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Soviet Scientific Space Program: Gaining Prestige

A Research Paper

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Soviet Scientific Space Program: Gaining Prestige

A Research Paper

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the Office of Scientific and Weapon Research

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Soviet Scientific Space Program: Gaining Prestige

Summary

Information available as of 27 November 1987 was used in this report.

The USSR has numerous, diverse, and, in many cases, ambitious scientific space missions planned for launch through the end of the century. These include missions in astronomy, planetary research, solar-terrestrial physics, and biomedical research. They form the basis for the increasing prestige of the Soviet scientific space program. On the basis of Soviet vested interest in carrying out their program as announced and our analysis of their technical capabilities, we believe that these missions are plausible.

The variety of missions planned reflects the increasing maturation of the Soviet scientific space program. In 1983, the Soviets launched their first spacecraft dedicated to astronomy; their future space astronomy program includes several more dedicated missions. The program is well planned and will address every range of the electromagnetic spectrum with the possible exception of the visible. Future Soviet planetary missions, unlike the missions in the 1960s and 1970s, include the investigation of multiple celestial bodies in a single mission—a testimony to the Soviets' growing confidence and the increasing sophistication of their spacecraft.

Some future Soviet scientific space experiments will further scientific understanding; others will reproduce, to some extent, experiments previously performed. For example, the Mars-Phobos spacecraft, the next generation of Soviet lunar/planetary/asteroid spacecraft, will carry instruments to perform the most detailed study of the Martian plasma environment ever conducted. However, we do not expect the other experiments on the Mars-Phobos mission to produce fundamental discoveries about Mars. Many of the observations planned were made by the US Viking missions in the 1970s and their predecessors. Among other missions planned by the Soviets are Prognoz 13, which will collect background radiation resulting from the creation of the universe; the Corona solar probe; and the Mars Orbiter. These missions will be comparable to the US Cosmic Background Explorer, the European Space Agency's Ulysses solar probe, and the US Mars Observer, respectively. Each of the Western missions is scheduled for launch within a couple of years of the respective Soviet mission.

The instruments and equipment to be carried by some future Soviet scientific spacecraft will be significant technological accomplishments. For example, the Soviets plan to automatically deploy a 10-meter-diameter parabolic antenna made of composite materials during their Radioastron very-long-baseline interferometry mission.

The USSR may accomplish some military objectives with its scientific space program.

[redacted]

The USSR's image as a major player in space sciences has been enhanced by its access to space. Not only do the Soviets have a vigorous scientific space program planned, they also have the ability to implement it without concern for launch standdowns, given the diversity and number of launch vehicles in their inventor

Contributing to the prestige of the Soviet scientific space program is its increased visibility. The successes of the Venus and Venus–Halley's Comet missions, launched in 1983 and 1984, respectively, were widely publicized. Soviet officials now speak with greater candor about future scientific space missions and permit more access to Soviet space facilities. In addition, international participation from Western as well as other Bloc countries has increased the program's visibilit

The Soviet scientific space program, by virtue of its scope, launch support, and publicity, presents a visible challenge to other nations' competing programs. Budgetary considerations and launch standdowns have forced the National Aeronautics and Space Administration to postpone and cancel scientific missions. Japan and the European Space Agency, the other two major space players, do not have as vigorous scientific space programs planned

The USSR will derive a variety of benefits from its scientific space program in addition to the advancement of scientific knowledge. These benefits include the following:

- Promotion of an image as a peaceful nation opposed to the militarization of space.
- International recognition as a major force in the space arena.
- Exposure to and acquisition of foreign technology and experience.
- A diplomatic tool.

The interest with which the present Soviet leadership views the scientific space program suggests that Soviet officialdom recognizes these benefits and will exploit them whenever possible

Contents

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Scope Note

In this paper, we primarily discuss missions whose main functions are the advancement of astronomy, planetary research, solar-terrestrial physics, and biomedical research. The discussion is based primarily on open-source information [redacted] Although we have a paucity of information on some missions, we have detailed information on others attributed directly to Soviet space official

This paper does not address future remote-sensing, meteorological, and oceanographic missions, or scientific experiments to be conducted on manned space platforms. Although these missions, too, will acquire scientific data, we believe most will also conduct research and intelligence-collection functions for the military. This is not to say space science missions have no application to intelligence collection and/or military support [redacted] major Academy of Sciences institutes supporting the scientific space program—such as the Institute of Space Research; the Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave Propagation; and the Institute of Geophysics and Analytical Chemistry—are funded heavily by the military

Soviet Scientific Space Program: Gaining Prestige

Introduction

The USSR has conducted work in the space sciences since its entry into space in 1957. This effort, pursued relentlessly over time, is the foundation for the scientific space missions to be launched in the late 1980s and into the next century

The Soviets' scientific space program, as defined in this paper, is a relatively small part of their entire space program. Only about 5 percent of the spacecraft launched in the past six years have been dedicated to scientific functions. (Seventy percent supported the military exclusively; 25 percent performed both civil/scientific and military missions.) We do not foresee an appreciable percentage increase in spacecraft dedicated to the space sciences through the end of the century. However, the USSR derives many benefits from its modest investment in scientific missions

On the basis of the Soviets' vested interest in carrying out announced scientific space missions and our analysis of their technical capabilities, we believe that the future scientific space missions addressed in this paper are plausible. On several of these missions, the USSR has elicited Western participation and shared an unprecedented number of details prior to launch. Because of the increasing international attention being given these plans, we believe the Soviets have an even greater interest in carrying them out and ensuring their success

The Soviet scientific space program—by virtue of its scope, launch support, and increasing visibility—presents a challenge to competing programs of other nations. In previous years, the US space science program was more advanced, sophisticated, and robust when contrasted with that of the USSR. However, current US launch standdowns and the National Aeronautics and Space Administration (NASA) budget constraints provide the USSR an opportunity to surpass NASA's accomplishments, at least in some areas. NASA's budget will need to accommodate a replacement shuttle orbiter, shuttle redesign work, and larger space station cost estimates than expected. US space science missions have therefore been delayed and canceled. For example, the launch of the US Mars Observer will be delayed two years, from 1990 to 1992, and some Spacelab shuttle flights have been canceled. The scientific space programs of the other two major space players—the European Space Agency (ESA) and Japan—have neither the diversity, scope, nor sophistication of the Soviets' program. The USSR currently has unequaled access to space: NASA is experiencing a launch standdown, and neither ESA nor Japan is able to launch at a rate approaching the Soviets'

Scientific Space Program: Making a Name for Itself

A major factor contributing to the strength of the Soviet scientific space program is the active support given it by the Soviet leadership. Open-source information states that in 1983 Yuriy Andropov, then General Secretary of the Communist Party of the Soviet Union, chose Vyacheslav Kovtunenko, whom he regarded as a brilliant designer, to revitalize the [illegible] ment work for the Mars-Phobos spacecraft to be launched in 1988.

