flights patterns which are much lower.

What one can say is that the three mystery flights went at an inclination which has been flown only by FOBS, and using a vehicle exclusively tied to military programs. Under these circumstances, the flights seems to be weapons-related.

ANTISATELLITES (ASATS)

One can imagine that Soviet military planners would see as a necessary ingredient in any stable of military space systems an ability to identify the missions of United States and Chinese satellites and to have the option of destroying certain payloads in times of crisis. Such actions could be motivated by a desire to blind the eyes which might be used to give an enemy warning of Soviet activities, deny the use of satellites for navigation, or to interrupt military communications.

In a July 16, 1962, interview with American newspaper editors, Soviet Premier Khrushchev stated that the Soviet Union had a missile that could "hit a fly in space." Some Western experts interpreted that statement as indicative of a Soviet ASAT capability and speculated that it could refer to a nuclear-armed Galosh missile such as deployed as an operational ABM (antiballistic missile) system around Moscow.

The only operational ground-based ASAT system developed by the United States used nuclear warheads launched by Air Force Thor missiles from Johnston Island and Army Nike-Zeus missiles from Kwajalein Atoll, both in the Pacific. Tests of the Army system were conducted beginning in May 1963, but the system was deactivated in 1964. The Air Force tested its system beginning in May 1964 and it remained operational until 1975.

The Soviet Union proceeded with development and flight tests of a coorbital interceptor.[49] Following the obscure missions of Kosmos 185 and 217 in 1967 and 1968, the first successful intercepts were made in the fall of 1968. The intercepts of Kosmos 248 by Kosmos 249 and 252 involved matching the oribital planes and placing the interceptors' perigees at the general height of the target's orbit. Subsequently, large numbers of fragments were found in the inter-

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[49] Perry, G.E. Russian Hunter-killer Satellite Experiments. Royal Air Forces Qy., vol. 17, winter 1977, pp 328-335

ceptors' highly elliptical orbits and, in each case, the interceptor's launch announcements stated that the scientific research program had been fulfilled. The exercise was repeated in 1970 with Kosmos 373, 374 and 375. Both target and interceptor spacecraft were launched by the SS-9, in the F-1-m configuration, out of Tyuratam.

The 1971 series of tests, involving three pairs of Kosmos satellites, introduced several significant departures from previous practice. Targets were launched from Plesetsk by the SS-5 or C-1 vehicle into 65.8° inclination orbits which were not groundtrack stabilized. Interceptions were delayed until some days after the launch of the targets. The Tyuratam launch at 65.1° inclination necessitated a small plane-change by the interceptor to match its orbital plane to that of the target satellite. The three tests, each at different heights, demonstrated an intercept capability for ELINT ferrets, navigation satellites, and low-orbit recoverable payloads.

Although Kosmos 521, in 1972, had orbital parameters characteristic of a C-1 launched target, no interception ensued and the purpose of this flight is open to conjecture.

Whereas the FOBS flights were never resumed, further interception tests were carried out from 1976 onward. It soon became apparent that these were no mere carbon copies of the earlier series and that considerable development had taken place. In many cases, the interceptor disappeared from orbit on the day of launch and a scarcity of unclassified Western tracking data led to speculations of some degree of failure.[50]

The first of the new targets was Kosmos 803 on February 12, 1976, at 66° inclination. Four days later, Kosmos 804 was placed in a 92.8 min, 65.1° orbit. Western tracking data revealed that the orbit was circularized during the first revolution and the plane changed to match that of Kosmos 803. The TASS announcement on the following day concluded by saying that the research program had been fulfilled.

Kosmos 814 made another interception on April 13. Only one set of Western tracking data is available and it appears that this was a first-orbit inspection with deorbiting of the interceptor over the ocean almost immediately thereafter. Some U.S. officials considered the possibility of photographic inspection and recovery rather than attack.[51]

On July 8, Kosmos 839 was placed in a much higher orbit than any of the earlier targets; 117 min, 2102-984 km, 65.9°. On July 21, Kosmos 843 was launched into a 89.4 min, 360-149 km, 65.1° orbit. Aviation Week concluded that it had failed to reach its target.[52] However, the possibility exists that the tracking data for July 21 and 22 related to an associated object which remained in the low orbit. That could explain the decay note, issued on July 23, giving the decay as occurring on July 21, the day of the launch. This may not have been a failure after all. The interceptor could have maneuvered close to the target shortly after launch and been recovered in less than one revolution.[53]

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[50] Aviation Week & Space Technology, Aug. 2, 1976.
[51] Aviation Week & Space Technology, Apr. 26, 1976.
[52] Aviation Week & Space Technology, Aug. 2, 1976.
[53] Perry, G.E., Royal Air Forces Qy., vol. 17, winter 1977, p. 333.

An interception test involving fragmentation of the interceptor was staged late in 1976 with the flights of Kosmos 880 and 886. This appeared to be a carbon-copy of the Kosmos 394/397 mission.

Tests similar to that of Kosmos 839/843 took place in the first half of 1977. The target, Kosmos 909, was placed into a 117 min, 2,112-991 km, 65.9° orbit on May 19. Interceptions by Kosmos 910, and Kosmos 918 on May 28, and June 17 may well have succeeded although no unclassified data exists to confirm this. It was reported by Aviation Week that the NORAD radar in the Aleutian Islands was the only U.S. sensor to acquire Kosmos 910 before it reentered [54] and that Shemya, AK (presumably the same facility), was the only NORAD sensor to acquire Kosmos 918.[55] In the latter piece, the magazine even went so far as to point out that a hydrogen-fluoride space-based laser used as a satellite-killer would not need the near-rendezvous required for a "hot-metal"-type kill. In the following issue of the magazine it was stated that trajectory for the pop-up maneuver places the attack spacecraft in a reentry profile so the vehicle never really completes a full orbit before intersecting the atmosphere where it is destroyed.[56] The media's thinking had swung from assuming inspection to attack.

On October 21, 1977, Kosmos 959 entered a low elliptical orbit with a period of 94.8 min. Seven days later, Kosmos 961 employed the pop-up profile and passed by Kosmos 959 within the 1 km kill-distance and reentered burning up over the Pacific Ocean and giving rise to numerous UFO reports in Japanese newspapers.[57]

The remaining tests through the end of 1980 reverted to using targets in near-circular 1,000 km orbits with the 105 min periods characteristic of Kosmos navigation satellites. Kosmos 967, launched on December 13, 1977 served as a target for two interceptors. Kosmos 970, launched 8 days later, flew a near coorbit after a two-orbit chase and subsequently exploded. This is generally regarded as a failure.[58] Five months later, Kosmos 1009 flew a similar mission profile in which the attack was judged to be successful.[59] It was then deorbited over the Western Pacific.

Kosmos 1171, launched on April 3, 1980, was another target with an orbit similar to Kosmos 967. Analysis by Robert Christy [60] shows that Kosmos 1174, launched on April 18, made a pass within 60 km of Kosmos 1171 about 1,000 km above Leningrad during its second revolution. He went on to show that Kosmos 1174, having executed another major maneuver, made a second approach to within 70 km of Kosmos 1171 off the west coast of the United States and, on the following day, as a result of a very small maneuver, passed within 20 km of Kosmos 1171 near Easter Island in the eastern Pacific Ocean. Kosmos 1174 was deliberately exploded on April 20.

Concerned over the resumption of tests in 1976 after a lull of 3½ years, the outgoing Ford administration approved a new ASAT de-

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[54] Aviation Week & Space Technology, May 30, 1977.

[55] Aviation Week & Space Technology, June 27, 1977.

[56] Aviation Week & Space Technology, July 4, 1977.

[57] Jasani, B.M., "Outer Space—Battlefield of the Future," SIPRI, 1978, p. 176.

[58] Peebles, C., op. cit., p. 112.

[59] Ibid., p. 111.

[60] Christy, R.D., Spaceflight, vol. 22, 1980, p. 326.

velopment effort which was subsequently confirmed by the Carter administration.[61] An agreement with the Soviets to ban space weapons would be actively sought simultaneously.

