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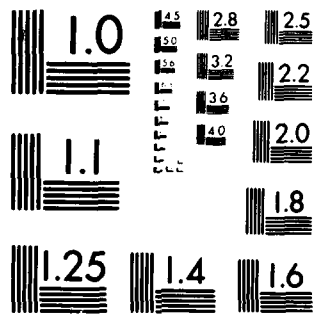
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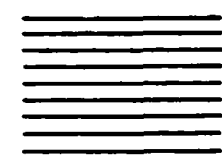
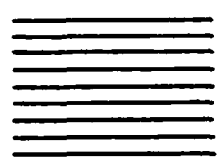


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STUDENT RESEARCH REPORT

THE SCENT OF THE FUTURE: MANNED
SPACE TRAVEL AND THE SOVIET UNION

1981
BARRY STEPHEN FIELD

GARMISCH, GERMANY

APO NEW YORK 09053

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THE SCENT OF THE FUTURE:
MANNED SPACE TRAVEL AND THE SOVIET UNION

Barry Stephen Field

June 1981

U.S. ARMY RUSSIAN INSTITUTE

Garmisch, Germany

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FOREWORD

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SUMMARY

The roots of the Soviet space program go back to the theoretical work of Tsiolkovski in Imperial Russia and to the experimental and design work of Zander, Korolev, Glushko and others in the 1920's and 1930's. Rocketry continued to develop throughout the wartime and postwar periods. In 1954, the USSR announced that it would participate in the International Geophysical Year. As part of that participation, the Soviets launched Sputnik-1 on 4 October 1957 using as a launch vehicle the first Soviet ICBM, which had been successfully test flown less than two months earlier. The program quickly developed, with manned flights beginning in 1961, multiply-manned flights in 1964, the first "spacewalk" in 1965, spaceships capable of maneuvering and docking in 1967 and long-term space stations in 1971. Nor was the unmanned program neglected: planetary probes, communications satellites, military satellites, meteorological and earth resources flights, and scientific studies have all grown in importance. The Soviets, by the end of 1980, had launched more than 1500 payloads to Earth orbit or beyond, including 45 manned flights.

While the USSR denies any military motivation for its space program, a large number of both manned and unmanned flights appear to have the characteristics of military missions, three quarters of Soviet cosmonauts are military officers, and the military provides all launch vehicles and facilities. There are also strong political, scientific and economic motivations for the program.

Present goals for the program include the development of larger, more sophisticated orbital stations and of economic applications programs.

New, more powerful launch vehicles and reusable manned spacecraft are probably under development at this time and can be expected to be put into use in future years. A long-term Soviet goal is manned lunar and planetary flight.

A NOTE ON UNITS

With the exception of atmospheric pressures, an attempt has been made to use metric units for all measurable quantities mentioned in this paper. The term "ton" should therefore be understood as referring to the metric ton, 1,000 kilograms, wherever it appears. One kilogram (force) is equivalent to 10 newtons.

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THE ANCIENT DREAM: FROM FANTASY TO REALITY

The Earth is the cradle of reason, but one cannot live
in the cradle forever.

-- Konstantin Eduardovich₁
Tsiolkovski

Ever since Man has recognized that there was a difference between the Earth and the heavens, he has dreamt of flying among the latter. The dream was changed from fantasy to science fiction in the late ~~XIX~~^{19th} Century when a schoolteacher in Kaluga, Russia, by the name of Konstantin Tsiolkovski began to lay down the theoretical basis for modern rocketry. In the latter half of the ~~XX~~^{20th} Century the dream was again transformed from science fiction into reality when the USSR launched Sputnik-1 on 4 October 1957.

Since that unsophisticated sphere began sending its famous beeping from overhead, the Soviet Union has maintained an active space program. What are the aims of that program? What do those aims portend? How does the Soviet program compare with others? What are its future directions likely to be?

This paper will investigate these questions, particularly as they apply to manned space flight and the cosmonaut program. The history of the Kremlin's space effort will be discussed, announced and deduced goals of the program will be examined, and Moscow's efforts will be compared with the programs of other space powers.

In view of the Soviet policy of secrecy concerning the space program, it should be noted that references to both current and future goals and progress are usually vague and often contradict one another. Many

Western analyses, however, present their conclusions much more positively than this author considers prudent. It is also difficult to find unbiased analyses of the Soviet space program: certain authors seem to think the Soviets are demigods who can accomplish anything at all, while others seem to consider them a race of congenital liars and incompetents incapable of designing a kite, let alone a spaceship. Some do at least try to be objective, and a few succeed: this author is among the "some" and hopes to be among the "few." Caveat lector!

ROCKING THE CRADLE: HISTORY OF THE FIRST SPACE FLIGHTS

One might say that in the history of technology there have been only three great inventions which have decisively influenced, or will so influence, the history of mankind for thousands of years. These are the wheel, with which man conquered the earth; the screw, with which they conquered the seas and the air; and now, at the start of a new era in human history, rocket propulsion, which will help men to conquer space and push forward to the stars.

-- Walter Dornberger, formerly
Commanding Officer of the
Peenemuende Rocket Research,²
Institute

The history of the Soviet space program really began in Imperial Russia in the late Nineteenth Century with the chemical theories of Mendeleev, the physical theories of Merscherasky [sic], who published his "Dynamics of a point with variable masses" in 1897, and -- most of all -- with the research on rocket propulsion of Tsiolkovskiy, begun in 1883 and published as "Exploring Cosmic Space with Reactive Devices" in 1903.³ Mendeleev's work led to a better understanding of chemical processes and eventually to the development and understanding of modern liquid fuels for rockets. The elaboration of the dynamics of a variable mass made it possible to describe with some precision the motion of a rocket -- the mass of which lessens as fuel is consumed and the acceleration of which therefore increases under constant thrust. Tsiolkovskiy had a more direct influence -- he developed a mathematical description of space flight, laying the basis for astronautics ("cosmonautics" in Soviet terminology); demonstrated that only rocket propulsion can be used in space; suggested the use of liquid, rather than solid, fuels; and put forward the concept of staging to increase the range and payload capacities of a rocket.