There have also been a variety of indications of the importance General Secretary Mikhail Gorbachev places on the Soviet scientific space program:

in August 1985 Gorbachev was so impressed by the successes of the Venus-Halley's Comet (Vega) and the Venera 15 and 16 missions that he gave permission to the USSR Academy of Sciences for an unmanned Mars soil sample return mission.

- Dr. R. Sagdeyev, director of the Institute of Space Research (IKI), publicly claimed that Gorbachev has a personal interest in general problems relating to space and that on certain occasions Gorbachev has expressed interest in special basic science projects. These claims are supported by the Soviet press, which reported in March 1986 that Gorbachev invited Sagdeyev, Kovtunenko, and a host of other Soviet space officials responsible for the Vega mission to the Kremlin to discuss the mission with him.

- [redacted] Gorbachev, recognizing the value of international cooperation on the Vega mission, decided in March 1986 to seek cooperation with the West, and the United States in particular, on future space missions. This decision was a reversal of his previous position of refusing to cooperate with the United States in space as long as the United States was pursuing its Strategic Defense Initiative (SDI).

The USSR's image as a major player in space sciences has been enhanced by its access to space. Not only does the USSR have a vigorous space science program planned, it has the booster capacity to implement it. The USSR has eight well-tested, reliable launch vehicles, and it launches about 100 spacecraft (mostly military) annually. In addition, the SL-X-17 heavy-lift launch vehicle and a shuttle are under development, and a new medium-lift launch [illegible] payloads can also be deployed from the Mir space statio[illegible]

Contributing to the prestige of the Soviet scientific space program is its increased visibility. The Soviet press has publicized the recent successes of the scientific space program, particularly the Venera 15 and 16 radar mapping missions and the Vega mission. Moreover, the Soviet leadership has permitted Soviet space officials greater candor in their discussions and has permitted Western scientists more access to Soviet space facilities, including IKI and the Tyuratam launch complex. Examples of this openness are the 1986 ABC *Nightline* coverage of the Vega encounter of Halley's comet televised from IKI and the many details of the Mars-Phobos mission provided to Western scientists by both individual Soviet scientists and the Soviet press

Also contributing to the prestige and visibility of the Soviet scientific program is international participation. In late 1985, the Soviets established a new organization, Glavkosmos, whose responsibilities include promoting international cooperation in space. Some Western space officials believe that Sagdeyev has been given an official mandate to seek international cooperation in the space sciences. This cooperation encompasses Western nations, including the United States and ESA, and other Bloc countries. For example, at least nine Western countries as well as ESA will provide hardware and/or technical expertise for the Mars-Phobos mission

Future Missions: Basis for Prestige

The diversity, number, and, in some cases, sophistication of Soviet scientific space missions planned through the end of the century form the basis for the scientific space program's increasing international prestige.

Astronomy Missions

Although the Soviet Union has had an ongoing scientific space program since 1957, it has conducted relatively few astronomical studies from space. Many such studies have been conducted by the West. The Soviets' first known launch of a spacecraft dedicated to astronomy was the launch in 1983 of Astron, which carries an ultraviolet telescope. Before 1983, the Soviets had conducted most of their space astronomical research from manned space stations. In April 1987, the Soviets docked Kvant, a space station module dedicated to astronomy, to their Mir space station

A composite view of future space astronomy missions suggests that the Soviets have a coordinated and well-planned program of astronomical investigation that spans the entire electromagnetic spectrum with the possible exception of visible light. We do not know if the Soviets are planning to conduct research in the visible range of the spectrum, as the United States will do with the Hubble Space Telescope [redacted]

Tables 1 and 2 provide detailed information on the Soviet astronomy mission [redacted]

Gamma 1. Gamma 1 will carry instruments to observe gamma-ray sources and locate new ones. Gamma rays are very energetic photons produced by nuclear reactions. Gamma rays originate from large cosmic bursts, where matter is in an extreme state—superhigh temperatures, exceptionally powerful magnetic fields, and intense radiation fluxes. Such conditions are very difficult to simulate on Earth [redacted]

Analysis of data collected by Gamma 1 could enhance understanding of the physical nature and evolution of objects in the universe. This analysis may also help define both the nature of gamma-ray sources and their relation to other astrophysical objects and expand knowledge of the laws of physical phenomena.

The launch of Gamma 1, also referred to by the Soviets as the "Gamma Observatory," has been delayed since 1979, but [redacted] we expect its launch in 1986. [redacted] delays were due to difficulties in fabricating the primary instrument, the gamma-ray telescope Skala, whose principal merits are its high angular resolution and sensitivity, and to problems with spacecraft design

[redacted]

Gamma 1 will probably include a camera in addition to its three reported telescopes (see table 2). According to Sagdeyev, the spacecraft will carry an experiment that will have photographic output, necessitating retrieval of film canisters from its 350-kilometer (km) circular orbit. No other details regarding this experiment are available [redacted]

Granat. Granat will carry instruments to locate gamma-ray and X-ray sources, determine their characteristics, and construct high-resolution images of these sources. Because the sources of gamma radiation are not well established or understood, astronomers want to ascertain the arrival direction of the gamma radiation and hence the location of these sources. The most effective technique for determining location is to make precision timing comparisons (triangulation techniques) using multiple spacecraft separated by long distances. Granat will operate in conjunction with three spacecraft—ESA's solar probe Ulysses and the two Soviet Mars-Phobos spacecraft. Using triangulation, sources of gamma bursts are expected to be located with an accuracy of 10 arc seconds. Data acquired during these missions may enhance understanding of the final stages of stellar evolution (for example, pulsars and black holes) and the nature of very energetic phenomena occurring naturally in deep space. The data may also improve the ability to forecast the future evolution of our own sun

[redacted] Granat will carry a Franco-Soviet X-ray and gamma-ray telescope with an energy range of 3 kiloelectronvolts (keV) to 10 MeV, as shown in table 2. This instrument will function in a range where nuclear events outside the atmosphere could be detected [redacted] this instrument could provide limited data relevant to a nuclear weapon detonation outside the atmosphere. Furthermore, given the involvement of the French and their expectations for data, we believe that the telescope was not designed exclusively for that purpose.