Defense Secretary Harold Brown confirmed the existence of an operational Soviet killer satellite system at a Pentagon briefing in October 1977.[62] He described the Soviet capability as being "somewhat troublesome" and characterized the U.S. antisatellite effort as being limited to a "preliminary exploration and design capability." Although the Vought Corp. had recently been awarded a DOD contract to design a new U.S. ASAT capability, Brown added, "I would hope we could keep space from becoming an area of active conflict."[63]

At President Carter's invitation, three rounds of talks on limiting space weapons began on June 8, 1978, in Helsinki. The first round ended on June 16 and a second session was held in Bern from January 23 through February 16, 1979. The third round of talks, at which the United States submitted a three-part proposal calling for an end to ASAT tests, the dismantling of the Soviet ASAT system, and mutual verification of the other's good intentions, opened in Vienna on April 23, 1979. The Soviets responded by demanding that a proposed moratorium on ASAT testing include the U.S. Space Shuttle.[64] The talks concluded at the end of June and, although it was intended to resume them in February 1980, the Soviet invasion of Afghanistan in December 1979 led to President Carter withdrawing the SALT II treaty and breaking off virtually all discussions with the Soviets.

Table 60 lists the Soviet ASAT tests and related target flights through the end of 1980.

Observations by radio amateurs in the United Kingdom threw a fresh light on the role of the target satellites. In 1978, John Branegan reported "unnatural ionization events" on the 2-meter band which were confirmed by G.T. Sasson, who described the signals as wideband with "squiggers" about every 4 kHz, stretching from 144.3 through 145.5 MHz.[65] In 1979, Branegan reported that the Naval Research Laboratory, Washington, DC, had identified the source of his signals as Kosmos 909 and 967, both ASAT targets.[66] He pointed out that transmissions were not received on every orbit.

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[61] Peebles, C., "Battle for Space." Blandford Press, 1983, p. 108.

[62] Aviation Week & Space Technology, vol. 197, No. 15, Oct. 10, 1977, p. 18.

[63] Ibid

[64] Peebles, C., op cit, pp. 108–115.

[65] Sasson, G T. "The Best of Oscar News," vol. 1, AMSAT-UK 1980, pp. 50–51.

[66] Branegan, J. Oscar News, No. 27, AMSAT-UK, autumn 1979, p. 33.

TABLE 60.—THE SOVIET ANTISATELLITE (ASAT) PROGRAM

Kosmos number	Launch date	Probable targets				Interceptors				Remarks
		Apogee (km)	Perigee (km)	Inc (deg.)	Period (min)	Apogee (km)	Perigee (km)	Inc. (deg.)	Period (min)	
185	Oct. 27, 1967	546	370	64.1	93.6					
		*888	*522	*64.1	*98.7					
217	Apr 28, 1968	262	144	62.2	88.5					RAE-data.
		*520	*396	*62.2	*93.4					Nothing tracked in this orbit.
248	Oct 19, 1968	*551	*490	*62.3	*94.8					
249	Oct. 20, 1968					*2,177	*514	*62.4	112.2*E	Came within 1 km of K.248 after a 2-orbit chase.
252	Nov 1, 1968					*2,172	*538	*61.9	112.5*E	Came within 1 km of K.248 after a 2-orbit chase. Success.
291	Aug 6, 1969	*574	*173	*62.3	*91.5					Failure.
373	Oct. 20, 1970	1.102	510	62.8	100.9					
		*553	*490	*62.9	94.8					
374	Oct 23, 1970					1,053	530	62.9	100.6	Passed near K.373 after a 2-orbit chase. Failure.
						2,153	*536	*63	112.3*E	
375	Oct 30, 1970					~1,000	~500	~62.8	~100	Passed near K.349 after a 2-orbit chase. Within 1 km. Success?
						*2,164	*538	*63	112.4*E	
394C	Feb 9, 1971	*619	*574	*65.9	*96.5					First target launched by C-1.
397	Feb. 25, 1971					~613	~144	~65.1	~92.1	Passed near K.400 after a 2-orbit chase. Within 1 km. Success?
						2,317	*593	65.8	114.7*E	
400C	Mar 18, 1971	*1.016	*995	*65.8	*105.0					Orbit characteristic of navsats.
404	Apr 4, 1971					799	169	65.2	94.2	Passed near K.373 after a 2-orbit chase. Within 1 km. Success? Deorbited over ocean.
						*1,009	*811	65.9	103*D	
459C	Nov 29, 1971	*277	*226	*65.8	*89.4					Orbit characteristic of reconsat.
462	Dec 3, 1971					*1,840	*237	*65.8	105.7*E	Passed near K.459 after a 1-orbit chase. Within 1 km. Success?
521C	Sept. 29, 1972	*1.030	*973	*65.9	*105.0					No interceptor launched to this.
803C	Feb 12, 1976	*624	*554	*66	*96.4					
804	Feb. 16, 1976					*698	*149	*65.1	92.8*D	Passed near K.803 after a 1-orbit chase. Failure? Deorbited over ocean.
						*615	556	65.9	96.4	
814	Apr 13, 1976					*474	*150	*65.1	90.6*D	Passed near K.803 after a 1-orbit chase. Within 1 km. Successful in disabling K.803? Deorbited over ocean.
839C	July 8, 1976	*2.101	*984	*65.9	*117					Intended to approach K.839.
843	July 21, 1976					*360	*149	*65.1	84.9*D?	No intercept. Failure.
880C	Dec 9, 1976	*624	*562	*66	*96.4					
886	Dec. 27, 1976					1,265	531	65.9	103	Passed near K.880 after a 2-orbit chase. Within 1 km. Success?
						2,328	*581	*66	115*E	

TABLE 60.—THE SOVIET ANTISATELLITE (ASAT) PROGRAM—Continued

Kosmos number	Launch date	Probable targets Apogee (km)	Probable targets Perigee (km)	Probable targets Inc (deg.)	Probable targets Period (min)	Interceptors Apogee (km)	Interceptors Perigee (km)	Interceptors Inc. (deg.)	Interceptors Period (min)	Remarks
909C	May 19, 1977	2,122	*991	*65.9	*117					
910	May 23, 1977					*560 1,774?	*149 −300?	*65.1 65.9?	91*D 99.6?	Completed less than 1-orbit before reentry.
918	June 17, 1977					*265	*131	*65.1	88.4*D	May have passed within 1 km of K.909 before plunging into ocean after successful climb to intercept in less than 1-orbit. Success?
959C	Oct 21, 1977	*891	*153	*66	*94.8					
961	Oct 26, 1977					*302 1,421	*125 269	*66 66.4	88.7*D 101.8	Probably passed within 1 km of K.959 after a 2-orbit chase. Deorbit to ocean. Success?
967C	Dec 13, 1977	*1,013	*973	*66	*105					
970	Dec 21, 1977					861 *1,160	144 *954	65.2 *65.8	94.7 106*E	Passed near K.967 after a 2-orbit chase. Failure?
1009	May 19, 1978					1,125 *1,378	147 *971	65.1 *66	97.4 109*D	May have passed within 1 km of K.967 after a 2-orbit chase. Deorbit to ocean Success?
1171C	Apr 3, 1980	*1,017	*976	*65.8	*105					
1174	Apr 18, 1980					340 *1,035 1,660	124 *387 381	65.2 *65.8 66.1	89.1 98.6 105.5*E	Passed near K.1171 but may have failed. Approached K.1171 again on the following day.

Notes

1. Those marked with an E were deliberately exploded after fulfilling their missions of interception. T[illegible] with [illegible] were commanded to reenter of deep ocean where their remnants would sink beyond recovery.
2. Flights marked with a C were conducted with the use of the C-1 type launch vehicle instead of F-1-m like [illegible]
3. The Soviet-announced orbital elements are marked with asterisks; all other elements were preliminary and later elements measured by Western sensors.

Evidently, the target satellites have an active role to play in the tests since earlier targets have still been in reasonably correct orbits when a fresh target has been launched at the start of a new series of tests. Moreover, there are plenty of "dead" satellites and spent rocket casings which could be used for "target practice" if a passive target was the sole consideration. Furthermore, recent targets have maintained their orbits by use of sustainer stages for periods of up to 2 years beyond the tests and obviously perform some other function in addition to the target role.

