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THE SOVIET SPACE PROGRAM: PUBLIC POLICY and PROGRAMS

The USSR has entered a new phase in its manned space effort and has announced ambitious programs for scientific and planetary research. Two major Soviet publications on their space program have appeared in recent months. These sources, together with a range of other open source materials, provide an overview of Soviet public space policy and plans for future space programs.

IN THIS ISSUE:

This paper was prepared by [redacted] Science and Technology Center, FBIS. Comments and queries are welcome and may be directed to the author on [redacted] or the Chief/S&TC/FBIS on [redacted] Selections from the two primary Soviet sources on which this paper is based will appear in forthcoming FBIS reports. Excerpts from "USSR Cosmonautics" will be published in the USSR REPORT: SPACE (FOUO). A collection of selected articles from the "Encyclopedia of Cosmonautics" will appear as a special issue of the same report series.

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For the USSR the start of 1986 has brought major successes in space. The encounter of the Vega spacecraft with Halley's Comet received worldwide attention. In February the launch of the Mir third-generation orbital station marked a major expansion in the Soviet manned program. The USSR has also announced a series of projects for the late 1980s and 1990s which comprise an ambitious program of space science and planetary research.

At the end of 1985 a new "Encyclopedia of Cosmonautics" was produced under the general editorship of V. P. Glushko, a major designer of rocket engines. The last such encyclopedia, also edited by Glushko but more limited in scope, appeared more than 15 years ago. Early 1986 saw the appearance of a lavishly produced large-format volume entitled "USSR Cosmonautics," written by an authorial collective which includes many of the major figures in the Soviet space program. While these books present no major changes in space policy, when taken together with a wide range of other available open source materials they present a fairly detailed picture of the public face of the Soviet space program. The following sections summarize this self-portrayal in terms of stated policy aims, details of specific near-term programs, and indications of long-range goals in the civil, scientific and applied areas of the Soviet space effort.

I. SPACE POLICY

A. THE MILITARIZATION OF SPACE THEME

Soviet media contrast a peaceful Soviet program undertaken for "science, the national economy, and the good of all mankind" with a U.S. policy intent on militarizing space and seeking military superiority. In an interview upon the publication of the new cosmonautics encyclopedia Glushko stated "the peace-loving policy of the Soviet state is reflected in the encyclopedia. Anyone seeking articles there on terms or objects connected with militarization of space will do so in vain." Under the entry "Space Program of the USSR" one finds a listing of institutes of the Academy of Sciences as the organs involved in developing and carrying out the Soviet space program. In the corresponding entry on the U.S. space program one reads that it is carried out by NASA and the Department of Defense. The entry continues: "funds and efforts are directed basically toward creation of satellites with military missions and for the militarization of space."

The militarization of space theme is dominant in the massive propaganda campaign directed against the U.S. Strategic Defense Initiative. Soviet media portray the SDI program as an attempt to create an arms race in space and to develop "space strike weapons." The ultimate strategic purpose of the system is alleged to be a desire to achieve military superiority by making possible a first strike against Soviet offensive nuclear missiles without danger of retaliation. The pervasiveness of the anti-SDI effort affected even Soviet reaction to the explosion of the Challenger. Media commentary almost immediately interpreted the explosion as an object lesson in the vulnerability and danger of highly complicated space systems. A similar explosion of a spacecraft in orbit, the argument ran, might be interpreted as the result of hostile action, which could trigger a nuclear war.

The SDI campaign has provided one of the few contexts in which reference is made to a Soviet military space program. Such comments are couched in terms of hypothetical countermeasures to U.S. deployment of a space-based ballistic missile defense system. Recently, a military commentator claimed that countermeasures such as space mines, launches of decoy missiles, and use of laser-reflective coatings on missiles could effectively foil a space-based BMD system and at only 1 to 2 percent of the cost of deploying such a system. The SDI program is also interpreted as an implied challenge to the

economic and scientific capacities of the USSR. After having just argued that an SDI system could be easily defeated by simple countermeasures, the same commentator goes on to cite the "bitter experience of 1941" and proclaim that the Soviet Union could develop a space-based BMD system of its own.

> "Today the material capabilities of the USSR and its scientific-technical potential are such that our country, if it is necessary, is entirely and realistically capable of responding to the U.S. with the same thing that they intend to threaten us with from space."

The capacity of Soviet science to meet any U.S. challenge was asserted by Defense Minister Sokolov in a 23 February PRAVDA article:

> "Now our country is capable of solving any scientific or technical problem and will not permit anyone to achieve military superiority over it, whether on Earth or in space."