[redacted]

Although we have details on only three of the experiments to be flown on Granat (see table 2), an IKI official has stated that it will carry seven primary

Table 1
Future Soviet Astronomy Spacecraft

Name/ Launch Date	Mission	Spacecraft	Orbit	Other Countries Involved	Mass	Expected Lifetime	Comments
Gamma 1 (late 1980s)	Collect data on the fine structure of known discrete gamma-ray sources and search for new ones	Modified Progress	350-km circular orbit with 65-degree inclination	France, Poland	1,500 kg	At least one year	Will have a large solar panel and be three-axis stabilized to within 0.5 degree
Granat (late 1980s)	Locate galactic and extra-galactic sources of gamma-ray and X-ray radiation, record time and spectral characteristics of gamma-ray and X-ray sources, and construct high-resolution images of these sources	Astron (Venera type)	200,000-km apogee, 2,000-km perigee, four-day period, 51-degree inclination	Bulgaria, France, Denmark	2,270 kg	18-24 months	
Aelita (early to mid-1990s)	Observe and analyze cosmic dust and molecular clouds and determine the distribution of submillimeter wavelength background radiation resulting from the creation of the universe	Possibly a modified Progress	400-km orbit	France		12-18 months	Telescope to operate between 0.1 mm and 1.0 or 2.0 mm; will be cooled to 27 K; aluminum alloy mirror made in USSR
Radio-astron (early to mid-1990s)	Study the structure and physical nature of compact super-powerful cosmic energy generators, study phenomena appearing to travel faster than the speed of light (superluminal phenomena), and study radio-wave scattering in interstellar space	Unknown	Initial orbit to have 7,400-km perigee, 77,000-km apogee, 24-hour period, and 65-degree inclination; final orbit to have 46.8-day period and 1-million-km apogee	FRG, Bulgaria, Netherlands, Australia		Two years	

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Table 2
Instruments on Future Soviet Astronomy Spacecraft

Name	Instruments (type/name)	Energy Range	Total Collection Area	Field of View	Angular Resolution	Energy Resolution	Detectors
Gamma 1	Franco-Soviet gamma-ray telescope—Skala	50 MeV-6 GeV	1,400 sq cm	20 degrees	10 arc minutes at best	55 degrees at 100 MeV; 34 degrees at 550 MeV	
	Franco-Soviet pulsar X-ray telescope—Pulsar X-2	2-20 keV	600 sq cm	10 by 10 degrees	3 degrees		
Granat	One-ton, French-built, gamma-ray spark chamber—Sigma	20-700 keV	2,600 sq cm	7 by 7 degrees	10 arc seconds (achieved when operating in triangulation mode)	8 degrees at 511 keV	Position-sensitive scintillator
	Franco-Soviet X-ray and gamma-ray telescope	3 keV-10 MeV					Xenon proportional counter; scintillator; bismuth-germanium oxide crystal
	Soviet X-ray proportional counter—Art Experiment	3-150 keV	600 sq cm			6 degrees at 100 keV; 20 degrees at 6 keV	
Aelita	1-meter-diameter telescope			3-15 arc minutes	25 arc seconds at best		French-built, 2-mm-diameter detector arrays will be cooled to 0.3 K

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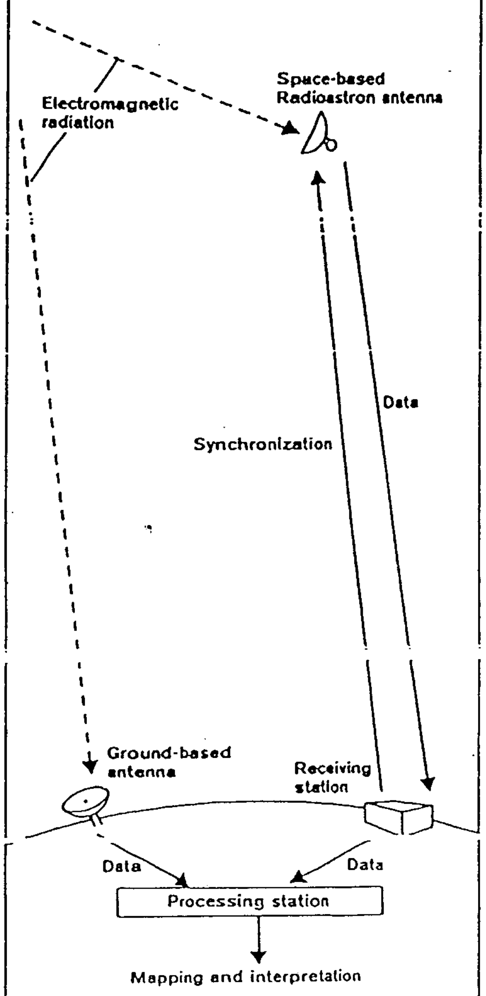
Figure 1
Use of Radioastron for Very-Long-Baseline Interferometry



experiments, with an emphasis on gamma-ray burst detection. One of the experiments [ ] will be an X-ray detector capable of focusing on a gamma burst within one arc second and of narrowing the field of view to improve accuracy

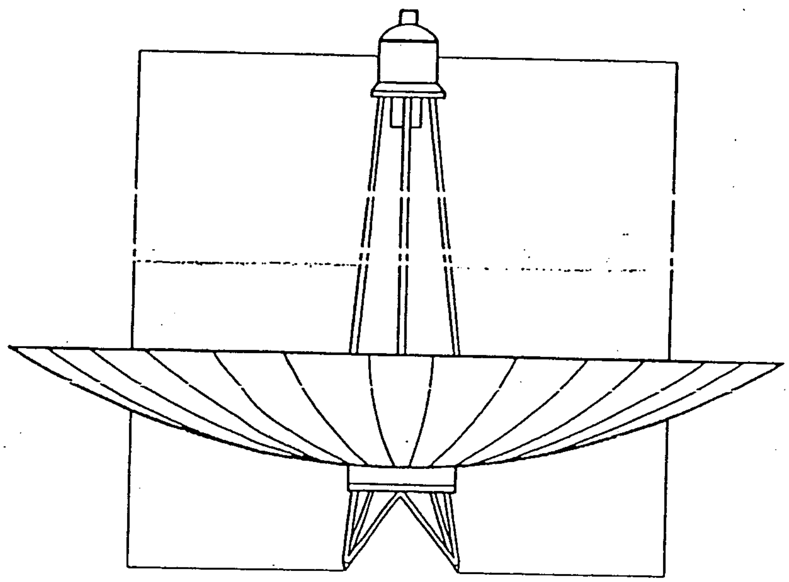
Aelita. Aelita will carry instruments to collect data on nonemitting matter—molecular and dust clouds—and background radiation (relic or residual radiation resulting from the creation of the universe

Analysis of data from this mission could clarify understanding of the processes involved in the formation of stars, the evolution of interstellar matter, and galaxies as a whole. A Soviet scientific journal stated that the mission was also designed to continue research on cosmic background radiation that the Soviets began with Prognoz 9, launched in 1983. The same journal stated that the aluminum alloy mirror for the telescope was made in the USSR and the detector arrays were made in France

Radioastron. Radioastron will carry instruments to collect data on the nature of superpowerful cosmic-energy generators and on radiowave scattering in interstellar space. Data acquired by Radioastron are expected to improve the ability of Soviet radio astronomers to map the structure of celestial radio sources, such as clouds containing molecules of water and hydroxide; radio stars; neutron stars; pulsars; black holes; radio galaxy nuclei; and quasars. This mapping accuracy is six orders of magnitude better than the best possible resolution using ground-based antennas.