DIRECTED ENERGY OR BEAM WEAPONS

Aviation Week, in late 1975, reported that the Russians were suspected of using laser weapons to blind the infrared [IR] sensors in United States early warning satellites. According to the story, the sensors were not permanently blinded, but only for periods of up to 4 hours. This happened three times to geosynchronous satellites and twice to semisynchronous satellites. The story said the intensity of the phenomena was from 10 to 1,000 times that of a forest fire or volcano, and that no weather satellite found any natural source for these events. The frequency of the signal was similar to that expected from a hydrogen-fluoride laser, and the signals had come from the western part of the U.S.S.R. The suggestion was that if the source was a laser, the intensity that might be expected if used against low-flying U.S. missions would reach levels 50,000 times as high. Since the early 1960s, the United States had probed Soviet satellites with lasers from Maui, HI, and Cloudcroft, NM, to determine lens and film-types used in Soviet photographic missions, but not in a manner to cause deliberate damage to such satellites, according to the magazine.[67]

This suspicion, if borne out, would have been of enormous consequence to detente, the SALT talks, and the military positions of the two countries. so naturally many public questions were raised. Secretary of Defense Rumsfeld responded by saying that investigations were continuing, but that the preliminary findings were that major gas pipeline explosions had caused the effect. He said known explosions and fires from over-pressurizing a major gas line correlated well with the satellite data, and he reviewed the United States use of laser probing of Soviet satellites.

It seems strange that gas fires, which have been observed many times before, have not previously had this same effect on satellites. If it is true that it was the intensity of these particular fires that affected the satellites, then this experience may help to calibrate and interpret future signals received by satellites.[68]

The 1981 version of the report, Soviet Military Power, anticipated that the Soviets would continue work on ASATs with the goal of negating satellites in high orbit, "as well as developing more effective kill mechanisms, perhaps using a laser or some other type of directed energy weapon."[69] It went on to describe the weapons as follows:

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[67] Aviation Week & Space Technology, Dec 8, 1975, p 12ff

[68] Aviation Week & Space Technology, Jan 5, 1976, p 18

[69] Soviet Military Power, Department of Defense, Washington, DC, 1981 P 68.

> The Soviets have devoted substantial resources to high technology developments applicable to directed energy weapons. Their knowledge of radio frequency weapons, as demonstrated in Soviet open literature, and the fact that they are developing very high peak-power microwave generators, gives rise to suspicions of possible weapon intent in this area as well. The Soviets have been interested in particle beam weapons [PBW] concepts since the early 1950s. There is considerable work within the U.S.S.R. in areas of technology relevant to such weapons. The Soviet high energy laser program is three-to-five times the United States level of effort and is tailored to the development of specific laser weapons systems * * *. The Soviet laser-beam weapons program began in about the mid-1960s. Since then the Soviets have been actively pursuing the development of all the high energy laser types considered most promising for future weapons applications. They have worked on the gas dynamic laser, the electric discharge laser and the chemical laser. Available information suggests that the Soviet laser weapon effort is by far the world's largest. Their development of moderate power weapons capable of short-range ground-based applications, such as tactical air defense and antipersonnel weapons, may well be far enough along for such systems to be fielded by the mid-1980s. In the latter half of this decade, it is possible that the Soviets could demonstrate laser weapons in a wide variety of ground, ship and aerospace applications. Pulsive power and energy conservation have been recognized as key technologies in the development of directed energy weapons. Possible applications include * * * strategic or defensive antiballistic missile and antisatellite weapons.
>
> A principal pacing factor in the development of directed energy weapons is the availability of a suitable supply of energy. Pulse power technology may be the pacing factor in a weapons program even after the feasibility of beam propagation and adequate lethality is demonstrated. Because the requirements of beam weapons are unique and, in many cases, exceed the current state-of-the-art, they have driven the major research and development efforts in the U.S.S.R.[70]

Information about the Soviet particle beam effort began to emerge in the late 1970s. The first test facility was built 56 km south of the town of Semipalatinsk. Later, it was revealed that work had begun on a new hybrid weapon combining laser and particle beam features, in November 1979, at the Sary Shagan ABM test site.[71] The same article cites a Soviet ASAT laser based near Moscow. The Sary Shagan facility was credited with conducting tests, some of which were said to be successful, against reentering warheads.[72]

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[70] Ibid., pp 75-76

[71] Aviation Week & Space Technology, July 28, 1980.

[72] Aviation Week & Space Technology, Feb. 16, 1981

MINOR MILITARY MISSIONS

The United States space program authorities in the Department of Defense regard as nonsensitive some kinds of supportive space flight activity which improves military capabilities. For example, even when the public information flow has been generally restricted, details on some types of multiple payloads were still being released. Among such announced U.S. military payloads are a variety of calibration devices of different shapes, sizes, and materials. Also, there have been hardware elements such as gravity stabilization experiments, and payloads of different densities to measure rates of decay from orbit due to air friction. There have been tests of solar cells and of structures, and of small thrusters.

Hence, one should expect to find somewhere within the Soviet program counterpart devices carried by flights, since the same kind of technological problems are faced.

The "minor military" category has tended to become the resting place for those Kosmos satellites for which a more obvious role is not immediately apparent and, as a consequence, the nonspecialist reader is in danger of assuming that all satellites which find themselves in this category are calibration and diagnostic payloads. A good pointer to such a role is to be found in the fragments associated with a particular launch. If, as is often the case, fragments appear, one or two at a time, at irregular but somewhat lengthy intervals during the flight, then it might reasonably be presumed that these "fragments" are being shed deliberately to simulate MIRV attacks to provide practice for ground units whose duty it is to detect and/or engage such objects.

A different role for some of these flights has been suggested for the C-1 launched Kosmos satellites with a 65.8° inclination with periods of 94.6 min or less. Since they are launched by the same vehicle as the ASAT target satellites and fly at the same inclination, certain Western observers have been ready to link them with the ASAT tests whereas others merely refer to them, for convenience, as nontargets. It was pointed out that launches of these lower-period satellites occur close in time to the actual ASAT tests.[73] However, it was not possible to find any evidence of a direct connection. In the only instance when one had been in orbit before the interception occurred, Kosmos 885 was on the opposite side of the Earth to Kosmos 880 when it was intercepted by Kosmos 886.[74]

A recent book about the Soviet Army describes steps that are taken to prevent American "spy-satellites" from obtaining intelligence over the Soviet Union.[75] The chief directorate of Strategic Deception is said to maintain a constant record, using "a huge American computer" at the central command post, of all intelligence-gathering satellites and orbiting space stations and of their trajectories. It continues:

> Extremely precise short- and long-term forecasts are prepared of the times at which the satellites will pass over

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[73] Aviation Week & Space Technology, Mar 21, 1977.
[74] Perry, G E., Royal Air Forces Qy., vol 17, 1977, p 335
[75] Suvorov, V., Inside the Soviet Army. N.Y., Macmillan, 1982, pp 106-107

> various areas of the Soviet Union * * *. Each chief directorate unit serving with a military district, a group of armies or a fleet makes use of data provided by this same American computer to carry out similar work for its own force and area. Each army, division and regiment receives constantly updated schedules showing the precise times at which enemy reconnaissance satellites will overfly their area, with details of the type of satellite concerned (photoreconnaissance, signals intelligence, all-purpose, etc.), and the track it will follow.

Apparently, orders are issued for all radio transmissions to stop and all radars to be switched off for the duration of each pass and special radio transmitters and radars, whose purpose is solely to provide signals for interception, are activated.

> The chief directorate has its own intelligence-gathering satellites, but, unlike those working for the chief intelligence directorate, they maintain a watch over Soviet territory, looking constantly for radio transmitters and radars which fail to observe the timetables laid down for communication security. Severe punishments await divisional or regimental commanders who are found to be ignoring the timetables.[76]

This example has been cited, not because of any implicit belief in its veracity, but to offer the reader another possibility for a "minor military" mission.

USING THE B-1

Kapustin Yar

From 1964 through 1966 all B-1 minor military flights originated from Kapustin Yar at inclinations between 48.4° and 49°. Following the introduction of the B-1 at Plesetsk in March 1967, only one or two flights per year came out of Kapustin Yar, the last occurring in 1972. The majority of the flights had periods close to 92 minutes but some had higher periods around 100 and, later, 109 minutes. All had perigees below 300 km.

There was some evidence of a possible pickaback payload in a higher orbit associated with Kosmos 93 and Kosmos 119 was unusual in that it did not separate from the final stage of the launch vehicle.