The further development of Russian rocketry was hindered by upheaval in the Empire and especially by the First World War, the February and October Revolutions, and the subsequent Civil War and interventions. On 1 March 1921, however, the Military Department provided funding for N. I. Tikhomirov to establish a laboratory for rocket propulsion research. Tikhomirov, who had been working with rocket propelled missiles since 1894, began operations in both Leningrad and Moscow, but all of the laboratory's facilities were moved to Leningrad by 1925, when an extruded smokeless powder propellant was developed. In July 1928, after a new solid fuel rocket was successfully launched, the laboratory was renamed the Gas Dynamics Laboratory (GDL) of the Revolutionary Military Council. By early 1933, the GDL had five sections, facilities at six Leningrad locations, and a staff of about 200.⁴ One of those sections, the Second Section, formed on 15 May 1929 at the suggestion of V. P. Glushko, was "the first experimental design organization" in the USSR to work on the development of liquid fuel and electrical rockets.⁵

In the same time period the Gruppa po izucheniyu reaktivnogo dvizheniya (Group for the Study of Reactive Propulsion) or GIRD was organized with branches in both Leningrad and Moscow. The first head of the Moscow group was A. F. Tsander, who had produced a plan for a rocket powered plane as early as 1924.⁶ Another active member of GIRD was Sergey Pavolvich Korolev, who played a major role in Soviet rocketry and space history until his death in 1967. In June 1932, Korolev, who had become chairman of the Research Council of Moscow's GIRD, was appointed as chief of a newly established "experimental organization for the development of rockets and rocket engines."⁷

After these institutions successfully demonstrated the gasoline-liquid oxygen fueled ORM-1 (Opytnyy reaktivnyy motor -- experimental reaction motor), designed by GDL and having a thrust of 20 kilograms (force), and Tsander's five-kilogram-thrust OR-1 in 1931, and GIRD had launched the R-09 and R-10 rockets in August and November 1933, the Reaktivnyy nauchno-issledovatel'nyy institut (the Research Institute of Jet Propulsion, as Glushko named it in English, or RNII) was formed between September and December 1933 by a merger of GDL and the Moscow GIRD. This institute worked on winged rockets, rocket airplanes, missiles (including the RS-82 and RS-132 air-to-ground missiles and the BM-13/Katyusha), and gyroscopic autopilots. I. T. Kleimenov [sic] was named director and Korolev, deputy director of the new institute.⁸ (G. E. Langemak, however, took over as deputy director in January 1934, apparently because Sergey Pavolvich resigned the post.⁹)

In 1936, a three-meter-long rocket with a thrust of 300 kilograms (force) was successfully launched by RNII on two occasions, the second time rising to an altitude of 2400 meters.¹⁰ Nevertheless, according to Leonid Vladimirov, the institute fell victim to the Great Purge of 1936-1939. In 1937 and 1938 many of the institute's major figures were executed. Korolev was arrested in 1938 as a former associate of aircraft designer Andrey Tupolev and was put to work in a prison design bureau attached to an aircraft factory. Later he was moved to another prison, where he was put to work designing jet engines. He remained in prison until 1945, when he was awarded the Badge of Honour for his "participation in the development and testing" of military aircraft engines.¹¹

Glushko's description of the 1938-1945 period differs from Vladimirov's in a number of respects. (It should be noted that Vladimirov is a former Soviet journalist who spent several years in a labor camp and who remained in London after an official trip in 1966, while Glushko is a prominent Soviet engineer and a full member of the Academy of Sciences of the USSR.) According to the academician, in 1939-1940 RNII was reorganized into the Gas Dynamics Laboratory Experimental Design Bureau (GDL-OKB) and received the Order of Lenin and the Order of the Red Banner of Labor. Korolev worked as a deputy chief designer in GDL-OKB and supervised flight tests in the period 1942-1946.¹²

Whatever the personal fate of Sergey Pavolvich during this period, his design work was successful. A small, unmanned rocket plan designed by him was successfully flown in 1939. It had a three-meter wingspan, a mass of 210 kilograms and a range of 50 kilometers. On 28 February 1940, the RP-318, a rocket-plane designed by Korolev, was successfully flown at an altitude of 3000 meters and a speed of 140 kilometers per hour.¹³

After World War Two came to an end, the Soviets captured a number of V-2 rockets, machinery for their manufacture, and designs for a two-stage successor to the V-2.¹⁴ Under the command of the USSR's General Gadyukov, many German rocketry technicians were put to work on a limited production of the V-2 at the Zentralwerke in the Soviet zone, but in October 1946 they were moved en masse to the Soviet Union where a number of V-2's were assembled and launched from a base 200 kilometers east of Stalingrad. (This launching site, Kapustin Yar, is still in use.) The Germans were later moved to an island 350 kilometers northwest of Moscow

where they worked on designing new rockets until the early 1950's. By 1958 most had been returned to Germany.¹⁵

Meanwhile, the Kremlin had established several institutes in 1946 to develop ballistic rockets for "the defense of the country", and the first launch of a ballistic rocket in the Soviet Union took place on 18 October 1947.¹⁶ Nevertheless, the Kremlin leadership was not satisfied. Georgiy M. Malenkov complained in 1947:

This V-2 is not what we want. We have improved it, we have more than reached the Peenemunde level of 1945, but, even so, it remains a blind, short-range, primitive weapon. Who, do you think, can we frighten with it? Poland? Turkey? But we are not going to frighten Poland. Our potential enemy is thousands of kilometers away. We must work on the development of long-range rockets. The importance of Sanger's project [a design for a rocket-powered bomber with a global range drafted by Dr. Eugen Sanger, who ended up in France after the war.¹⁷] must be seen in that it can fly long distances. And we certainly cannot wait until the American imperialists add Sanger's rocket plane to their B-29 and atom bomb.¹⁸