Radioastron will operate in conjunction with 70-meter ground-based antennas in the USSR to conduct very-long-baseline interferometry (VLBI; see figure 1). This configuration will provide high angular resolution that cannot be achieved by observations made solely from Earth. Western radio astronomers recognize, however, that the 1-million-km apogee orbit chosen for the final phase of the mission will cause difficulties in calibrating the antenna beam because at that distance it will be difficult to find unresolved sources.

Figure 2
Design of the Radioastron Antenna



A 10-meter-diameter parabolic antenna will be deployed automatically on Radioastron. The antenna will operate at frequencies of 327, 1665, and 4830 megahertz and 22.2 gigahertz. It will have carbon fiber composite panels arranged in a petal design around a 3-meter, solid central paraboloid (see figure 2). Automatic deployment and the use of composite materials are significant technological advances over the design of an earlier 10-meter-diameter, rib-truss, wire-mesh-covered antenna manually assembled on Salyut 6 in 1979. (The 10-meter-diameter antenna deployed on Salyut 6 is the largest parabolic antenna deployed by the Soviets in space.) According to a Soviet technical paper, the pointing accuracy of the Radioastron antenna will be 120 arc seconds and possibly can be improved to 40 arc second

[redacted] the Federal Republic of Germany, Bulgaria, and the Netherlands have agreed to develop cooled transistors that will reduce receiver noise. In addition, Australia has agreed to build an L-band receiver and antennas in

New South Wales and Tasmania, Australia, to support the mission. The Soviets have also sought cooperation, technologies, and instrumentation for the Radioastron mission from NASA—including use of the US Deep Space Network (DSN), magnetic wideband recorder technology, and data-processing systems. If the Soviets use sites only within their land mass and Australia, rather than those in the DSN, potential communication time with Radioastron would be reduced. Magnetic wideband recorder technology is available from Western countries other than the United States. Data-processing systems, however, may be a key concern for Radioastron planners. We believe that the Soviets will be forced to build their own data-processing equipment for this mission, timeshare possible existing Soviet data-processing systems with other Soviet users, or acquire the capability abroad, either through the purchase of data-processing systems or an agreement with a foreign company to process the data. The Soviets have also expressed interest in participating in the proposed ESA-NASA Quasat VLBI mission. However, if the Soviets fail to reach agreement with NASA and ESA, they are prepared to conduct the Radioastron mission independently

Other Space Astronomy Missions. As early as the late 1970s and until 1984 [redacted] discussed a possible radio astronomy mission using a 30-meter-diameter antenna in space. The mission entailed construction of the antenna by cosmonauts in low-Earth orbit. Low-Earth orbit is generally considered to be an orbit whose apogee is no more than 400 km. We believe that, although the Soviets may have a continuing interest in such a mission, it has not been officially approved. Possible, not-strictly-scientific applications of a 30-meter-diameter, space-based antenna include signal collection, radiometric surveillance (the radiometric measurement of electromagnetic emissions at microwave frequencies—for example, emissions from rocket plumes and the surface of water), radiometric remote sensing, and possibly communication

The Soviets are also pursuing an ultraviolet space telescope project, although we do not know if it is funded. According to an East European press report, scientists from the USSR, the German Democratic Republic, and Czechoslovakia attended a three-day meeting in January 1985 to discuss the project. More recent press reports indicate that the United Kingdom is considering whether to place instruments on a Soviet "extreme-ultraviolet and X-ray astronomy satellite" to be launched in the 1990s. These reports may refer to the Spektr-Roentgen-Gamma mission now being planned for launch in the early 1990s. According to the Soviet press and [redacted] Spektr-Roentgen-Gamma will be an international mission and will carry ultraviolet, X-ray, and gamma-ray sensors

Lunar and Planetary Missions

The Soviets have undertaken lunar and planetary missions since the early days of their space program. Although not always successful, their desire to explore space has been relentless. The Soviets have not launched a spacecraft to Mars since 1973; however, 13 launches were attempted before 1973. By 1976, the year of their last lunar launch, 48 spacecraft had been launched to the Moon. The Soviets have launched 26 spacecraft to Venus, the most recent in 1984

Soviet planetary spacecraft launched in the 1980s after Venera 13, which was launched in 1981, have increased lifetimes and extended flights. Yet none of these spacecraft will collect data on the outer planets. On the basis of comments by Sagdeyev and the Soviets' past use of RTGs, we believe that an inadequate power supply, specifically inadequate RTGs, has prevented Soviet exploration of the outer solar system. The USSR has not employed RTGs in space since their use on two Kosmos missions in 1965 and on lunar rovers in the early 1970s. Although a nuclear reactor could supply enough power for a mission to the outer planets, the Soviets have been unwilling to accept the weight penalty of a reactor for such a mission. The Soviets may reconsider such missions now that testing of the SL-X-17 heavy-lift launch vehicle has begun

Table 3
Future Soviet Planetary Missions

Name	Mission	Launch Date	Spacecraft	Orbit	Other Participants
Mars-Phobos	Collect data on the Sun, interplanetary space, Mars, and Phobos	Mid-July 1988	First of new generation of planetary spacecraft	Martian	Austria, France, FRG, Switzerland, United Kingdom, Brazil, Bulgaria, GDR, Poland, Finland, Sweden, ESA, Czechoslovakia, Hungary
Mars Orbiter	Perform geochemical and climatological experiments	Early-to-mid-1990s	Mars-Phobos type	Martian	France
Mars soil sample return	Return soil and rocks from Mars for analysis	Late 1990s	Mars-Phobos type	Martian	

The Soviets have shown interest in a Jupiter mission since the 1970s. Although a Soviet interplanetary scientist stated that a mission to Jupiter and its moons has been under consideration since early 1985, we have no indication that the Soviets are giving it serious consideration

Beginning in early 1986, the Soviets most likely switched their focus from research on Venus to a long-term investigation of Mars. Table 3, detailing future Soviet planetary missions, reflects this switch. The focus on Mars [redacted] will be sustained at least through the 1990s. We do not know the specific reasons for the realignment of effort. Venus may now hold less attraction for the Soviets because it is better known. The most recently launched Venera and Vega spacecraft acquired much high-quality data on Venus. In addition, in the late 1980s or early 1990s, the United States plans to launch the Magellan spacecraft, whose mission will be to map the entire surface of Venus using a synthetic aperture radar (SAR

The Soviets may believe that they can attain greater prestige internationally by focusing on Mars. Relatively little attention has been given Mars since the mid-1970s, when the US Viking program was active. The United States plans to launch the Mars Observer in the early 1990s; however, the US mission is being designed with limited resources and will focus on geoscience and atmospheric studies

A new trend in Soviet mission planning for planetary spacecraft is evolving. Multiobjective missions with several participating nations began in 1984 with the launches of the Vega spacecraft, which collected data on both Venus and Halley's comet. The Mars-Phobos mission to be launched in 1988 follows this trend. Multiobjective missions, in addition to being economical, indicate the Soviets' increasing confidence in their ability to successfully complete complicated interplanetary missions

Mars-Phobos. The Soviets intend to separately launch two sophisticated, unmanned spacecraft in mid-1988 as part of a scientific investigation of Mars and Phobos, one of its two moons (see inset). The 460-day mission will entail 22 experiments designed to collect data on the Sun, interplanetary space, Mars, and Phobos (see table 4). Non-Soviet Bloc nations will participate in at least 13 of the 22 experiments on the mission. Additionally, three distinguished US scientists have been named as interdisciplinary investigators

Mars-Phobos: An Ambitious Mission

The Mars-Phobos mission is an ambitious undertaking. Its complexity rivals that of the US Viking mission, which landed an impressive biochemical analysis package on the Martian surface. Openness about the goals of the mission demonstrates Soviet confidence in their planetary program gained from the Venera 15 and 16 missions and from the Vega missions

Phobos will be only the fifth extraterrestrial body to be directly sampled by a spacecraft. Phobos is a body of great scientific interest because it may be of asteroid origin. Knowledge of its composition and structure could provide insights into the origin of the solar system. Previously, asteroids could be studied only by ground-based instrument.