B. PUBLIC RATIONALE FOR THE SOVIET SPACE PROGRAM

NATIONAL PRESTIGE

National pride in the achievements of the space program has been a prominent element in Soviet public discussion since the launch of Sputnik and the first manned orbital flight of Yuriy Gagarin. The civilian and scientific achievements of the space effort have been extensively exploited as proof of world leadership of Soviet science and technology and, therefore, as a validation of the Soviet system. The following example occurred in a 1984 Soviet journal devoted to problems of historiography:

> "The first steps taken in mastering outer space at the turn of the fifties resulted from the work of the Soviet people and, at the same time, were an original symbol of their socioeconomic progress. Soviet man's leap into space embodied both the heights already reached by, and the unlimited potentials of, socialist society."

The same theme is taken up in the first pages of "USSR Cosmonautics":

> "Each stage in the development of Soviet cosmonautics is a major historical milestone along the path of mastery of space, an outstanding contribution to world science and space technology. The Soviet people may be justly proud that the chapters inscribed in the history of cosmonautics by our country begin for the most part with the words 'for the first time in the world', thus confirming the indisputable priority of the Soviet Union in the conquest of space."

After the launch of the new Mir space station, TASS was quick to pick up statements characterizing the event as a major advance of the Soviet space program over the U.S. For example, on 19 and 22 March, TASS in English reported statements by a U.S. space official and an aerospace executive to the effect that the new Mir station has put the U.S. space program 10 years behind the Soviet Union.

SCIENTIFIC VALUE

The value of the Soviet space effort to pure and applied science has been a dominant theme in public discussion since the inception of the space program. Study of near-Earth space and extra-atmospheric astronomy have been stressed as major research areas for the manned program and have been pursued in a number of unmanned programs such as the Prognoz solar research satellites and the recent Astron high-apogee observatory spacecraft for research in the X-ray and UV wavelengths.

The Soviet planetary program has achieved a number of significant scientific successes including transmission of the first pictures from the surface of the Moon and from the surface of Venus. Recent

missions have included a successful radar mapping of Venus by Venera-15 and -16. The first phase of the Vega mission to Halley's Comet dropped off landers and balloon probes for atmospheric research during a Venus flyby. Details on these missions are now appearing extensively in the scientific literature.

In the area of scientific applications, the Earth resources program has been given special emphasis. Remote sensing of Earth resources is given extensive coverage in reports on cosmonaut research activity. In 1980 the Academy of Sciences began publication of a new scientific journal devoted to remote sensing from space. Technical details on such systems as the Meteor-Priroda satellites and the Cosmos-1500 oceanographic satellite have appeared in this journal.

Although all Soviet space activity is reported as in the interests of science, only about 30 percent of the total number of spacecraft launches are identified in the media. In 1985 TASS reported 97 space launches which placed in orbit a total of 118 satellites or spacecraft. These include 13 communication satellites, six navigation satellites, three weather satellites, five launches related to manned missions, seven satellites for remote sensing of resources, the Prognoz-10 solar research satellite and the Cosmos-1667 biosat. The remaining 82 spacecraft were reported as generic "Cosmos" launches. These are announced in a standardized TASS format which varies only in the satellite number, launch date and orbital parameters. The only indication of mission is the formulaic phrase: "aboard the spacecraft there is installed scientific apparatus for the continuation of space research." The Cosmos series has been described as a broad scientific research and engineering program which uses a standardized satellite design. However, of the more than 1,600 Cosmos satellites launched by the signed-to-press date (18 March 1985) of the "Encyclopedia of Cosmonautics" only 29 missions are given individual descriptive entries in the text.

ECONOMIC BENEFITS

Soviet commentators frequently cite economic benefits provided by space technology. Communications satellites are well suited to a country with the large area and diverse geography of the USSR. The Soviets claim that in areas east of the Urals, satellite communication is three times cheaper than radio relay lines. Satellite systems such as Ekran and Gorizont now allow USSR Central Television broadcasts to reach 93 percent of the population of the country.

According to the director of the Priroda State Center, Yuriy Kiyenko, some 300 economic programs now use space photographic data. Over 1 million photographic documents per year are provided to about 1,000 separate organizations. Areas of application include cartography, geology, oil and mineral exploration, agriculture, and fisheries. An example of economic effect which has appeared more than once in the literature is the use of space data for territorial evaluation of resource potential. It is claimed that such an evaluation can be accomplished three to four times more rapidly than with traditional methods and at a cost 12 to 15 times lower.