A "Council of Chief Designers", including Sergey Korolev (who was revealed, after his death, to have been the Chief Designer of spacecraft) and Nikolay Alekseevich Pilyugin (who designed control systems), was set up to oversee research and development of rockets.¹⁹

Design work on the first Soviet long-range ballistic rocket began in 1947. The first flight tests of this vehicle, the R1, took place in the spring of the succeeding year and its development was completed in 1949. Lacking a separable nose cone, the R1 was used to study temperature profiles of ballistic flight, to evaluate computational methods for prediction of trajectories, and to test equipment and parts designs. The V1B and V1V successors to the R1, also lacking separable nose cones, were used for scientific studies at altitudes of up to 100 kilometers. The R2, first launched in 1949, had twice the range of the R1 despite its greater launch weight, represented the first use of aluminum alloys in

Soviet rocketry, and had a separable nose section. The geophysical rocket V2A was used for upper atmosphere, solar spectrum and biomedical systems beginning in 1951. It had a 2200 kilogram payload consisting of a 1340 kilogram instrument module and an 860 kilogram geophysical module, and was stabilized by a pendulum system ["mayatnikovaya sistema stabilizatsii"] daring flights to altitudes up to 212 kilometers. The V5A and V5V, stabilized by oxygen gas jets boiled off from the liquid oxygen (LOX) tanks were used for astronomical, geophysical biological and ionospheric studies at altitudes up to 512 kilometers.²⁰

During the period 1949-1952, biomedical research was conducted using fourteen dogs launched to altitudes of up to four hundred kilometers²¹ (higher than the orbits of the Salyut space stations). Monitoring of the animals' vital signs led to the conclusion that there was no scientific or medical reason why manned space flight would not be possible.

A discussion in the home of an American scientist on 5 April 1950 has also become part of the history of the Soviet space program. On that evening a group "of eminent scientists" meeting in the home of physicist James Van Allen in Maryland discussed the possibility of a year of international cooperation in the exploration of the Earth's surface and our planet's complex relationship with the sun. This was originally to be a follow-up to the First Polar Year of 1882 and the Second Polar Year of 1932, but grew in scope to eventually become an eighteen-month period (1 July 1957 to 31 December 1958) of extensive geophysical research promoted by an international preparatory committee, Comite Special pour l'Annee Geophysique Internationale (Special Committee for the International Geophysical Year (IGY). In May 1952, CSAGI sent invitations to participate in the IGY "all over the world", including to the Academy of Sciences of the USSR.²²

Two years later, in May 1954, a number of significant events took place. At the third Symposium on Space Travel at the Hayden Planetarium in New York, George P. Sutton of North American Aviation remarked that the Soviets would soon have the capability to launch either manned or unmanned satellites.²³ On 26 May, Korolev wrote to the Central Committee (CC) of the Communist Party of the Soviet Union (CPSU) and reported that an artificial satellite could be constructed.²⁴ The month was also the scheduled deadline for the submission of detailed plans by the IGY committees of each nation participating, a deadline which passed without any response from Moscow to CSAGI's invitation. CSAGI nevertheless held its scheduled 30 September - 4 October 1954 session in Rome, at which a resolution was adopted recommending "that thought be given to the launching of small satellite vehicles" in connection with the IGY. It was also at this meeting that a message was received from the Soviet Embassy in Rome, expressing the sudden acceptance of CSAGI's invitation.²⁵

Final development of the RD-107 and RD-108 rocket engines also began in 1954.²⁶ These kerosene-liquid oxygen fueled engines have four combustion chambers and exit nozzles fed by one fuel supply, pump, and tank pressurization system and operating at chamber pressures of 60 atmospheres. The RD-107 has two steering nozzles, a vacuum thrust of about 102 tons and a specific impulse of 314 seconds, while the RD-108 variant has four steering rockets and a 96-ton thrust. These engines powered the booster stages for the first Soviet intercontinental ballistic missiles and for the standard launch vehicle used for Sputnik and for manned space flights.²⁷

The formation of a permanent commission to coordinate and direct all work concerned with "mastering cosmic space", including the

development of artificial satellites was announced on 16 April 1955. The new body, under the Astronomy Council of the Academy of Sciences, bore the long-winded title of the Interdepartmental Commission for the Coordination and Control of Scientific-Theoretical Work in the Field of Organization and Accomplishment of Interplanetary Communications and included physicists, astronomers, military engineering experts, mathematicians, and other scientists in fields related to rocketry and space.²⁸

On 29 July 1955, the United States announced that, as part of the IGY, it would orbit "small unmanned earth-circling satellites". Three days later, Academician Leonid I. Sedov, chairman of the Interdepartmental Commission on Interplanetary Communications, announced similar Soviet plans. Exactly four weeks after Sedov's announcement at a Copenhagen press conference, on 30 August, Korolev told a meeting in the office of the Vice President of the Academy of Sciences that a launch vehicle would be available in one to one and a half years and that a scientific program should be drawn up.²⁹

The USSR's press agency TASS announced on 26 August 1957 that an ICBM had been successfully tested "a few days ago".³⁰ Although the U.S. had not yet tested its own ICBM's, this announcement was overshadowed — at least as far as the general public was concerned — by the launch on 4 October 1957 (exactly three years after the close of the CSAGI session in Rome) of an 83.6-kilogram, 580-millimeter aluminum sphere into an orbit with a 947-kilometer apogee. Sputnik-1 remained aloft for 92 days and about 1400 orbits. Thirty days later, Sputnik-2, a 508.3-kilogram spacecraft carrying the dog Laika, was launched into an orbit with an apogee of 1647 kilometers. It remained aloft for 160 days and 2370 orbits.³¹ The Space Age had begun.