According to open-source reporting, both Mars-Phobos spacecraft will be three-axis stabilized, will have star orientation sensors capable of a stabilization accuracy of ±1 degree, and will be the first of a new generation of modular interplanetary spacecraft adapted for future flights to planets, asteroids, and comets (see figure

The scientific merit of the Lima-D laser experiment (see table 4) has been questioned. [redacted] *Some prominent Soviet space officials have openly criticized the experiment, which weighs 70 of the 400 kilograms (kg) total weight of the 22 experiments on the missior*

We believe that the Soviets may have other reasons to justify the inclusion of this experiment in the mission. One reason might be the opportunity to obtain information on how the West designs, develops, and space-qualifies a laser—a step that could be necessary in the development of a space-based military laser. Although the Lima-D experiment is not a test of a prototype space-based weapon, its performance [redacted] *is very similar to lasers required for some strategic defense applications, particularly laser radar*

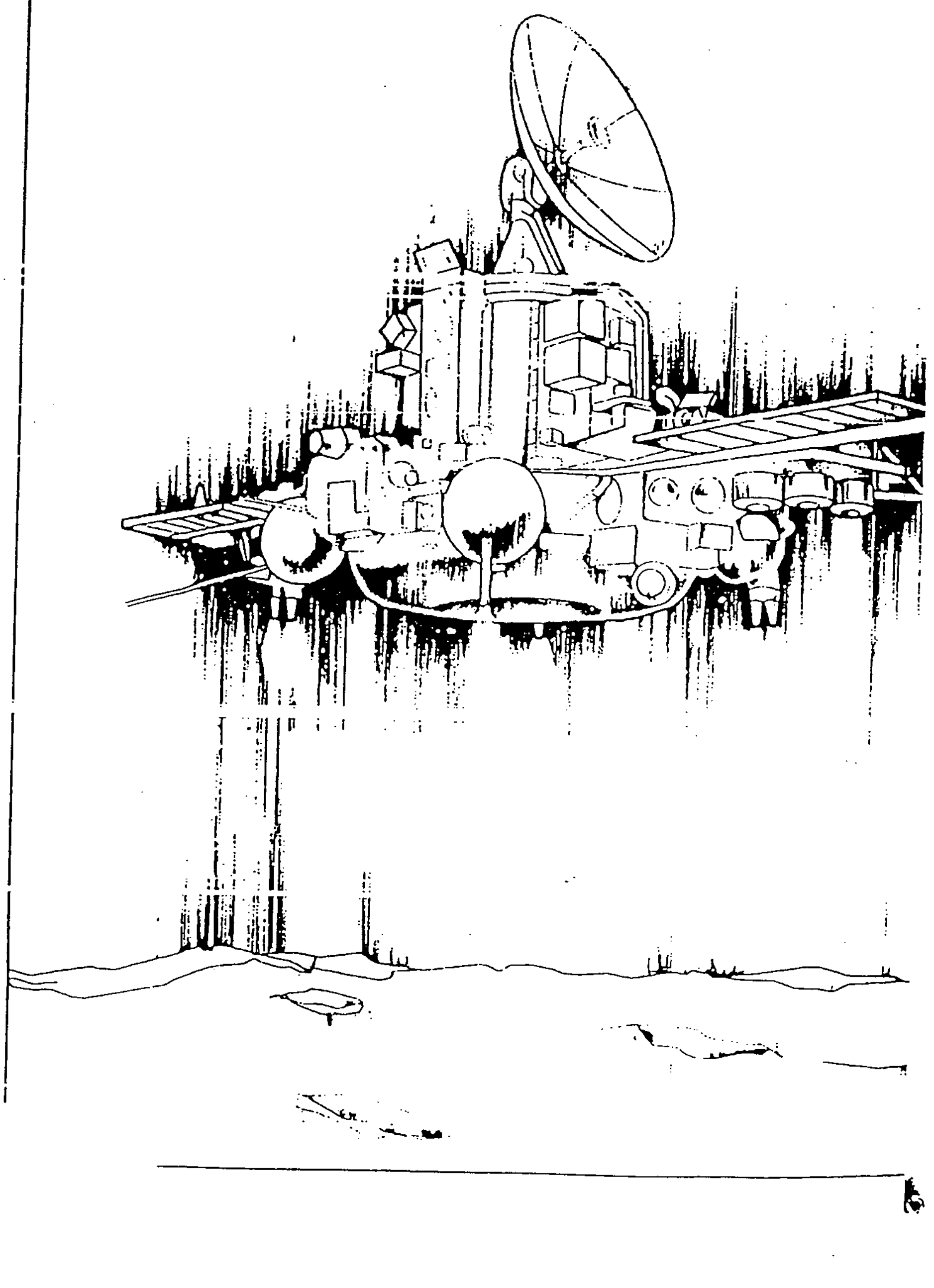
During the near encounter with Phobos, when the spacecraft will hover above the Moon's surface, very precise navigation will be required. The relief on Phobos can be as great as 1 km. Furthermore, Phobos's small, unmapped gravitational field, which is undoubtedly highly irregular because of Phobos's shape, adds to the complexity of the navigation problem. (According to an open source, the Soviets will equip the spacecraft with footpads. These may be intended to serve as shock absorbers in case of collision with Phobos.)

Soviet space officials have discussed two landers for the mission. The hopper lander will weigh 20 kg and have whiskerlike rods to orient itself. It is designed to hop approximately 20 meters in each of its 10 planned hops. The hopper will transmit data to the Mars-Phobos spacecraft for relay to Earth

The stationary lander will be spin stabilized on its descent from the spacecraft to Phobos and will be fixed to the surface by an anchor. The lander will weigh approximately 30 kg, will be powered by three deployable solar panels, and will carry a 5-meter-long surface penetrator. Data transmissions from the fixed lander to Earth would be planned during 30-minute communications sessions every other orbit of Phobos around Mars. The expected lifetime of the lander is one year.