Soviet claims of savings in ruble amounts range from the impressionistic to the highly specific. The head of the new organization USSR Glavkosmos stated recently that the economic effect of space photography and cosmonaut observations over the past five-year plan for the Central Asia regions alone amounted to "tens of millions of rubles." According to a 1983 article in IZVESTIYA, the use of weather data from meteorological satellites saves 500 to 700 million rubles per year for the national economy. The article goes on to say that in the future the effect of resources studies from space will be 12 to 17 rubles for every ruble spent.

The amounts cited are of more anecdotal than analytic value since no figures are provided on investment in individual space systems or for the space program as a whole. In view of the frequent claims of economic gains flowing from the space program it is rather curious that the chairman of the State Committee for Science and Technology opened a recent roundtable discussion with the following statement:

"The problem facing this country is to make cosmonautics a paying branch of the economy."

Terms such as "profitability" and "economic return" are prominent in discussions of the new Mir orbital station. In an interview after the launch of the Mir a space engineer stated that economic considerations were a major element in the design of the station. He pointed out that the enhanced docking capacities of the Mir "will make it possible to use expensive equipment at full capacity."

INTERNATIONAL COOPERATION

The Soviet Union has developed a number of international space programs which have yielded both political and scientific benefit. A number of countries have attained the prestige of "spacefaring nations" by using Soviet launch services, placing experiments on Soviet space missions, and having cosmonauts participate in Soviet space flights. In addition to the good will and propaganda value gained by these programs the USSR has also been able to exploit the scientific capacities of the participant countries. To cite only one example, the MKF-6 multispectral camera system was developed as a cooperative program of the GDR and USSR. The camera was manufactured by the GDR company Karl Zeiss Jena and became a standard instrument on Salyut-6 and Salyut-7.

The Intercosmos organization was founded formally in 1970 to coordinate space cooperation between the USSR and the six East European communist states (Hungary, GDR, Bulgaria, Poland, Czechoslovakia, and Romania). Original members also included the Soviet clients Mongolia and Cuba. Vietnam became an Intercosmos member in 1979. Five permanently operating working groups coordinate activities in the fields of space physics, meteorology, communications, biomedicine, and remote sensing. To date, 22 dedicated Intercosmos satellites have been launched by Soviet rockets as well as 11 geophysical sounding rockets in the Vertikal series. A major element in the Intercosmos program has been the launch of cosmonauts from member countries as participants in short-term visits to the Salyut-6 space station. In the period 1978-1981 cosmonauts from all nine Intercosmos countries participated in these one-week flights. In 1982 a French cosmonaut flew as a member of a visiting crew to Salyut-7 and, most recently, an Indian cosmonaut visited the station in 1984.

The Intersputnik organization was formed in 1971 by the then nine members of Intercosmos to provide international satellite service for telephone, telegraph, and TV transmissions. The organization's functions paralleled those of the Intelsat consortium which was founded in 1964. In the period 1979-1984, six countries were added as Intersputnik members: Afghanistan, Laos, South Yemen, Vietnam, Syria, and North Korea. Communication services are provided by two Soviet Gorizont satellites in geostationary orbit. Fourteen ground stations are located in member countries as well as in Iraq and Algeria. Stations are reportedly under construction in Libya, Nicaragua and elsewhere.

The Soviet Union has also undertaken a number of bilateral space agreements. Cooperative programs with France began as early as 1966 and have included a number of experiments such as Araks and Arkad. Three Indian satellites have been launched by Soviet rockets. Sweden has flown experiments on the Intercosmos-16 and Prognoz-7 satellites. The first cooperative programs between the U.S. and USSR began as early as 1962. The high water mark occurred in 1975 with the Apollo-Soyuz flight. A new cooperative agreement was signed in Geneva in 1977 but expired in 1982 when the U.S. declined to extend it.

New cooperative efforts reported in the media include plans for a visit by a Syrian cosmonaut to a Soviet orbital station. Two Syrian cosmonaut candidates are now training in the USSR. A protocol has also been signed for a second French cosmonaut to work aboard a Soviet station in 1988. It has been specified that this will be a longer mission than the usual one-week visit by previous non-Soviet crew members. Scientific contacts with other West European countries are widening. The FRG and Austria participated along with the Intercosmos countries in the Vega project. Sweden and Finland will be added to that group for the upcoming Phobos mission.

II. CURRENT AND FUTURE SPACE PROGRAMS

A. THE ORBITAL SPACE STATION PROGRAM

The role of permanently operating orbital stations with rotating crews has long been stressed as the main road for development of Soviet cosmonautics. Cosmonaut crews have logged impressive records in mission duration and have shown skill and adaptability in dealing with difficult situations in flight. Supplementary solar panels have been added to the main panels of Salyut-7 by three separate crews between November 1983 and August 1985. Successful repairs on a fuel line were carried out during cosmonaut EVAs in 1984. Most recently, in June 1985 two cosmonauts were able to reactivate the Salyut-7 station after a complete loss of electrical power. This was followed in September 1985 by the first crew rotation.