Plesetsk

Almost 1 year to the day after Kosmos 12 became the first satellite to be launched from Plesetsk, a B-1 launch vehicle placed Kosmos 148 into a 71° inclination orbit with a period of 91.3 min. Many more such flights were to follow together with a series in a higher orbit with periods close to 95.5 min. For the even higher period around 102 min an 81.9° inclination was chosen. The final B-1 flight in this category was Kosmos 919 on June 18, 1977.

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[76] Ibid.

Table 61, prepared by Dr. Charles Sheldon, lists all the B-1 flights in the minor military category.

USING THE C-1

Plesetsk

The first flight out of Plesetsk to match the 109 min period of the highest flights from Kapustin Yar required the intermediate C-1 vehicle. On June 18, 1974, Kosmos 660 was put into an 83° inclination orbit between 1,995 and 409 km. Kosmos 807 in 1976 had a similar orbit but Kosmos 1179 in 1980 had a period of 103.5 min more nearly like the old 102 min B-1 flights. In addition to these three flights at 83°, there were the nontarget flights at 65.8° and seven flights at 74° inclination with 95 min periods. Many fragments are associated with a number of these flights.

Kapustin Yar

Following on from the last B-1 flight from Kapustin Yar the C-1 made one launch in each of the years 1978 through 1980. In all three cases, the parameters were very similar; 50.7° inclination, 93.4 min period, and heights between 555 and 345 km.

Table 62, prepared by Dr. Charles Sheldon, lists all the C-1 flights in the minor military category through the end of 1980.

TABLE 61.—SOVIET CALIBRATION MISSIONS WITH THE B-1 LAUNCH VEHICLE

Launch date	Kosmos number	Launch Site		Orbit characterization					Apogee (km)	Perigee (km)	Inc (deg)	Period (min)	Decay date	Days life	Remarks
		KY	PL	48 8 low	48 9 high	71 low	71 medium	82 high							
1964															
June 6	31	X		X					508	228	49	91.6	Oct. 20, 1964	136	
July 30	36	X		X					503	259	49	91.9	Feb. 28, 1965	213	
1965															
July 2	70	X		X	X				1,154	225	48.8	98.3	Dec. 18, 1966	535	
July 23	76	X		X					531	261	48.8	92.2	Mar. 16, 1966	236	
Oct. 19	93	X		X					522	220	48.4	91.7	Jan. 3, 1966	76	Possible pickaback at 435 X 370. km.
Nov 4	95	X		X					521	207	48.4	91.7	Jan 18, 1966	75	Rocket exploded.
Dec 21	101	X		X					550	260	49	92.4	July 12, 1966	203	
1966															
Jan 25	106	X		X					564	290	48.4	92.8	Nov. 14, 1966	293	
Apr 26	116	X		X					478	294	48.4	92	Dec. 3, 1966	221	
May 24	119	X			X				1,305	219	48.5	99.8	Nov. 30, 1966	190	No separated rocket.
July 8	123	X		X					529	263	48.8	92.2	Dec. 10, 1966	156	
1967															
Mar 3	145	X			X				2,135	220	48.4	108.6	Mar. 8, 1968	371	
Mar 16	148		X			X			436	275	71	91.3	May 7. 1967	52	
Mar 25	152		X			X			512	283	71	92.2	Aug. 5, 1967	153	
June 12	165		X					X	1.542	211	81.9	102.1	Jan. 15 1968	217	
Aug 24	173		X			X			528	280	71	92 3	Dec. 17, 1967	115	
Sept 12	176		X					X	1.581	206	81.9	102.5	Sept. 3, 1968	357	Rocket exploded.
Nov 12	191		X			X			518	281	71	92.2	Mar. 2, 1968	102	
Dec 26	197	X		X					505	220	48.5	91.5	Jan. 30, 1968	35	
1968															
Feb 20	202	X		X					502	220	48.5	9[illegible]	[illegible] 24, 1968	32	
Mar 5	204		X				X		873	282	71	95.9	Mar. 2, 1969	362	
Apr 9	211		X					X	1,574	210	81.9	102.5	Nov. 10, 1968	215	
May 24	221	X			X				2,108	220	48.4	108.4	Aug 31, 1969	464	
May 30	222		X			X			528	277	71	92.3	Oct 11 1968	134	
July 18	233		X					X	1,545	210	82	102.1	Feb. 7, 1969	203	

Sept. 20	242		X		X			440	280	71	91.3	Nov. 18, 1968	54
Oct 3	245		X		X			509	282	71	92.1	Jan 15, 1969	104
Dec. 3	257		X		X			479	282	71	91.1	Mar. 5, 1969	92
1969													
Feb. 7	265		X		X			485	283	71	91.9	May 1, 1969	83
Mar 5	268	X		X				2,186	219	48.4	109.2	May 9, 1970	430
Mar 28	275		X			X		805	284	71	95.2	Feb. 7, 1970	316
Apr 4	277		X		X			494	280	71	92	July 6, 1969	93
May 27	283		X				X	1,539	210	82	102.1	Dec 10, 1969	197
June 3	285		X		X			518	279	71	92.2	Oct. 7, 1969	126
Aug 22	295		X		X			500	282	71	92	Dec. 1, 1969	101
Oct 18	303		X		X			492	282	71	91.9	Jan 23, 1970	97
Oct. 24	307		X		X			2,178	220	48.4	109.1	Dec. 30, 1970	432
Nov 4	308		X		X			422	282	71	91.3	Jan. 5, 1970	61
Nov 24	311		X		X			496	284	71	92	Mar. 10, 1970	106
Dec. 11	314		X		X			491	282	71	91.9	Mar. 22, 1970	101
1970													
Jan 15	319		X				X	1,539	209	82	102	July 1, 1970	167
Feb. 27	324		X		X			492	283	71	92	May 23, 1970	85
Mar 18	327		X			X		855	279	71	95.6	Jan 19, 1971	306
Apr 23	334		X		X			508	281	71	92.1	Aug. 9, 1970	108
June 12	347	X		X				2,073	223	48.4	108	Nov. 7, 1971	513
June 27	351		X		X			494	282	71	92	Oct. 13, 1970	108
Aug 19	357		X		X			500	282	71	92	Nov. 24, 1970	97
Sept 16	362		X			X		854	281	71	95.7	Oct. 13, 1971	392
Oct 8	369		X		X			534	2,178	71	92.3	Jan 22, 1971	106
Nov 24	380		X				X	1,548	210	82	102.2	June 17, 1971	205
Dec 18	388		X		X			532	281	71	92.3	May 10, 1971	143
1971													
Jan 14	391		X			X		828	277	71	95.4	Feb. 21, 1972	403
Jan 26	393		X		X			512	283	71	92.2	June 26, 1971	141
Apr 24	408		X				X	1,542	211	82	102.1	Dec. 29, 1971	249
May 19	421		X		X			492	283	71	92	Nov. 8, 1971	173
May 27	423		X		X			511	282	71	92.2	Nov. 26, 1971	183
Aug 27	435		X		X			505	282	71	92.1	Jan. 28 1972	154
Sept 24	440		X			X		814	282	71	95.3	Oct. 29, 1972	401
Oct 19	453		X		X			522	281	71	92.2	Mar. 19, 1972	152
Nov 17	455		X		X			516	282	71	92.2	Apr. 9, 1972	144