The spacecraft are expected to make the most detailed study ever conducted of the plasma environment near Mars. However, the experiments devoted to the study of Mars itself are not expected to produce fundamental discoveries about the planet, although they will contribute to climatological studies. The spacecraft will measure the composition of the atmosphere, determine how atmospheric temperature varies with altitude, map the surface, and search for water. Such observations have been made by the US Viking orbiters and several earlier Mariner probes. Furthermore, the Viking landers made direct measurements of atmospheric and surface properties.

The Mars-Phobos Spacecraft



Mockups of the Mars-Phobos spacecraft displayed at the Paris Air Show, June 1987.

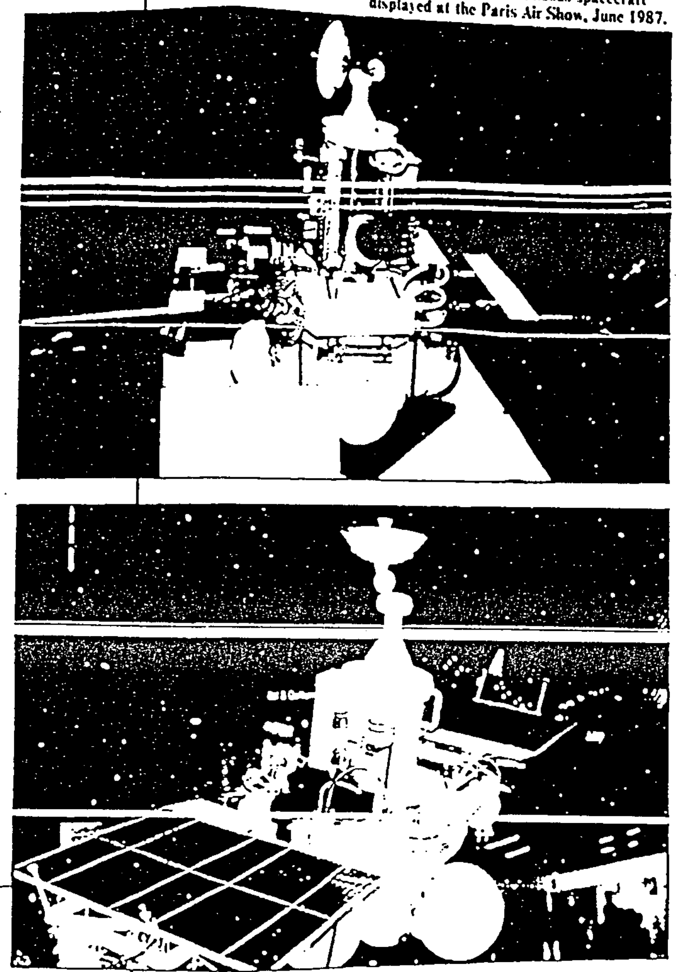


Table 4
Experiments To Be Conducted During Mars-Phobos Mission

Experiment	Subject of Study	Participating Countries
Fregat (television coverage)	Phobos surface	Bulgaria, GDR, USSR
Lima-D (laser-mass spectrometric analysis)	Phobos soil composition	Austria, Bulgaria, Czechoslovakia, GDR, FRG, USSR
Grunt (radar study)	Phobos soil composition	USSR
KRFM, ISM, and Termoskan (radiometric and spectral measurements)	Surface temperatures of Mars and Phobos	USSR, France
Stationary lander	Phobos soil, inner structure, and libration point	USSR, France, FRG, Hungary
Hopping lander	Phobos gravity, soil, and magnetic field	USSR
August (spectrometric study)	Composition and structure of Martian atmosphere	France, USSR
Aspêra (cosmic plasma analyzer)	Martian atmosphere	Finland, Sweden, USSR
APV-F (plasma wave studies)	Martian magnetosphere and interplanetary medium	Czechoslovakia, ESA, Poland, USSR
GS-14 (gamma emission study)	Gamma radiation from Martian and Phobos surfaces	USSR
IPNM (measurement of neutron flux intensity)	Neutron radiation from Phobos surface	USSR
Sovikoms (spectrometric study of the energy mass and charge composition of the solar wind)	Solar wind and plasma near Mars	Austria, FRG, Hungary, USSR
Taus (spectrometric study of solar wind)	Solar wind	Austria, Hungary, FRG, USSR
AEG-F (spectrometric study of angular distributions of low-energy electrons)	Interplanetary space and plasma near Mars	USSR, Hungary
Let (high-energy solar cosmic-ray spectrometry)	Cosmic rays	ESA, Hungary, FRG, USSR
Sled (low-energy solar cosmic-ray spectrometry)	Cosmic rays	Hungary, FRG, USSR
Plazma (radiosounding)	Martian ionosphere	USSR
FGMM and Magma (magnetometry)	Martian magnetosphere and magnetic characteristics of Phobos	GDR, USSR, Austria
Terek (solar X-ray study)	Solar activity	Czechoslovakia, USSR
RF-15 and SUPR (monitoring of X-ray and ultraviolet solar radiation)	Solar activity	Czechoslovakia, USSR
VGS and Lilas (cosmic solar and gamma bursts study)	Solar activity	France, USSR
Iphir (solar oscillation study)	Sun's inner structure	ESA, France, Switzerland, USSR

According to open-source information, the spacecraft will rendezvous with Phobos and hover 50 meters above its surface for a period of 15 to 20 minutes. During this time, the spacecraft will drop a long-lived, stationary lander and perhaps a lander that will hop along the surface. The lander(s) will carry instruments to study seismology, soil composition, temperature, and the orbital dynamics of Phobos. Also during this time, a laser and a particle beam will be fired at Phobos to produce an ion cloud composed of vaporized soil. The ion cloud will be analyzed to determine the composition of Phobos's surface and to identify ions implanted by the solar wind. After the hovering phase, the spacecraft's orbit will be changed to facilitate sensing of the Sun and Mars and further sensing of Phobos.

Mars Orbiter. This mission, consisting of two spacecraft, will include geochemical and climatological experiments much like the US Mars Observer. A variety of sensors, including a SAR, a penetrometer (a device for measuring the penetrability of a solid), and a high-resolution television camera, are being considered for the mission. Also under consideration are a rover and balloons instrumented with a wide variety of sensors [redacted], the mission is being considered for 1994.

Mars Rover and Soil Sample Return. Key Soviet space officials have repeatedly expressed interest in another mission to Mars. This mission may include a rover to collect data about the surface of Mars and a soil sample return. The mission is being considered for the late 1990s. According to one official, Gorbachev has approved a soil sample return mission.

Manned Mars Mission. Soviet officials [redacted] have stated that the USSR is pursuing a long-term goal of a manned Mars mission. In addition to these and similar statements, we have three indicators of Soviet preparations for a manned mission to Mars:

- The long-duration stays in space by cosmonauts.
- A [redacted] report of the development of magnetoplasma dynamic thrusters for a manned Mars mission.
- The mention of the possible development of a nuclear rocket engine for a manned Mars mission in the Soviet *Encyclopedia of Cosmonautics*.