During 1958, while the U.S. launched its first five satellites, the only Soviet satellite launched was Sputnik-3. This 1327-kilogram vehicle carried 12 scientific instruments, multichannel telemetry equipment with data storage capabilities and other support equipment using both vacuum tube and solid state technology.³² The next year, all three Soviet launches were lunar probes. Luna-1, launched on 2 January, passed the moon and went into solar orbit, becoming the first "artificial planet".³³ The 361.3-kilogram payload which included a "minimum collection" of geophysical instruments and a package of metallic emblems with the coat of arms was apparently intended to strike the Moon, but missed by over five thousand kilometers. Its batteries failed on 5 January.³⁴ On 13 September 1959, Luna-2 struck the Moon 435 kilometers from the center of the visible hemisphere. The 278.5-kilogram Luna-3 passed the Moon on 18 October, two weeks after launch, and transmitted back to the Earth pictures showing 498 lunar features, including 400 which are not visible from Earth. The solar-powered probe returned to Earth and was destroyed by reentry.³⁵

The first true precursors of the Soviet manned spaceflight program were launched in 1960. On 15 May of that year Korabl'-sputnik-1 (Ship-satellite-1) went into orbit. This 4540-kilogram vehicle had 1477 kilograms of instrumentation and equipment and a 2500-kilogram self-sustaining biological cabin containing a dummy to test the life-support system (LSS) and flight stresses. Telemetry and prerecorded voice signals (the latter a choral group) were transmitted to ground stations. Incorrect attitude of the spacecraft during the firing of the retrorockets (retrofire) resulted in a higher orbit, rather than reentry. Three months later, Korabl'-sputnik-2 was launched on 19 August for a one-day flight carrying

the dogs Strelka and Belka. Recovery of the dogs was successful. A third Korabl'-sputnik burned on reentry on 2 December after a one-day flight. The dogs Pchelka and Mushka carried on this craft have been called "the first important casualties of orbital flight".³⁶ On 9 March and 25 March 1961, two more spacecraft in the Korabl'-sputnik series were launched. Each contained a dummy cosmonaut and a dog, and each was successfully recovered after one orbit.³⁷ Finally, on 12 April 1961, the era of manned orbital flight was ushered in with the single orbit of Vostok-1, piloted by Major Yuriy Alekseyevich Gagarin.

SUBSTRUCTURE FOR SPACE: SOVIET FACILITIES AND EQUIPMENT

...the commitment of considerable resources and effort to space activities is indicative of the Soviet Union's broad program...

-- Lt. Gen. Thomas P. Stafford,
Deputy Chief of Staff for
Research and Development of³⁸
the United States Air Force

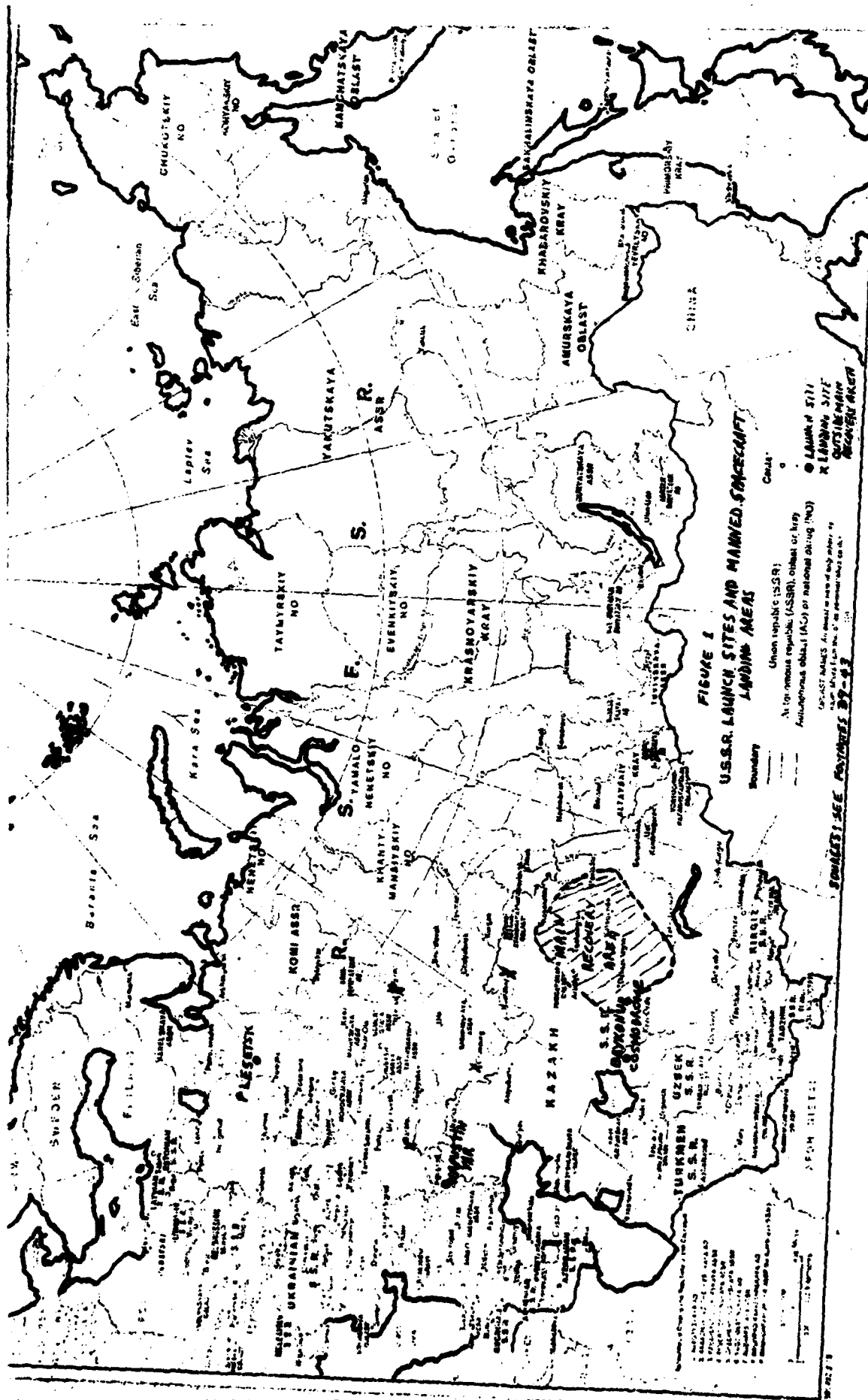
The Soviet Union maintains three launch sites for space flights. The northernmost is referred to as Plesetsk in Western sources, although it had never been named or pinpointed in open Soviet sources as late as 1976. (This author has found no Soviet reference to it at any later time, either.) According to a study by the Library of Congress of the United States, Plesetsk is located at about 62.8°N 40.1°E, on the Moscow-Arkhangelsk railroad. Because of its northern location, it is used for missions requiring extensive coverage of the planet's surface and, therefore, requiring polar or near-polar orbits. This includes navigational and weather satellites, extreme latitude scientific flights, Molniya communications satellites, and most military satellites. Its activities have been equated to those of the American space center at Vandenberg Air Force Base in California.³⁹ Kapustin Yar, which has been referred to as Volgograd Station by the Soviets, has been cited as the USSR's equivalent to White Sands, New Mexico, and Wallops Island, Virginia. This site at 48.4°N 45.8°E, on the Volga below Volgograd, is used for vertical probes, small military and civilian satellites and military tests.⁴⁰