TABLE 61.—SOVIET CALIBRATION MISSIONS WITH THE B-1 LAUNCH VEHICLE—Continued

Launch date	Kosmos number	Launch Site		Orbit characterization					Apogee (km)	Perigee (km)	Inc (deg)	Period (min)	Decay date	Days life	Remarks
		KY	PL	48-8 low	48-9 high	71 low	71 medium	82 high							
Nov 29	458		X			X			523	281	71	92.3	Apr. 10, 1972	143	
Dec 17	467		X			X			502	279	71	91	Apr. 18, 1972	123	
1972															
Jan 25	472		X					X	1,568	207	82	102.4	Aug. 8, 1972	206	
Apr 11	485		X			X			506	280	71	92.1	Aug 30, 1972	141	
Apr 21	487		X			X			531	278	71	92.3	Sept. 24, 1972	156	
June 30	497		X				X		812	282	71	95.2	Nov. 7, 1973	495	
July 5	498		X			X			511	282	71	92.1	Nov. 25, 1972	143	
July 12	501	X			X				2,129	222	48.5	108.8	May 9, 1974	667	
Oct 5	523		X			X			507	283	71	92	Mar. 7, 1973	153	
Oct 11	524		X			X			537	277	71	92.3	Mar. 23, 1973	165	
Oct 25	526		X			X			511	282	71	92	Apr. 8, 1973	165	
1973															
Jan 24	545		X			X			521	279	71	92.2	July 31, 1973	188	
Apr 12	553		X			X			519	282	71	92.2	Nov. 11, 1973	213	
May 17	558		X			X			526	279	71	92.3	Dec. 22, 1973	219	
June 5	562		X			X			510	282	71	92.1	Jan. 7, 1974	216	
Aug 22	580	X				X			518	282	71	92.2	Apr. 1, 1974	222	
Oct 16	601		X					X	1,561	210	82	102.3	Aug. 15, 1974	303	
Nov 20	608		X			X			528	281	71	92.3	July 10, 1974	232	
Nov 28	611		X			X			507	280	71	92	June 19, 1974	203	
Dec 13	615		X				X		859	280	71	95.7	Dec. 17, 1975	734	
1974															
Feb 27	633		X			X			516	280	71	92.2	Oct 4, 1974	219	
Mar 5	634		X			X			516	281	71	92.2	Oct 9, 1974	218	
June 26	662		X				X		838	282	71	95.5	Aug. 28, 1976	794	
July 25	668		X			X			519	281	71	92.2	Feb 21, 1975	211	
Sept 26	686		X			X			515	281	71	92.2	May 1, 1975	217	
Nov 20	695		X			X			493	283	71	92.2	July 15, 1975	237	

1975															
Jan. 21	703		X					X	1,545	207	82	102	Nov. 20, 1975	303	
Jan. 28	705		X			X			524	281	71	92.3	Nov. 18, 1975	294	
Apr 8	725		X			X			508	283	71	92.1	Jan. 6, 1976	273	
June 24	745		X			X			540	274	71	92.4	Mar. 12, 1976	262	
July 17	750		X			X	X		830	281	71	95.4	Sept. 29, 1977	489	
1976															
Feb. 5	801		X				X		823	279	71	95.3	Jan. 5, 1978	700	Exploded.
May 18	818		X			X			506	281	71	92.1	Mar. 7, 1977	293	
Aug. 18	849		X				X		889	276	71	96	Apr. 24, 1978	614	
Aug. 26	850		X			X			518	280	71	92	May 16, 1977	263	
1977															
Apr 5	901		X				X		845	279	71	95.5	June 28, 1978	449	
June 18	919		X				X		847	278	71	95.6	Aug. 28, 1978	436	

TABLE 62.—SOVIET CALIBRATION MISSION WITH THE C-1 LAUNCH VEHICLE

Launch date	Kosmos number	Launch site		Orbit characterization					Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay date	Days life	Remarks
		KY	PL	50.7 Low	65.8-66 Low	74 Low	74 Medium	83 High							
1974															
June 18	660		X					X	1,995	409	83	109.2			
Oct 11	687		X				X		717	242	74	94.5	Feb. 5, 1978	1,213	
1975															
July 24	752		X		X				526	480	65.9	94.6	Feb. 28, 1981	2,046	
1976															
Mar 12	807		X					X	1,985	403	83	109.1			
Apr 28	816		X		X				525	482	65.9	94.6	Nov. 24, 1979	1,305	Many pieces.
May 28	822		X				X		729	284	74	94.6	Aug. 8, 1978	802	

TABLE 62.—SOVIET CALIBRATION MISSION WITH THE C-1 LAUNCH VEHICLE—Continued

Launch date	Kosmos number	Launch site		Orbit characterization					Apogee (km)	Perigee (km)	Inclination (degrees)	Period (min)	Decay date	Days life	Remarks
		KY	PL	50.7 Low	65.8–66 Low	74 Low	74 Medium	83 High							
1977															
Feb 2	891		X		X				518	466	65.8	94.4	Feb. 4, 1981	1,463	
May 30	913		X			X			523	475	74	94.5	Dec. 29, 1979	943	Many pieces.
July 19	930		X			X			528	482	74	94.6	May 12, 1980	1,028	Rocket attached.
July 22	933		X		X				418	385	65.8	92.5	Nov. 1, 1978	467	
Dec 8	965		X			X			520	469	74	94.4	Dec. 16, 1979	738	Many pieces.
1978															
May 12	1006		X		X				417	383	65.8	92.5	Mar. 14, 1979	306	
Dec 22	1065	X		X					556	346	50.7	93.7	Aug. 1, 1979	222	Many pieces.
1979															
Feb 8	1075		X		X				521	475	65.8	94.6			
July 6	1112	X		X					552	345	50.7	93.4	Jan. 21, 1980	199	Many pieces.
Dec 5	1146		X		X				497	441	65.9	93.9			
1980															
Mar 27	1169		X		X				521	478	65.8	94.5			
May 14	1179		X					X	1,570	310	83	103.5			
June 6	1186		X			X			519	473	74	94.5			
July 31	1204	X		X					546	346	50.7	93.3	Feb. 23, 1981	207	
Oct 14	1215		X			X			553	449	74	95.1			

Chapter 5 Annex

Kosmos Coverage of the Early Stages of the Gulf War

INTRODUCTION

In the previous report [77] an attempt was made to identify possible targets of photographic reconnaissance. The majority of the examples were drawn from two periods of major conflict; the Indo-Pakistani war at the end of 1971 and the Yom Kippur war in 1973. At times of international crisis it is not difficult to conclude that certain recoverable Kosmos satellites have been programmed to obtain imagery over the battle areas. The Gulf war presently raging between Iran and Iraq provides examples of the coverage obtained by current types of recoverable Cosmos missions.

SETTING THE SCENE

Reasons for the sudden escalation of the long drawn-out border conflict between Iran and Iraq in September 1980, are well set out in an article by Norman Kirkham in the Sunday Telegraph.[78] The renunciation, by President Saddanhussdin of Iraq of the 5-year-old treaty giving shared control of the Shatt al Arab waterway at the head of the Persian Gulf, depletion of Iran's forces due to the acute shortage of spare parts for planes and tanks following American and British embargoes on arms supplies to Iran, and the fall in morale of the Iranian armed forces under the rule of the Ayatollah Khomeini were all cited as contributory causes.

However, not all journalists were in agreement about the effectiveness of satellite monitoring of the early stages of the conflict. Writing in the Daily Telegraph, John Bullock [79] claimed that "Right from the start 6 days ago American satellites have been beaming back hourly pictures of the situation on the ground * * *"; a claim revealing a lack of understanding of orbital mechanics. Two days later in the same newspaper, Ian Ball, writing from New York stated that the war had "spotlighted serious deficiencies in the United States' intelligence-gathering abilities in

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[77] Soviet Space Programs, 1971-1975, pp. 463-475.

[78] Kirkham, N. How Iraq Challenged the Ayatollah, Sunday Telegraph, London, Sept. 28, 1980.

[79] Bullock, J. "U.S. Spy Satellite Reveals True Extent of War," Daily Telegraph, London, Sept. 27, 1980.

the Persian Gulf."[80] A rather better appreciation of satellite operation was shown by his final comment to the effect that "Retargeting a spy satellite from Russia to the Gulf, for example, might require changing its orbit—a maneuver which often reduced the vehicle's life expectancy." Neither article referred to the use of Kosmos satellites for such purposes by the Soviet Union.

PHOTOGRAPHIC RECONNAISSANCE MISSIONS.

HIGH RESOLUTION

KOSMOS 1210 AT 82.3°

This was one of only two 82.3° launches from Plesetsk in 1980 that were not announced as having an Earth resources role. Launched on September 19, it was already in orbit at the outbreak of hostilities on September 22, and making daily passes over the Persian Gulf. On September 23, it passed close to the head of the Gulf and on the following day passed directly over the Shatt al Arab waterway. By the 10th day of the flight, it had obtained its complete coverage and the orbital period was then increased in order to obtain additional coverage from the remainder of the 14-day mission. Figure 73 shows ground tracks over the area of the Persian Gulf for this satellite. It will be seen that the spacing of ground tracks on consecutive days from revolutions 158 through 206 is approximately twice that of the earlier phase of the mission. A TF recovery beacon was observed on October 3.