The Soviet manned program stands alone in terms of experience with long-duration missions. The last U.S. long-duration flight was the 84-day Skylab mission launched in 1973. Soviet commentators have argued that long flights are more efficient since it takes up to a month and a half for cosmonauts to attain optimum working capacity. This applies both to gaining familiarity with onboard conditions and equipment and also to developing visual acuity for various observation and survey programs. According to Soviet academicians, the present orbital flight record of 237 days may be surpassed. The president of the Academy of Sciences has stated that no insurmountable biological obstacles have been encountered which would prevent prolonged human stay in space, on the order of a year.

THE MIR STATION

The launch of the Mir station in February of this year marks the introduction of the third generation of Soviet orbital stations. The design represents an evolutionary advance over the Salyut spacecraft, the main new feature being a multiple docking port which gives the Mir a capacity for receiving six spacecraft simultaneously. Scientific and production operations will be housed in specialized modular craft such as the Cosmos-1686 which is currently docked with Salyut-7.

Media coverage since the launch of the Mir has provided some additional details on new features of the station's design and operation. A commentary in the 12 March issue of EKONOMICHESKAYA GAZETA stated that the Mir has two main solar panels with a total area of 76 square meters, versus the three panel 60 square meter configuration of Salyut-7. It was also revealed that the Mir panels use gallium arsenide solar cells which provide a "substantial" but unspecified increase in the station's power capacity. In a 12 April interview the flight director for the Mir mission stated that the Mir has a system of seven separate onboard computers for specific tasks. The Salyut-7 has only one computer.

A new data relay satellite system has been inaugurated. A TASS report on 29 March identified the Cosmos-1700 satellite, now designated as Luch, as a relay satellite used for communications from the station to the Flight Control Center during periods when the station is beyond radio range of Soviet territory. Previously, data relays were handled by space support ships in open ocean areas. The original TASS launch announcement for Cosmos-1700 (launched on 25 October 1985) stated only that the satellite carried experimental equipment operating in the centimeter band.

A new generation of transport ships designed specifically for operations with the new modular complex is apparently to go into service with the next flight of cosmonauts to the station. Commentators have stated that the Soyuz T-15, which brought the first crew of two cosmonauts to the Mir, is the last craft in the Soyuz T series.

The role of Salyut-7 in the current operational plan has been clarified somewhat. The 22 March issue of the French aerospace journal AIR & COSMOS quotes the deputy director of the Cosmonaut Training Center Aleksey Leonov to the effect that a new crew will be sent to reman Salyut-7 in the near

future. Leonov went on to say that there are no plans to dock Salyut-7 with the Mir, although this would be technically possible, because Salyut-7 is "too old." According to one Soviet commentator, cosmonauts will "commute" back and forth between the Mir and Salyut-7.

NEAR- AND LONG-TERM STATION OPERATIONS

If no major problems occur during the present checkout period, additional crew members will probably be sent up to the Mir shortly. Press comments have suggested that the base crew may consist of six cosmonauts. This stage should be accompanied by launches of modular spacecraft and the first use of the Mir's lateral docking ports. References have been made to dedicated modules for astrophysics, remote sensing, biological research, and materials production.

No details have yet appeared on new equipment or research programs to be housed in the new modular complex. However, one area being discussed more than others is materials processing. In an interview on the day of the Mir launch, General Leonov described the station as a space laboratory which would start the transition from the research stage to large-scale production activities in space. Some success has already been achieved with experimental production operations aboard Salyut-6 and Salyut-7. The Soviets claim that the "Tavriya" electrophoresis unit has produced a highly pure protein which was later used at a biomedical facility to prepare a trial batch of influenza vaccine. During the 211-day flight in 1982 the "Korund" apparatus reportedly produced an 800 gram crystal of cadmium selenide 30 cm long and 30 mm in diameter. It has also been reported that an electron pumped UV laser at the Academy of Sciences Physics Institute uses a crystal produced in orbit and has shown outstanding operating characteristics. Orbital production of semiconductor materials is considered to be a near-term possibility. Commentators point out that although the output of a unit like the "Korund" is relatively small, the annual requirement for such materials for electronics instruments is only on the order of tens to hundreds of kilograms.