The most important space launching center in the Soviet Union is the Baykonur Cosmodrome. This is the equivalent of the Kennedy Space Center

in the U.S., inasmuch as it is the launch site for many research, some observation, and all manned, lunar and planetary flights. Despite its name, the Cosmodrome is believed to be about 370 kilometers southwest of the town of Baykonur, near the village of Tyuratam (by which name it is referred to in many Western sources). The Congressional Research Service of the Library of Congress estimates its coordinates to be 45.6°N 63.4°E. Photography by Landsat-1 shows a complex spread over an area of about 135 by 90 kilometers, with an impact area for first stages on the steppe nearby.⁴¹ A small city populated by space workers has grown up near the Cosmodrome and has been named in Western sources both as Leninsk and as Zvezdograd (Star City).⁴²

The primary recovery area for manned spacecraft in the USSR lies to the northeast of the Cosmodrome, roughly in an ellipse with its foci between Dzhezkazgan and Tselinograd. The first two Vostok flights, however, landed near Saratov; Voskhod-1, near Kustanay; Voskhod-2, which missed its designated recovery zone, near Perm; Soyuz-1 crashed near Perm; and the "April 5 Anomaly", an aborted Soyuz launch, landed southwest of Gorno-Altaysk, 320 kilometers north of the Chinese border.⁴³

The cosmonauts, when not in flight, live in a special suburb of Moscow, Zvezdnyy Gorodok (Star Village). This is also the location of the Center for Cosmonaut Training named for Yu. A. Gagarin (Tsentr Podgotovki kosmonavtov imeni Yu. A. Gagarina), established on 12 April 1960. Here the cosmonauts train in classrooms, isolation chambers, centrifuges, simulators, laboratories, and space craft mockups.⁴⁴ In particular, a "hydrolaboratory" is used for weightlessness training: "All types of work are worked out in advance at the Training Center on a special mock-up...in the hydrolaboratory, which permits imitation of weightless conditions."⁴⁵



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Ground support centers have been built at Yevpatoriya, Tbilisi, Dzhusaly, Kolpashevo, Ulan-Ude, Ussuriysk and Petropavlovsk. The center in Yevpatoriya is the Flight Control Center for manned spaceflight. Ground support is also provided by at least 11 ships operated by the Academy of Sciences in the Atlantic, Indian, and Mediterranean Oceans and by other -- probably naval -- ships in the Pacific. Tracking centers have been established in Cuba, Guinea, Chad, Mali and other countries.⁴⁶

Other facilities prominent in the space program include the GDL-OKB (discussed above), the Institute of Biomedical Problems on the outskirts of Moscow, the Institute of Space Research of the Academy of Sciences in Moscow, and the military Kirov Medical Academy in Leningrad.⁴⁷

The Soviets have five operational space launch vehicles, designated A, B, C, D, and F in studies by the Congressional Research Service. The A vehicle is based on the original Soviet ICBM -- the SS-6 Sapwood -- and without an upper stage has an orbital lift capacity of 1360 kilograms. (This version is called Raketa-nositel' "Sputnik" ["Sputnik" launch vehicle] by the Soviets, as it was used to launch the first artificial satellites.) With various upper stages it has been used to launch a wide variety of vehicles, including all manned spacecraft to date. The B vehicle, based on the SS-4 Sandal missile and first used in 1962, the C launcher, based on the SS-5 Slean and first used in 1964, and the SS-9 Scamp-based F launcher, first used in 1966, are all smaller and are used for various classes of unmanned flights. The fifth launch vehicle, the D or Raketa-nositel' "Proton", is a heavy lift vehicle capable of putting 20 tons into Earth orbit, over 4800 kilograms into circumlunar orbit, or 4650 kilograms into a Mars transfer orbit.⁴⁸

In its Vostok version, which the Soviets say was developed during 1958-1960 under the direction of Sergey Pavlovich Korolev (although only the third stage differs from the Sputnik launcher), the A vehicle has six independent units. The first stage consists of four "strap-on" units, each 19 meters long with a maximum diameter of three meters and powered by an RD-107 engine. On liftoff, these are fired simultaneously with the second stage -- the 28-meter long central cylinder to which the "strap-on" units are attached. This central unit is powered by an RD-108 engine which continues to fire after the first stage units have burned out and separated. The third stage, mounted on top of the other units is 10 meters long and 2.58 meters in diameter, powered by a single-chamber engine with four steering jets and eight to 12 tons of thrust. The fuel for all six engines is kerosene and liquid oxygen and the fuel tanks comprise part of the load-bearing structure of the vehicle. The total mass at launch is 295 to 300 tons, of which the structure is 28 tons and the payload is up to 4,725 kilograms. The version used to boost Voskhod and Soyuz vehicles into orbit has a modified third stage with a four-chamber engine.⁴⁹