We believe that the Soviets have established a goal of placing man on Mars. Although a manned Mars flyby—probably one year in duration with a crew of three—could precede a manned landing, two factors suggest that the Soviets are considering a landing for their first manned Mars mission. First, recent comments by Soviet space officials indicate that the duration of the mission will range from one and a half to three years—longer than a flyby would require. And second, the recently announced unmanned Mars missions planned for launch in the 1990s could provide the necessary scientific data and technology experience—which a manned flyby might otherwise provide—to plan and support a manned Mars landing.

The Soviets probably will not attempt a manned mission to Mars before the year 2000. A manned Mars mission depends on successful development of the propulsion system, on-orbit assembly techniques, and other advanced systems (cryogenic cooling and improved insulation). The manned Mars spacecraft and propulsion system will have to be assembled in low-Earth orbit. Such an undertaking will require the SL-X-17 heavy-lift launch vehicle, now under development; a manned space station to support the assembly in orbit; and probably a space tug, now under development, to move large components into position for assembly.

[redacted] indicate that the Soviets are investigating using nuclear energy to propel the spacecraft from Earth orbit. Launch vehicles equipped with either nuclear rocket engines or conventional rocket engines with cryogenic propellants would minimize the number of support launches required to assemble a spacecraft in low-Earth orbit. However, both engines will require the development of advanced refrigeration and insulation techniques to maintain the cryogenic propellants in a liquid state. (The current Soviet rocket engine technology requires considerably more propellant and, hence, more support launches.) We believe that the Soviets possibly could have both engines available by the mid 1990

Venus. [redacted] indicates that the Soviets have no plans for a mission to Venus at least through the 1990s. However, in the early 1980s, the Soviets focused their interest on missions to Venus. These missions were to include a lander with high-temperature electronics capable of withstanding the harsh Venusian environment for several months, a lander with a much shorter lifetime, a rover, balloons, Venus radar mapper(s), and payloads launched on a Venus-Earth-Mars trajectory. Any of these missions could be reinstated in the future

Moon. The lunar polar orbiter that had been an approved mission intended for launch in 1990 or 1991 has been canceled for budgetary reasons. Although Soviet space officials have voiced interest in establishing a lunar base, [redacted] indicate that it has not been included in their current space plan. This is probably the five-year plan that began in 1986.

While we can identify no compelling reason for the Soviets to go to the Moon in the near term, a lunar polar orbiter could survey the lunar surface for sites for an eventual lunar base. A base could be the center for logistic support of large space complexes. As an example, propellants (hydrogen and oxygen) mined from the lunar surface would be more efficiently supplied to an orbiting station than those from Earth.

Vesta. The Vesta mission, in which the French were to have participated, was designed to collect data on comets and asteroids, possibly including the asteroid Vesta, in the solar system. [redacted] suggests that the mission has been canceled because of a lack of French funding for it.

Solar-Terrestrial Physics Missions

Solar-terrestrial physics addresses the flow of energy (in the form of particulate and electromagnetic radiation) from the Sun to Earth and the effects of that energy flow on the space and atmospheric environment in the immediate vicinity of Earth. Soviet solar-terrestrial physics experiments have been flown primarily on Prognoz and Interkosmos spacecraft; some have been included on interplanetary, lunar, and meteor missions. Since the late 1970s, Prognoz spacecraft have been launched every other year. The Soviets launched 22 Interkosmos spacecraft between 1969 and 1981, and none have been launched since then. Table 5 summarizes future Soviet solar-terrestrial physics missions.

An understanding of solar-terrestrial physics is of practical importance. Solar activity can affect the maximum and minimum usable frequencies of a high-frequency (HF) communications network. Also, advance assignment of a communications channel requires a knowledge of expected solar activity levels. Solar activity can also perturb spacecraft orbits; disrupt and degrade surveillance, detection, and tracking systems; and interfere with the operation of spacecraft electronics. The Soviet manned space program relies on the monitoring of solar radio emissions when planning and performing extravehicular activities. Furthermore, evidence that solar activity affects global weather patterns is now fairly conclusive, although the nature of the interaction is still a complete mystery. A knowledge of the upper atmosphere (altitudes between 60 and 500 km) is also important because at these altitudes reentry vehicles experience their maximum heat loads and the orbits of low-altitude spacecraft are affected most by atmospheric drag

Active. The Active spacecraft will collect data on the spatial structure of wave ducts, nonlinear distortion of [illegible] (RF) heating of plasma, and RF discharge around the spacecraft. In addition to their scientific merits, the experiments aboard Active could relate to Soviet intelligence and/or military efforts [redacted]

Table 5
Future Soviet Solar-Terrestrial Physics and Biomedical Space Missions

Name	Mission	Launch Date	Spacecraft	Orbit	Other Participating Countries
Active (also called Aktivnyy-(k)	Study the following: spatial structure of wave ducts by focusing on plasma waves, energetic particles, and cold plasma measurements; nonlinear distortion of wave signals; particle precipitation; RF heating of plasma; and RF discharge around the spacecraft	Late 1980s	Interkosmos automatic universal orbiting satellite (AUOS) with a subsatellite	Highly elliptical, highly inclined	Bulgaria, Czechoslovakia, Poland, GDR, Romania, Hungary, Cuba
Apex	Study plasma under conditions that cannot be duplicated in the lab, as well as model and simulate geophysical processes by means of injection of electron and plasma beams	1989 or 1990	Interkosmos AUOS	Highly elliptical, highly inclined	GDR, Bulgaria, Czechoslovakia, Poland, Romania, Hungary
Prognoz 11 and Prognoz 12 (with Interball experiment)	Determine more precisely the nature and extent of the effects of solar bursts and flares on the Earth's ionosphere and magnetosphere	Early 1990s	Prognoz with subsatellite	One Prognoz will have a 250,000-km apogee, a 500-km perigee, and a 96-hour period; the other Prognoz will have a 20,000-km apogee, a 500-km perigee, and a five-hour period	Czechoslovakia, Bulgaria, Hungary, GDR, Cuba, Poland, Romania, France, Austria, Canada, ESA, Sweden, Finland
Prognoz 13 (with Relict experiment)	Measure the solar wind and the Earth's magnetosphere; study the large-scale structure and dynamics of the development of our galaxy; collect background [illegible] universe	Early 1990s	Prognoz	To be placed at the L2 Lagrange point	Bulgaria
Low-Altitude Auroral Cluster	Study coherent electromagnetic structures of auroral longitudinal currents and the physics of ionospheric ion injection into the magnetosphere	Mid-1990s	AUOS with four unoriented subsatellites	1,500-km apogee and 500-km perigee	
Magnetospheric Mission	Will perform radio sounding to study global plasma structures, release gas, possibly barium in the plasma sheet to trigger substorms, and will measure local plasmas and fields	Mid-1990s	Two Prognoz; each will eject a subsatellite		
Biosat 1989	Collect data for use in the study of space biology and medicine	Sep or Oct 1989	Vostok type	Inclined 62 degrees	France