Along with the claimed successes there are also indications that unforeseen difficulties have been encountered on both the technical and theoretical levels. In a 12 November 1985 PRAVDA article a State Prize laureate wrote:

> "The general picture of physico-chemical processes in weightlessness has turned out to be far more complex than the simple models that were accepted in the initial stage of research. The behavior of various substances in weightlessness still requires detailed research."

Scientific commentators are now calling for a coordinated approach under the rubric of a new independent branch of science to be known as "physics of weightlessness." A step in this direction was the recent creation of a new Academy of Sciences Scientific Council for Problems of Space Materials Science.

The authors of "USSR Cosmonautics" convey a highly optimistic view of the near-term prospects for space manufacturing. They cite industrial production of materials and alloys as one of the areas best prepared for transition to modular station operations. Production in orbit is said to make possible new materials which either cannot be obtained in normal gravity conditions or which require very expensive techniques. In addition to the equipment already used aboard orbital stations the authors indicate several new technologies which will be developed. These include shaping of molten metals by weak magnetic fields to form ingots of any required shape without casting in molds. The authors claim that magnetic shaping would produce highly pure metals with virtually no internal stresses. Foam materials are also mentioned as ideally suited to production in weightlessness. For example, a foam steel containing 13 percent metal and 87 percent gas would have the strength of steel but weigh only as much as aluminum. Manufacture of crystals will be developed for both structural and electronics applications. The authors claim that large-dimension acicular monocrystals grown in space could be used as structural elements. Large sapphire "needles" produced in weightlessness could withstand pressures up to two tons per square millimeter. Crystals of semiconductor compounds produced in spherical shapes will be used in "new classes" of electronic devices.

The scaling up of orbital manufacturing operations is viewed by the Soviets as the principal factor determining the next stage of development of transport operations to and from orbit. Modular complexes will require a higher flow of supplies and raw materials. The need to return to Earth the output of the "space production shops" will require that the next generation of cargo transport craft have a return capacity. It should be stressed that the term employed in this context is "returnable," not "reusable." The first stage in the development of this capacity is said to be the use of a return module on the Cosmos-1443 craft which returned about 350 kilograms from orbit.

Soviet statements indicate that a possible long-range development of the orbital station program may involve placing a number of modular complexes in a range of Earth orbits. Press commentary on the Mir station refers to a "unified complex of large-scale orbital structures placed in orbits from 200 to 40,000 kilometers and connected with each other and with the Earth by transport ships for cargo and passengers and controlled from a unified center." This description of a unified system of orbital installations in the specific range of orbits from 200 to 40,000 kilometers is repeated almost verbatim from a November 1983 PRAVDA article on the potential of orbital stations. The 1983 article, coauthored by president of the Ukrainian SSR Academy of Sciences Boris Paton, and Doctor of Technical Sciences Yu. Semenov, goes on to specify that the orbital system will include specialized research laboratories, housing modules, energy installations, a refueling station, repair workshops, and construction sites for producing and installing standardized construction components.

According to the "Encyclopedia of Cosmonautics" entry on orbital stations, plans exist for placing stations at orbital libration points and in lunar orbit where they would serve as outfitting bases for flights to the planets of the solar system.

B. UNMANNED SCIENTIFIC PROGRAMS

The concluding section of "USSR Cosmonautics" discusses several near-term scientific programs. Launch schedules are not given, but the following five projects are said to be planned for "the next few years", presumably the period of the late 1980s and early 1990s.

Two programs will study Earth's magnetosphere and solar-terrestrial relations:

— PROJECT INTERBALL

Two Prognoz-type satellites will be used, each with a maneuverable subsatellite. The Tail Probe satellite will intersect the plasma layer in the tail of the magnetosphere at a distance of 100 to 150 thousand kilometers from the Earth. The second satellite, Auroral Probe, will orbit above the polar auroral oval at an altitude of 10 to 15 thousand kilometers. Each of the main satellites will have a subsatellite which will be able to vary its position relative to the main satellite by using correcting engines.

— PROJECT ACTIVE-IK

This program calls for an active diagnostics experiment to study reaction of the magnetosphere to a wave propagating within it. A transmitter aboard a spacecraft will inject a VLF signal into the magnetosphere. The Active-IK spacecraft will also utilize a controllable subsatellite.

Member countries of Intercosmos will participate in both of these projects.