The B vehicle, or "Kosmos" launch vehicle, is based on the two-stage SS-4 Sandal, the missile introduced into and removed from Cuba in 1962. The first stage of the 30-meter (length) by 1.65-meter (diameter) rocket is powered by an RD-214 engine, while the second stage has an RD-119 engine. The RD-214, developed at GDL-OKB in 1952-1957, has a 74-ton thrust, burns nitric acid and kerosene, and -- according to Chief Designer of Rocket Engines Glushko -- has the largest specific impulse (264 seconds) of all nitric acid-hydrocarbon engines. The RD-119, developed in 1958-1962 at GDL-OKB, burns unsymmetrical dimethylhydrazine and liquid oxygen to produce 11 tons of thrust, and -- again according

to Glushko -- has the highest specific thrust (352 seconds) of engines "burning oxygen and a high-boiling-point fuel". The booster is used for small Kosmos missions, especially for flight from Kapustin Yar at orbital inclinations of 48°-49°. ⁵⁰

The C vehicle has been estimated to have a 500-1000 kilogram payload capacity and has been used for multiple launches of as many as eight payloads per flight. It may have a largely military role, as does the four-stage F vehicle. The latter is the launcher believed to have been used for Soviet tests of a fractional orbit bombardment system (FOBS). The fourth stage was the retrofire engine for returning the payload or warhead to Earth. ⁵¹

The "Proton", or D, vehicle, with its estimated maximum Earth-orbit payload capacity of up to 27 tons, was first used in 1965 to launch the 12.2 ton Proton-1 scientific satellite and has since launched other Proton satellites, lunar and planetary probes, Salyut space stations, and other missions. However, a Western source reported in 1977 that the Proton booster had a very high failure ratio. ⁵²

WAR AND PEACE: SOVIET GOALS IN SPACE

Rockets are weapons and science.

-- Sergey Pavolvich Korolev⁵³

The Soviet Union sees its space program as a means of fulfilling four sets of goals: scientific, economic, military and political. Many of the scientific goals are demonstrated directly by the nature of the flights themselves. Biomedical studies began with the second orbital mission (even if one ignores the studies previously conducted using vertical probes). The first Soviet lunar probe was launched only 15 months after Sputnik-1. Venus probes have been launched many times since 1961; and the first probe successfully injected into a Mars transfer orbit by the USSR was launched in late 1962. The "Prognoz" series of flights is intended to study solar activity and its interaction with the Earth's magnetosphere, while the "Proton" and "Elektron" series have studied primary cosmic ray activity and the circumterrestrial radiation belts. In addition, the original announcement of the "Kosmos" series on 16 March 1962 cited seven areas of scientific research to be conducted.⁵⁴ Over 1200 satellites have been launched under the "Kosmos" designation, although the Kremlin does not usually announce the missions of these flights (Western sources have identified many as military observation, antisatellite target and interceptor, missile early warning, earth resources, military weather, and so on). A good deal of scientific work -- especially in astronomy, geophysics, earth resources, materials processing, and space engineering -- has also been performed by cosmonauts during manned missions.

Economic goals have been widely touted by the USSR. Leonid Il'ich Brezhnev has said, "Expanding our activity in the study of space, we are not only laying the foundations for the gigantic future achievements of mankind, the fruits of which future generations will enjoy, but we extract direct practical benefit today for the population of the Earth, for our peoples, for the matter of our communist construction."⁵⁵ The XXV congress of the Communist Party of the Soviet Union, in its resolution on "Basic directions of development of the national economy of the USSR for 1976-1980," resolved: "to continue the exploration and opening up of space, to expand research on the application of space technology in the study of the natural resources of the Earth, in meteorology, oceanology, navigation, communication, and for other needs of the national economy."⁵⁶ Indeed the Soviets have developed an extensive communications satellite network and have conducted a good deal of earth resources photography, both aboard unmanned Kosmos missions and during manned flights. In 1979, Moscow began supplying such imagery to other countries, including imagery from the MKF-6 six-spectral-band, 25-meter-resolution camera used aboard Salyut missions.⁵⁷

Despite the above quotation from Sergey Pavlovich, the Soviets are more reticent about the military aims of their space program. In fact, they constantly insist on its completely peaceful nature, as opposed to the increasingly militaristic goals they ascribe to the American program. The magazine Tekhnika-molodezhi (Technology for young people), for example, has published a number of articles in a series called "Pokoriteli kosmosa -- o zhizni, o zemle, o vseleynoy" (Conquerors of space -- on life, on the Earth, on the Universe). Each of these articles consists of the answers of a particular cosmonaut to an unchanging set of six questions, one of which concerns the effects of spending on other things the money "wasted

on the arms race." Cosmonaut Vladimir Afanas'evich Lyakhov, in one of these articles subtitled "V Kosmos -- s mirnymi tselami" (Into space -- with peaceful goals) in the third issue of 1980, stated "If the capital currently going to the arms race (about a million dollars a minute) were to be spent on the development of cosmonautics, then mankind would achieve outstanding new successes in this field. Undoubtedly there would have already been manned flights to Venus, to Mars, and maybe even to the mysterious satellites of Jupiter." [It is noteworthy, also, that Lyakhov's estimate of arms expenditures, made for a Soviet audience, was in dollars rather than in rubles!] The East German cosmonaut Colonel Sigmund Jen, in a similar article in issue number five for 1980 subtitled "Mne bylo khorosho s nimi" (It was good being with them), wrote that "...I am convinced: in near-Earth space will only peaceful craft and scientific laboratories." [Again the choice of words is of interest: the adjective "peaceful" is used specifically with the noun "craft" rather than with both nouns; also, the Russian word "korabli" -- rendered here as "craft" -- is usually used by the Soviets only in connection with manned vehicles -- an unmanned spacecraft is an "apparatus" ("apparat").] Leonid Il'ich himself has linked the space program to peace. Prior to the takeoffs for the Apollo-Soyuz Test Project on 15 July 1975, he opined, "The Soviet and American spacemen will go up into outer space for the first major joint scientific experiment in the history of mankind. They know that from outer space our planet looks even more beautiful. It is big enough for us to live peacefully on it, but it is too small to be threatened by nuclear war."⁵⁸ Similar sentiments were reportedly expressed by Colonel Yuriy Gagarin shortly after his lift-off in Vostok-1: "Victories in the mastering of space we consider the achievements not only of our people, but also of

all mankind. We happily lay them at the service of all peoples in the name of progress, fortune, and the welfare of all people on the Earth."⁵⁹