[redacted]

The Active spacecraft may collect information relevant to Soviet investigations of communications between spacecraft and submerged submarines. [redacted]

The Active mission consists of a main spacecraft and a 35-kg subsatellite. [redacted] payload instrumentation on the primary spacecraft will include a pulsed VLF transmitter having 5- to 10-kW peak power and operating at 10 kilohertz, using a 10- to 20-meter loop antenna. [redacted]

Apex. The effects of both electromagnetic and particulate (xenon gas) injections into the ionosphere will be sensed by instruments on the Apex spacecraft. [redacted]

Prognoz 11 and 12 With Interball Experiment. The Interball experiment to be flown on the Prognoz 11 and 12 spacecraft will collect data useful in modeling solar effects on the magnetosphere. Such a model will be useful in a variety of both Earth- and space-based civilian and military programs, including over-the-horizon radar operations and communications. The experiment involves the ejection of 35-kg Czechoslovakian-built subsatellites (daughter satellites) from the Prognoz spacecraft. The Prognoz spacecraft will have a scanning photometer capable of ultraviolet imaging.

Prognoz 13 With Relict Experiment. Instruments to be flown on the Prognoz 13 spacecraft will measure the solar wind and the Earth's magnetosphere, as well as conduct an astronomy experiment. The Relict astronomy experiment consists of microwave radiometers that, like instruments on the Aelita spacecraft, are designed to detect radiation (relict radiation) left over from the creation of the universe. This experiment is a continuation of the Relict experiment conducted on Prognoz 9, launched in 1983.

International Solar-Terrestrial Physics Program. NASA, ESA, and the Japanese Institute of Space and Astronautical Science are developing the International Solar-Terrestrial Physics Program (ISTPP) to make a long-term, comprehensive assessment of solar-terrestrial interactions. In support of this program, ESA has proposed Cluster—a group of one main and three companion, spin-stabilized satellites—and the Solar and Heliospheric Observatory (SOHO), which is intended to orbit the Earth-Sun L1 Lagrange point.

The USSR has expressed much interest in participating in the ISTPP and has suggested several ways that this might be accomplished. [redacted] state that the Soviets are planning two spacecraft missions—the Low-Altitude Auroral Cluster and the Magnetospheric Mission—that complement the ISTPP's missions. In addition, the Soviets have offered to support the ISTPP with the Corona solar probe. These three spacecraft will be launched at two-year intervals to study solar flares and the solar corona. [redacted] many Interkosmos countries have been invited to participate in the Corona missio

Biomedical Missions

The USSR has a continuing biological satellite (biosat) program and over the past 20 years has launched nine dedicated biomedical missions. Biomedical experiments have also been performed on the unmanned precursors of manned spacecraft, on manned spacecraft, and on recoverable reconnaissance spacecraft. The tightly focused, stated, long-term goal of all these missions is to achieve unlimited human spaceflight. Of the many biological and medical experiments conducted by the Soviets in space, most have addressed the effects of weightlessness and radiation exposure. One of the primary advantages of the biosats is that they fly at higher inclinations than do Soviet space stations (63 degrees versus 52 degrees), and thus are exposed to higher levels of radiation. With these spacecraft then, the Soviets can acquire data on radiation exposure without human risk. The concern over radiation exposure to humans is particularly relevant to long-term manned spaceflight, particularly manned interplanetary spaceflight, because of the cumulative nature of radiation injury, unpredictability of solar activity, and increased exposure as one goes beyond the Earth's radiation belt

The most recent biosat (launched in September 1987) was a 13-day mission. On board were two large primates, probably rhesus monkeys, as well as a variety of smaller animals and plants. According to recent, reliable reporting, the USSR will continue the biosat program with launches every two years.

Benefits of the Soviet Scientific Space Program

Over the years, the USSR has derived a variety of benefits and advantages from its pursuit of the space sciences. We believe these benefits will increase in number and appeal as the program captures a wider audience. Given the support of Soviet officialdom, we believe that the leadership recognizes these benefits and will continue to support a strong scientific space program

Scientific space missions can build or promote a national image. The Soviet leadership may consider one of the most valuable benefits of its space program to be the promotion of the USSR as a peace-loving nation, as opposed to the United States, which the Soviets claim is militarizing space through its SDI. Numerous examples of this—all approved by the Soviet leadership and some intended for international consumption—are found in Soviet literature and especially in the Soviet news media:

- *Pravda* in July 1986 noted that "Moscow and Paris are setting an example of the peaceful development of space by cooperating with states belonging to different social systems."
- On 14 July 1986, TASS broadcast a program in English stating that the USSR has chosen to advance science through programs such as Vega in contrast to the United States, which hopes to advance science by its SDI.
- Sagdeyev has publicly joked before international audiences that the laser to be flown on the Mars-Phobos mission "is 10-to-the-minus seventh to 10-to-the-minus eighth the strength of a laser for Star Wars"

A strong scientific space program can also promote the image of the USSR as a technologically advanced nation and a major player in space. International recognition as a space power probably depends to a great extent on visible accomplishments. Neither the United States nor the USSR publicizes its military and intelligence missions. Consequently, Soviet press releases and television coverage of peaceful scientific missions could influence world opinion, particularly when they have unequaled access to space. In addition, at the Space Forum, a symposium hosted by the USSR in Moscow in October 1987 and attended by approximately 300 Western scientists, the Soviets demonstrated confidence and prowess in openly discussing their scientific space program. Although the symposium was nonpolitical and noncontroversial, it was politically profitable. This enhanced image could favorably influence customers seeking commercial launches

The USSR also benefits internally from a strong space science program. Technologies tested on scientific space missions have been incorporated into more expensive and more critical missions supporting the

Soviet military and intelligence services. Gallium arsenide solar panels were first flown on Venera 13 and 14 in 1981 and were later incorporated into the manned space program on Salyut 7. Furthermore, SARs tested on civil/scientific missions probably will aid the Soviets in developing SARs for military applications

The USSR has acquired foreign instrumentation and operational procedures as a result of international participation in its scientific space program. For example, the Canadians are participating in the Interball mission, according to the Soviet press. They have proposed providing two cameras based on the design for the imager supplied by Canada for Sweden's Viking satellite. If the cameras are to be placed on the Interball, state-of-the-art technology in staring imagers will be transferred to the USSR. In other cases, the Soviets have gained access to foreign development and test facilities. Foreign participation can reduce the mission cost to the Soviets and/or minimize the risk of equipment failure. Whenever foreign technology is also applicable to military systems, the payoff of international participation is even more appealing

As a diplomatic tool, the Soviet scientific space program can be used to promote cooperation and foster trust among nations. With offers to cooperate in scientific space missions, the USSR can use to its advantage the frustration that some Western scientists feel over the uncertainties in US programs