In the area of high-energy astrophysics, plans exist for orbiting instruments in the second half of the 1980s with observational capacities over a wide range of the spectrum, including X-rays, soft gamma radiation and submillimeter waves. Projects are under way for three orbital astronomical observatories:

— PROJECT GRANAT

Granat is apparently the current designation for the joint Soviet-French project earlier referred to as Gamma-1. The Gamma-1 telescope, which weighs around 1,500 kilograms, will be the

basic instrument on the satellite. The total scientific payload will weigh over two tons and will include a smaller gamma telescope and an X-ray telescope. French participation in development of the telescope system involves scientists at the Saclay Nuclear Research Center and the Toulouse Space Research Center. A system for precision angular orientation has been developed at the Warsaw Polytechnical Institute. The observatory will be placed on a Soviet high-apogee stabilized satellite with a period of revolution of four days. Studies will be made of spectra of sources in the 3 to 2,000 keV energy range and high precision imagery of sources in the 3 to 500 keV range will be carried out. The project has been in development for over 10 years and apparently has been delayed for unexplained reasons.

— PROJECT ROENTGEN

Roentgen is an X-ray observatory for detailed spectroscopic study of X-ray sources in the 2 to 800 keV range. Scientific equipment for the mission is being developed by the Netherlands, the Federal Republic of Germany and other ESA members. In a West German press report this mission was referred to as "Salyut-HEXE" (High Energy X-Ray Experiment). According to this report the observatory spacecraft would operate in conjunction with a Salyut orbital station. West European participants in the project were identified as the University of Utrecht (Netherlands), the Max Planck Institute for Extraterrestrial Physics (FRG), and the University of Birmingham (Great Britain).

— PROJECT AELITA

Aelita is a project for research in the submillimeter range at wave lengths of 0.1 to 2 mm. A spacecraft will place in near-Earth orbit a cryogenically cooled telescope with a one-meter mirror and a 3-15′ field of view. The telescope will operate in a high sensitivity mode with a variable spectral filter or in a spectrometry mode using a Fourier spectrometer. Research will be performed on "cold matter" in the galaxies and irregularities in the galactic background radiation. There is no mention of any non-Soviet participation in this project.

According to "USSR Cosmonautics," the development of space astronomy will be accomplished by placing still larger telescopes in orbit.

"In principle, at the present time no problems remain which would prevent the placing in orbit of telescopes with mirrors several meters in diameter for observations in the optical, UV and IR ranges. Such instruments would have stabilization and pointing accuracy of about .001 second of arc and resolution of .01 second of arc."

"USSR Cosmonautics" reports that orbital radiotelescopes are also to receive "intensive development in upcoming years." Large radiotelescopes in the centimeter and decimeter ranges will reportedly be used as the orbital components of radiointerferometers with practically unlimited resolution. The KRT-10 antenna deployed on Salyut-6 in 1979 is described as the first stage in this development. According to the authors, final work is now proceeding on improved instruments of this type and structural elements are being developed for assembly of radiotelescopes of any required dimensions.

C. PLANETARY PROGRAMS

According to "USSR Cosmonautics", the Soviet planetary program will carry forward previous research on Venus and Mars, as well as inaugurate new programs for study of comets and asteroids. Specific new missions in the Venera series are not identified, but the authors refer to a program for Venus research which includes further surveys of the planet's surface, search for evidence

of volcanism and long-term measurement of the planet's cloud layer. The success of the Vega mission has reportedly encouraged scientists to consider new projects. For example, instead of the comet flyby flight profile used by the Vega spacecraft, a flight is under consideration in which a spacecraft would enter the tail of a comet and slowly approach the nucleus while performing detailed studies over a long period of time. How such a craft would be shielded during such a long-term stay inside a cometary tail is not explained.

— PROJECT VESTA

Vesta is described as a multipurpose program which would include a Venus research phase as well as encounters with dozens of asteroids and possibly a comet. The asteroid flybys would occur over several years during the course of several orbits around the Sun. In at least one case the flyby craft would release a descent probe which would make a hard landing on an asteroid's surface. Although U.S. publications have reported that France will play a major role in designing the Vesta spacecraft, the authors of "USSR Cosmonautics" make no reference to any non-Soviet participation in the project.

According to a report in the 24 March issue of AVIATION WEEK AND SPACE TECHNOLOGY, director of IKI Roald Sagdeyev has stated that the original plan for a Venus flyby has been changed to a Mars flyby trajectory. The originally scheduled launch date of 1992 may be delayed for two years at the request of the French national space agency to allow more time for development of the asteroid flyby craft.

— PROJECT PHOBOS

Discussions of the Phobos project have appeared in open source materials since mid-1985. This mission represents an ambitious expansion of the Soviet planetary research program. Since the early 1970s the Soviet planetary program has concentrated exclusively on Venus. No spacecraft have been launched to Mars since the limited successes achieved by the Mars-4, -5, -6 and -7 missions of 1973.