These protestations, however, fail to compensate for the ample evidence of military motivation -- of both defensive and offensive nature -- for much of the Kremlin's space effort. Actual space operations are largely controlled by military organizations. Cosmonaut training is under the control of the Air Force. Launch sites and all launch operations are controlled by the Strategic Rocket Forces, as are some tracking facilities. Civilian organizations are primarily responsible for coordination of research plans, operation of cosmonaut hiring and training facilities, and data analysis.⁶⁰ Additionally, a major part of the cosmonaut corps consists of military officers. Of the 55 men and one woman who have flown orbital missions from the Baykonur Cosmodrome, 42 were military officers (76 percent). Every non-Soviet cosmonaut who has flown on a Soviet spacecraft has been a captain or higher in his nation's armed forces.

Marshal of the Soviet Union V. D. Sokolovskiy, in his book Military Strategy published in the USSR in the 1960's, wrote, "In this regard Soviet military strategy takes into account the need for studying questions on the use of outer space and aerospace vehicles to strengthen the defense of the socialist countries...We must oppose the imperialists with more effective means and methods for the use of space for defensive purposes."⁶¹ The Library of Congress estimated, in 1978, that about 68 percent of all Soviet space flights, both manned and unmanned, are for strictly military purposes.⁶² Among the "means and methods" mentioned by Sokolovskiy, the Soviets have tested, developed, and/or deployed such systems as intelligence gathering satellites (photo reconnaissance, radar ocean surveillance,

Figure 2

SOVIET COSMONAUTS: 12 April 1961 - December 1980

<u>Cosmonaut</u>	<u>Flights</u>	<u>Rank at time of first flight</u>	<u>Comments</u>
Aksenov	Soyuz-22, Soyuz T-2	Civilian	Military aviation cadet/mid-50's
Artyukhin	Soyuz-14	Lt. Colonel	
Belyayev	Voskhod-2	Lt. Colonel	
Beregovoy	Soyuz-3	Colonel	
Bykovskiy	Vostok-5, Soyuz-22, -31	Lieutenant	
Demfin	Soyuz-15	Eng. Colonel	
Dobrovolskiy	Soyuz-11	Lt. Colonel	
Dzhanibekov	Soyuz-27	Lt. Colonel	Former AF Instructor
Farkas	Soyuz-36	Captain	Hungarian
Feokistov	Voskhod-1	Civilian	
Filipchenko	Soyuz-7, -16	Lt. Colonel	
Gagarin	Vostok-1	Major	
Germashevski	Soyuz-30	Major	Polish
Glazkov	Soyuz-24	Lt. Colonel	Former AF parachute instructor
Gorbalko	Soyuz-7, -24, -37	Lt. Colonel	
Grechko	Soyuz-17, -26	Civilian	
Gubarev	Soyuz-17, -28	Lt. Colonel	
Ivanchenko	Soyuz-29	Civilian	
Ivanov	Soyuz-33	Eng. Major	
Jen	Soyuz-31	Colonel	Bulgarian
Khrunov	Soyuz-5	Lt. Colonel	German (GDR)
Kizim	Soyuz T-3	Lt. Colonel	
Klimuk	Soyuz-13, -18, -30	Major	
Komarov	Voskhod-1, Soyuz-1	Eng. Colonel	
Kovalenok	Soyuz-25, -29	Lt. Colonel	
Kubasov	Soyuz-6, -19, -36	Civilian	
Lazarev	Soyuz-12, April 5 Anomaly	Lt. Colonel	
Lebedev	Soyuz-13	Civilian	
Leonov	Voskhod-2, Soyuz-19	Lt. Colonel	

SOVIET COSMONAUTS: 12 April 1961 - December 1980 (cont.)

<u>Cosmonaut</u>	<u>Flights</u>	<u>Rank at time of first flight</u>	<u>Comments</u>
Lyakhov	Soyuz-32	Lt. Colonel	
Makarov	Soyuz-12, -27, April 5 Anomaly, Soyuz T-3	Civilian	
Malyahev	Soyuz T-2	Lt. Colonel	
Nikolaev	Vostok-3, Soyuz-9	Major	
Patsayev	Soyuz-11	Civilian	
Popov	Soyuz-35	Lt. Colonel	
Popovich	Vostok-4, Soyuz-14	Colonel	
Remek	Soyuz-28	Captain	Czechoslovak
Romanenko	Soyuz-26, -38	Major	
Roshdestvenskiy	Soyuz-23	Eng. Lt. Colonel	
Rukavishnikov	Soyuz-10, -16, -33	Civilian	
Ryumin	Soyuz-25, -32, -35	Civilian	
Sarafanov	Soyuz-15	Lt. Colonel	
Sevastyanov	Soyuz-9, -18	Civilian	
Shatalov	Soyuz-4, -8, -10	Colonel	
Shonin	Soyuz-6	Lt. Colonel	
Strekalov	Soyuz T-3	Civilian	
Tamayo	Soyuz-38	Lt. Colonel	Cuban
Tereshkova	Vostok-6		Only woman; Eng. Col. by late '75
Titov	Vostok-2	Major	
Tuan	Soyuz-37	Lt. Colonel	Vietnamese
Volkov	Soyuz-7, -11	Civilian	
Volynov	Soyuz-5, -21	Lt. Colonel	
Yegorov	Voskhod-1	Lieutenant	
Yeliseyev	Soyuz-5, -8, -10	Civilian	
Zholobov	Soyuz-21	Lt. Colonel	
Zudov	Soyuz-23	Lt. Colonel	

et cetera), military communications satellites, fractional orbit bombardment systems (FOBS), and satellite interceptors.