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[80] Ball, I "Gulf War Shows Up Cracks in the U S Spy Networks," Daily Telegraph, London, Sept 29, 1980

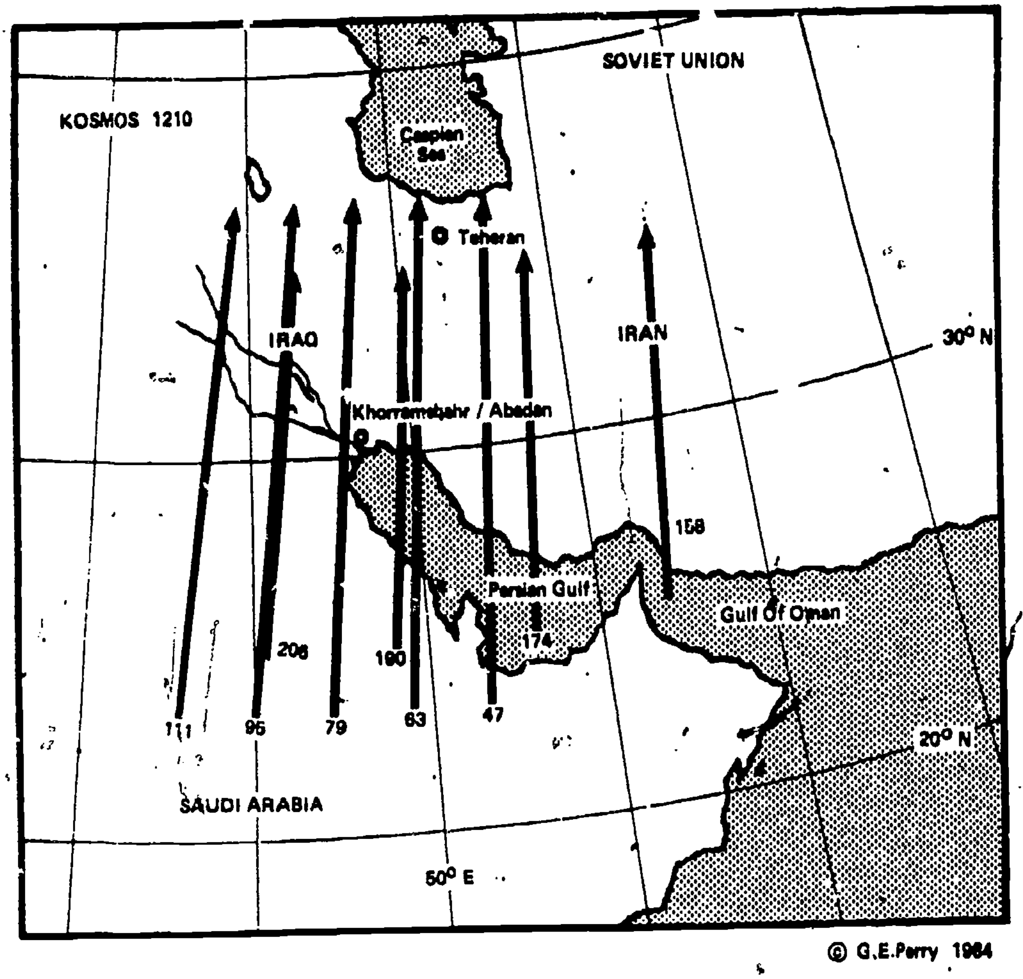

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FIGURE 73.—Ground tracks of Kosmos 1210 over the Persian Gulf.

KOSMOS 1213 AT 72.9°

This was the first of two launches from Plesetsk into 72.9° inclination orbits during the period under consideration and transmitted the two-zone frequency-shift-keyed beacon characteristic of third generation spacecraft. Daily ground tracks throughout its missions are shown in figure 74. This high resolution flight repeated the mission profile of Kosmos 1210 although at a different inclination. It was launched on October 3, the date of Kosmos 1210's recovery.

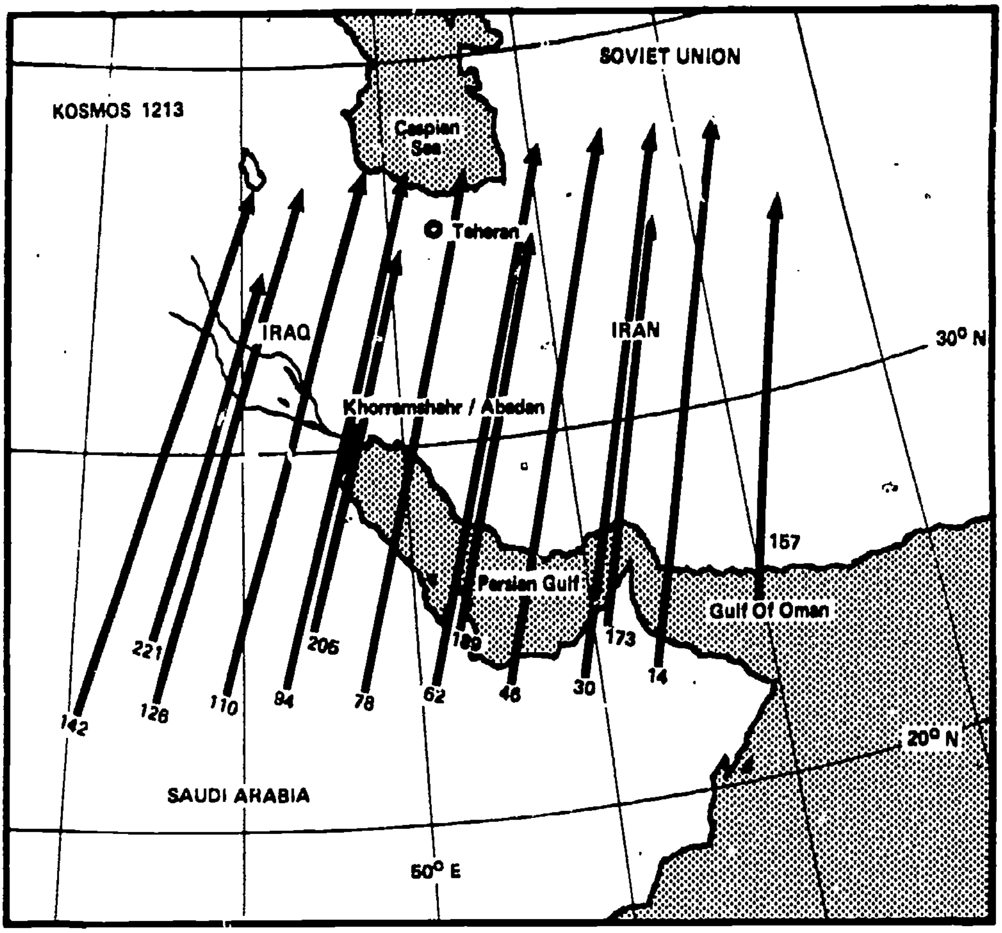

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FIGURE 74.—Ground tracks of Kosmos 1213 over the Persian Gulf.

Once again the orbital period was raised on the 10th day when complete coverage had been obtained. However, in this case, whereas daily passes of Kosmos 1210 had always occurred later on successive days, during the first phase of the mission passes were coming 5 to 6 minutes earlier each day. Following the maneuver this changed to around 4 minutes later every day. It will again be seen that ground track separations for the later phase of the mission are approximately double those of the earlier phase providing, in effect, double coverage of the area. A TF recovery beacon was observed on October 17.

KOSMOS 1214 AT 67.2°

The third high resolution flight of this period, launched from Plesetsk at 67.2°—yet another different inclination—came midway through the flight of Kosmos 1213 on October 10. Ground-track separation on consecutive days was permitted to decrease as a natural consequence of a decaying orbit until the battle area had been passed. Then, following revolution 139, the orbital period was increased to ensure complete coverage recovery after 13 days on October 23. No recovery beacon was observed by the Kettering Group on this occasion. Figure 75 shows the ground tracks of this satellite over the Persian Gulf.