According to "USSR Cosmonautics," the plan includes three main phases, the first being a study of solar radiation over a wide frequency range during the flight to Mars. In the second phase, spacecraft would be placed in orbit around Mars to perform research on the atmosphere and ionosphere of the planet. The final phase of the mission involves a flyby of the Martian satellite Phobos to within "a few dozen meters" of its surface. This would permit high resolution TV imagery of the surface, study of Phobos's internal structure by means of radio waves and determination of the chemical and isotopic composition of the surface layer.

Media reports in the second half of 1985 and early 1986 have clarified the basic flight plan. Two Soviet interplanetary spacecraft will take part in the mission. A launch date of mid-1988 has been firmly set because of the availability of a favorable launch window. The Earth to Mars flight will take approximately 200 days. After a period of research in Mars orbit, both spacecraft will be shifted to circular orbits close to that of Phobos. Both craft will approach Phobos to a distance between 30 and 70 meters from the satellite's surface. Some elements of the research program to be carried out in this phase seem to be still awaiting final determination. The scientific instrumentation for the flight is being developed by a collective of participating countries. This includes the same group which took part in the Vega program, i.e. five East European Intercosmos members (Bulgaria, Hungary, GDR, Poland, and Czechoslovakia) along with France, the FRG, and Austria. New participants in the Phobos project include Sweden, Finland and scientists of the European Space Agency. Commentary as late as April of this year indicates that the surface of Phobos will be studied by color TV cameras and laser and ion beams whose effects will be analyzed by spectrometers to determine the chemical composition of the surface layer. Deployment of both fixed and mobile landers to the surface of Phobos is said to be under consideration. The entire mission is scheduled to last for 18 months.

— MANNED MISSION TO MARS

The exact status of a manned mission to Mars in Soviet space plans is difficult to determine from the available open references. After the 237-day flight by three cosmonauts in 1984, TASS claimed that this was "precisely the time which a spacecraft needs to reach Mars with the modern level of technology." A few weeks later Moscow World Service in English reported that Soviet "space experts" were working on preparations for a manned flight to Mars and quoted president of the Soviet Academy of Sciences Anatoliy Aleksandrov to the effect that such a mission was technically feasible but involved solution of a series of complicated matters. In the concluding section of "USSR Cosmonautics" which discusses future space programs there is a conspicuous absence of any mention of a manned Mars flight in the foreseeable future. The authors discuss the possibility of manned lunar bases, but the question of manned missions to the planets, Venus and Mars in particular, is mentioned only in the context of permanent habitation in the far distant future. On the other hand, the entry on nuclear rocket engines in the "Encyclopedia of Cosmonautics" claims that while a Mars expedition would be "very problematical" using chemical propulsion systems, a nuclear engine would make such a flight realizable. Technical data for such an engine system and spacecraft are specified:

> "Such a spacecraft would have a mass in near-Earth orbit of about 1000 to 1500 tons, including several nuclear boost engines each having 0.5 to 1 MN of thrust, a specific impulse of about 8200 m/s and an operating time of 30 to 60 minutes. There would also be a nuclear braking engine for insertion of the spacecraft into Mars orbit and a nuclear boost engine for return to Earth. The Mars expedition craft would have liquid fuel engines for landing and takeoff. The flight is calculated for a duration of one and a half to two years."

The 6 February issue of PRAVDA carries a commentary by Roald Sagdeyev on the proposal advanced by Carl Sagan for a joint Soviet-American manned mission to Mars. Sagdeyev responds favorably to the idea of space cooperation, but goes even further, saying that the project would be beyond the capacities of any single country:

> "Our experience in preparing projects for exploration of distant space has shown that realization of such grandiose projects as an expedition to Mars is impossible without international cooperation."

The Sagan proposal was raised again in an interview with the chairman of Intercosmos Vladimir Kotelnikov in the 11 April issue of IZVESTIYA. Kotelnikov characterized such a project as "technically complex, but feasible," but he stipulates that it would depend on a change in the political situation.

In his PRAVDA comments Sagdeyev indicates that a manned flight to Mars would obviously be preceded by a stage of unmanned exploration of the planet. He maintains that unmanned spacecraft may even be more productive in terms of scientific results. A number of unmanned Mars projects have been referred to in the literature. These include a soil sampler return mission and a powered "Mars plane" for study of the Martian atmosphere. The "Encyclopedia of Cosmonautics" notes that a number of proposals have been published for self-propelled Mars rover vehicles. Such a "marsokhod" could be designed either for transport of cosmonauts on the planet's surface or as an autonomous research vehicle along the lines of the Soviet lunokhods.