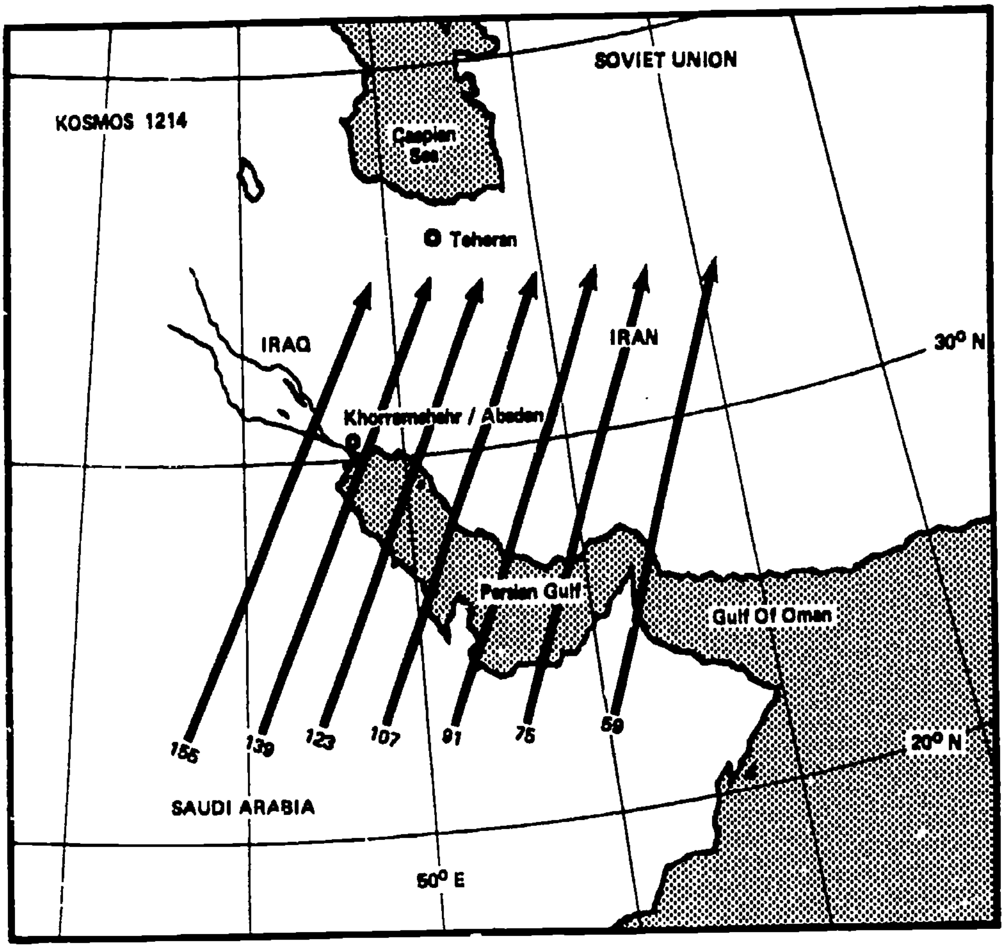

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FIGURE 75.—Ground tracks of Kosmos 1214 over the Persian Gulf.

ANNOUNCED EARTH RESOURCES

KOSMOS 1209

Launched from Plesetsk on September 3 at 82.3° inclination, this satellite, which had been announced as an Earth resources payload, was recovered on September 17 after a normal 14-day flight, 5 days before the outbreak of hostilities. It is just possible that its imagery may have given some indication of the preparations for the Iraq assault, but one cannot be certain that this was so.

KOSMOS 1212 (PRIRODA)

Launched yet again into an 82.3° inclination orbit on September 26, this satellite was announced as having an Earth resources mission and reporting results to the Priroda (Nature) Center. It was recovered after a 13-day flight and transmitted a TK recovery beacon. Its ground tracks did not take it over the battle area until the 6th day of the flight. The ground tracks, shown in figure 76, show the characteristic eastward daily drift of the ground tracks which had come to be associated with the earlier recoverable missions with 81.4° inclinations. Kosmos 1212, although capable of returning imagery from the battle area is not believed to have been directly concerned with the conflict, but rather to have been a routine flight in a planned series of remote sensing missions.

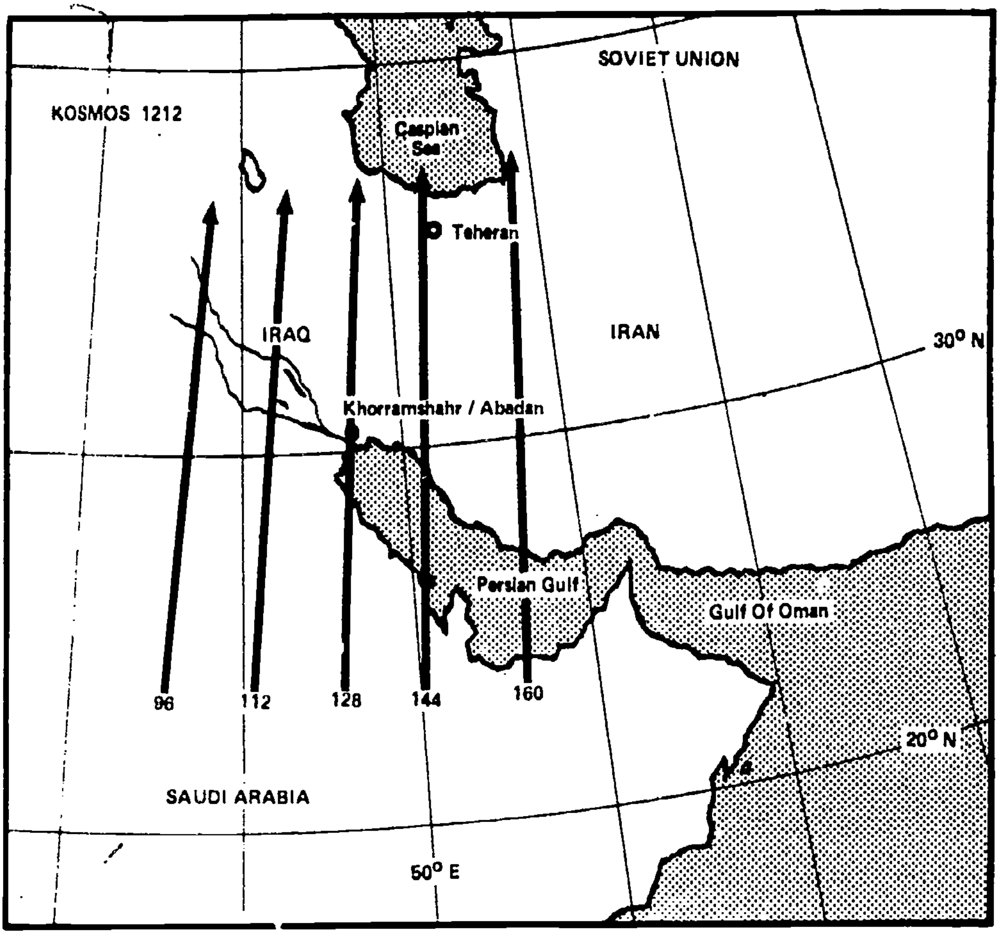

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FIGURE 76.—Ground tracks of Kosmos 1212 over the Persian Gulf.

A POSSIBLE GEODETIC AND MAPPING MISSION; KOSMOS 1211

Kosmos 1211 was the second of the two 1980 launches at 82.3° for which Earth resources roles were not announced. Its ground tracks are shown in figure 77. Comparison with the ground tracks of Kosmos 1212 in the previous figure will show that it, too, had the characteristic eastward daily drift, but with a slightly increased daily spacing. This increased spacing ensured that when it was recovered on revolution 176 after a flight of only 11 days, complete coverage had been achieved as shown by the near-coincident ground tracks for revolutions 15 and 176.