A definite denial that a manned Mars mission is in preparation occurred during a press conference held in Moscow on 7 April at which cosmonauts Kizim and Solovyev commented on the current flight of the Mir. A number of space officials and scientists were present and responded to journalists' questions. The 8 April PRAVDA account of the press conference includes the following question and answer exchange (the speakers are not identified):

"Is an expedition to Mars really being prepared in the Soviet Union?"

"No, such a project does not exist. But there are preparations under way for the Phobos project to study the satellite of Mars."

— LUNAR POLAR ORBITER

The 31 March issue of AVIATION WEEK AND SPACE TECHNOLOGY reports that officials at the Institute of Geochemistry and Analytical Chemistry imeni Vernadskiy have stated that a spacecraft for a lunar polar orbiter mission is under development with a launch scheduled for 1991. The spacecraft would reportedly carry a scientific instrument package weighing 300 kilograms and would be intended to expand scientific knowledge of the dark side of the moon and the polar regions. No discussion of this project has yet appeared in Soviet media.

D. LONG-RANGE PROJECTIONS

The concluding section of "USSR Cosmonautics" discusses a number of projections for space at the turn of the century and beyond. The authors describe these programs as "not on the current agenda" and as not yet having received detailed design, technical, and economic analysis. However, they are viewed as plausible projections, based on the experience of the past three decades of cosmonautics and "the general tendencies of its development."

By the year 2000, large orbital complexes should be in near-Earth orbit. They will have crews of 20 to 30, and eventually more than 100 persons. One such station would have the equivalent scientific and production capacities of dozens of currently operating orbital stations. These large manned complexes would, in turn, be the forerunners of even larger "ethereal settlements," the oft cited phrase of Soviet space pioneer Konstantin Tsiolkovskiy referring to human colonization of space.

In addition to large-scale manned orbital complexes there would also be specialized complexes designed to function autonomously with only periodic servicing by cosmonauts. Such complexes would include astrophysical observatories, production facilities, solar power stations, and solar reflectors.

A key factor in the realization of such projects will be the development of an economical system for delivery of large volumes of payload—on the order of many hundreds of tons—to orbit. This will require development of "new principles of space power engineering."

Continued development of space industrialization will involve expansion of operations to the Moon and asteroids. The first lunar bases with crews of 10 to 12 people could be constructed from modular units placed in Earth orbit and then transported to the Moon by interorbital tugs. Permanent lunar bases would eventually be built, probably by adapting existing terrain features. For example, a series of lunar craters could be roofed over and connected by sealed passageways.

The authors view the question of manned bases on other planets of the solar system, Mars and Venus in particular, as somewhat more doubtful. If such settlements are considered as desirable in the future, the authors view the best strategy as a "transformation of the nature of these planets" so as to make human habitation possible in conditions close to those on Earth. In the authors' opinion there is no doubt that human colonization of space will become not only desirable but also a basic necessity in the "not distant future." This follows inevitably from the fact that the natural environment of the Earth is a finite system the capacities of which will eventually be exhausted.

In conclusion the authors argue that the most complete and efficient strategy for the enormous task of development of the solar system would be based on broad international cooperation.

One of the more intriguing features of the final section of "USSR Cosmonautics" is a series of three uncaptioned illustrations accompanying the text. Two of these artist's renderings show variants of a modular structure connected by a spherical multiposition docking unit very similar to the new docking unit on the Mir station. (Note that the book was typeset almost 10 months before the launch of the Mir.) A connecting lattice of girders has been added to the modular elements. The second illustration shows a group of cosmonauts working on the assembly of such a girder system in open space.

Perhaps more interesting is the inclusion of a winged spacecraft in two of the illustrations. The craft appears to have a deltawing design with wingtip winglets. A forward compartment with windows is visible and a propulsion unit is housed in a slightly flared rear compartment. The craft has no vertical stabilizer. The last illustration shows what appears to be the same spacecraft with an open central cargo bay similar to that of the U.S. shuttle orbiter.

It would obviously be a mistake to read too much into these artist's renderings. In point of fact, what we seem to have here is an imaginative conflation of two distinct types of spacecraft: a cargo-carrying shuttle craft and a spaceplane with lifting body design. In general, the public Soviet position has been that the present system of expendable transport craft and unmanned Progress resupply vehicles is the most efficient approach for the current stage of orbital operations. On occasion commentators have discussed the need for developing orbital transfer vehicles and small highly maneuverable craft for assembly operations and individual return of cosmonauts. However, there have been no indications in Soviet open media that the USSR has any active programs under way for production of a spaceplane or a reusable shuttle spacecraft. In a recent television press conference in Moscow, Sagdeyev stated that the USSR is conducting research in both reusable and nonreusable space technology. He provided no further elaboration.