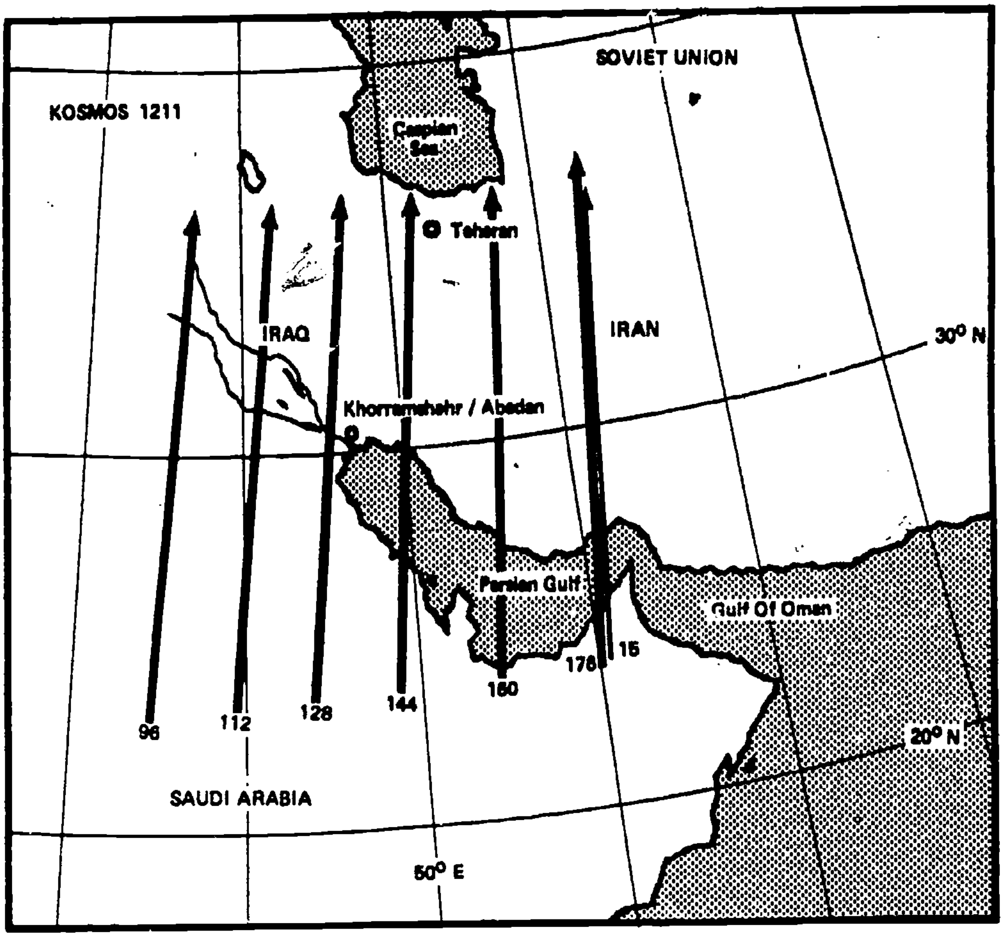

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FIGURE 77.—Ground tracks of Kosmos 1211 over the Persian Gulf.

The transmission frequency of 19.994 MHz, rather than the more usual 19.989 MHz, lack of in-flight maneuvering, and a TL recovery beacon reveal that Kosmos 1211 was a member of the special subset thought to be employed for mapping and geodesy. Once more, this flight is not considered to have been directly concerned with the conflict but rather a coincidental flight in a long-running series of specialist missions which had been planned for that time long before the mission was actually mounted.

Thus, it will be seen that the three 82.3° flights during the early stages of the Gulf war, Kosmos 1210, 1211 and 1212, had quite distinct purposes of close-look imagery, mapping and geodesy, and remote sensing respectively and did not necessarily duplicate each other.

HIGH PERIGEE; KOSMOS 1216

Kosmos 1216 from Plesetsk at 72.9° was launched on October 16 one day prior to the recovery of Kosmos 1213, the other 72.9° flight under consideration. However, the two flights were quite different in character. Ground tracks for this flight are shown in figure 78.

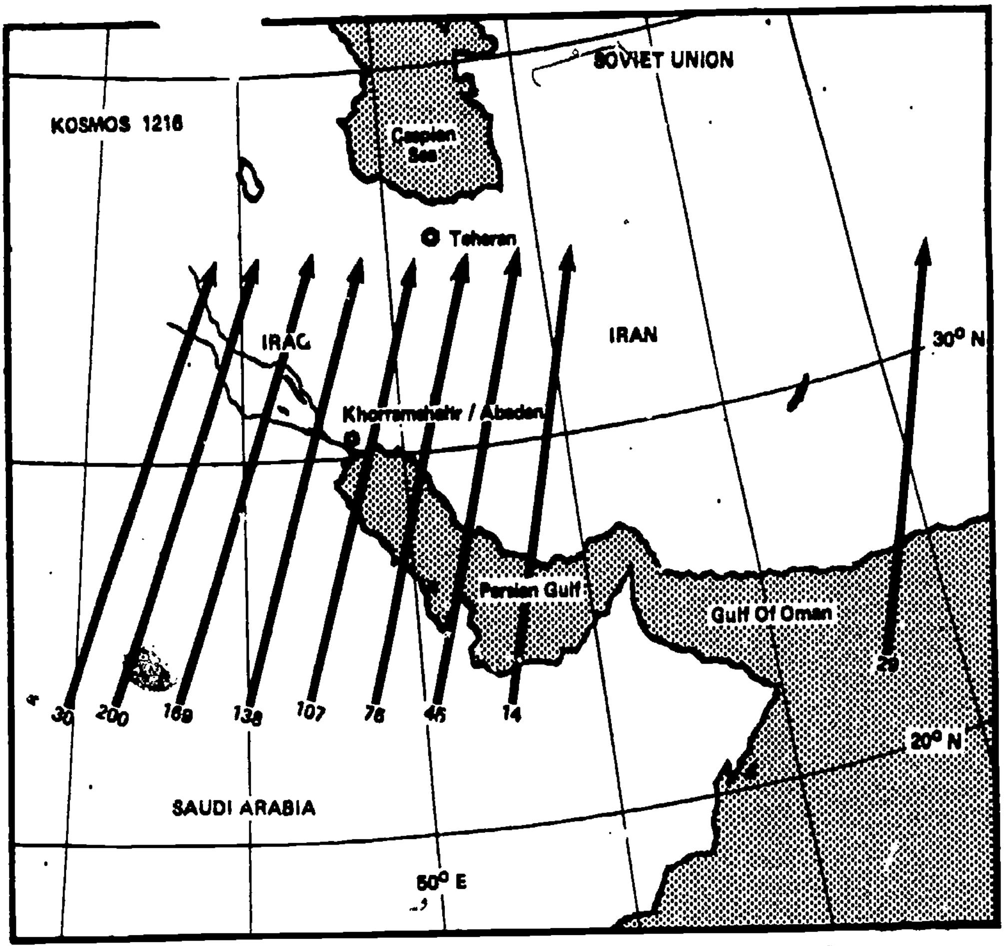

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FIGURE 78.—Ground tracks of Kosmos 1216 over the Persian Gulf.

Toward the end of the 1st day in orbit the perigee was raised above 300 km producing the interlaced ground tracks characteristic of these high-perigee, medium resolution flights which are presumed to fill an area search and find role. By this time, the conflict had been raging for more than 3 weeks and interest in developments well behind the front lines would have been of interest to the Soviets.

From figure 78 it can be seen that revolution 14 on the second day of the flight lies approximately midway between the ground tracks for revolutions 29 and 30 on the 3d day. Furthermore, it will be seen that the ground tracks at 2-day intervals after 31 revolutions show a steady westward drift which, by the end of the mission will have provided complete coverage of the whole area on an alternate day basis. No further maneuver is necessary. Kosmos 1216 was recovered after 14 days and a TF recovery beacon was observed.

FOURTH GENERATION; KOSMOS 1208

The only fourth generation flight during the 1st weeks of the war was that of Kosmos 1208 which had already been in orbit for 27 days when the conflict erupted. Flying at an inclination of 67.1°, its ground tracks on the 364th and 380th revolutions on September 18 and 19 would have been very close to those shown for revolutions 139 and 155 of Kosmos 1214 in figure 75. Termination of the flight on the 29th day might have been due to a desire to obtain film taken immediately prior to the outbreak of hostilities but it is by no means certain that such payloads are recovered at the end of their missions and a 30-day duration is not unusual.

CONCLUSION

The early stages of the Gulf war in September and October 1980 show how the different types of recoverable Kosmos missions were employed to obtain imagery over the battlefield and lines of support. In addition, two missions, probably unrelated to the war, were flown as preplanned flights for remote sensing, mapping and geodesy. In addition to the Tass announcement of the Earth resources mission, direct indications from transmission frequencies and recovery beacons, intercepted by observers of the Kettering Group, provided evidence to support the contention that not all of these flights were direct consequences of the war. In the absence of such indications, the extent of Kosmos coverage of the early stages of the Gulf war might well have been overestimated.

○