The Soviet FOBS tests, which ended in 1971, consisted of launching a satellite "on a path avoiding the United States" and reentering the "test warhead" over Soviet territory just before the completion of the first orbit. Although presumably conducted without the use of nuclear materials, these tests aroused interest since the USSR is a party to a treaty banning the placing of nuclear weapons in orbit. The inherent disadvantages of reduced accuracy and reduced payload may have played a role in Moscow's cessation of FOBS testing.⁶⁸

Also of significant interest are tests of interceptor satellites conducted by Moscow between October 1968 and December 1971, between February 1976 and December 1977, and again in 1980. These tests consisted of flybys of target satellites by interceptor craft at distances of a kilometer or less, often with the interceptor being exploded after the rendezvous. In 1976, the ability to make an interception in less than one orbit was demonstrated. Ground tests conducted during the 1972-1976 period proved that the booster used for these tests -- the SS-9-based F vehicle -- would be erected and fueled in 90 minutes. So far no antisatellite capability has been demonstrated at intermediate (19,000-kilometer) or geosynchronous (35,888-kilometer) altitudes, but a switch to another booster could increase the operational altitude at a cost in difficulty and warning time. In October 1972, Andrey Gromyko presented to the United Nations a draft treaty which, in part, would have reserved to each party the right to destroy a satellite if it were to broadcast "illegal or erroneous information" to the population of the party in question. The Soviets have participated in negotiations to limit antisatellite systems

(the start of these negotiations coincided with the cessation of Soviet interception tests in 1978). However, Moscow's negotiators have pressed for language which would allow the USSR to attack non-U.S. spacecraft without violating the proposed treaty and which would allow the Kremlin to keep its system operational, a situation Washington wishes to avoid.⁶⁴ It is also of interest that three years prior to the first test interception, in 1965, the military publishing house of the Ministry of Defense of the USSR published Slovar' osnovnykh voyennykh terminov (A dictionary of basic military terms) in which (on page 182) "the destruction of an enemy's space equipment, utilized in military matters, in the orbits of its flight" by means of "special space ships and installations (satellite-interceptors)" under either remote ground control or crew direction is defined as being a component of air defense called "Protivo-kosmicheskaya oborona" (space defense).

The major political goal of the Soviet space program is enhanced prestige among the less developed nations, primarily, as well as among the countries of the West. As Pravda proclaimed on 5 October 1957, "Artificial Earth satellites will pave the way to interplanetary voyages, and our contemporaries will evidently live to see how the liberated and purposeful work of the people of a new, socialist society makes mankind's boldest dreams come true."⁶⁵ Soviet media repeatedly praise the "courageous" cosmonauts, point out Soviet space firsts (the first man in orbit, the first woman to fly in space, the first docking of two manned craft, the first "international" crews, and so on), and trumpet Moscow's claim to be performing its space research for the benefit of "all peoples" of the world. For example, one report stated that: "In February 1977, the Soviet delegation to the technical subcommittee of the UN announced the desire

of the Soviet Union to place the achievements of Soviet space science and technology in the field of remote sounding of the Earth from space at the service of world society."⁶⁶ Reports of cooperative efforts with other nations are played up as examples of how the socialist camp is leading the way to world peace through equitable cooperation. Coverage of joint efforts and exchanges of information with the U.S. are especially praised as furthering the process of detente.

Purely U.S. space efforts, however, are often denigrated by Soviet sources as being military in nature, as being too costly, as being dangerous and inefficient in using human crews as opposed to automated devices, or as some combination of these. Apollo-14, for example, was criticized for not accomplishing all of its goals (the astronauts did not climb the ridge of Cone Crater and take samples as originally planned), with Pravda's correspondent in Washington, D.C., claiming "Alas, lunar conditions proved poorly suited to the activity of man."⁶⁷ The crew's fatigue and the prior failure of Apollo-13 were heavily stressed. Soviet sources have also criticized America's Space Shuttle program, pointing to the many delays in its development, its limited flight duration, its payload limits, its cost overruns, and its militaristic nature. According to one article, "Apparently the basic goal of the development of the 'Space Shuttle' is the striving of the militarist circles of the U.S.A. to create better conditions for the development of new forms of weaponry..."⁶⁸ This same article criticizes the Shuttle for having toxic combustion products in its exhaust and because its exhaust could disrupt the ozone layer. These faults are often contrasted with the successes of the Soviet Salyut space station program, to further build Soviet prestige and decrease that of the U.S.

THE EAST LEADS THE WAY: MANNED SPACE FLIGHT

A real conquest of space is impossible without the direct participation of man with his emotional perception of his surroundings, with his capacity for making decisions in situations which unexpectedly arise.

-- G. Beregovoy, Pilot-⁶⁹
Cosmonaut of the USSR

On 12 April 1961, more than three weeks before the first American manned suborbital flight, Yuriy Gagarin became the first man to fly in space, making one orbit during a 108-minute flight in a capsule named Vostok (The East). The 4.73-ton spacecraft, together with its 1.44-ton final rocket stage, had an overall length of 7.35 meters and was launched by the A-1 vehicle, or Raketa-nositel' "Vostok", described earlier. The nearly spherical, ablative-coated cabin had three small portholes, external radio antennae, and an ejection seat. The service module, resembling two truncated cones set base to base with a ring of gas bottles around the upper cone contained chemical batteries, orientation jets, and retro rockets. The life support system (LSS), on all Vostok flights was sufficient for 10 days, and the orbit was designed to decay naturally within 10 days although no flight lasted that long. In flight the payload (i.e., the spacecraft as a whole) was allowed to tumble slowly in order to even out heat loading from insolation and radiation. The craft could be stabilized, however, for Earth observations, communications sessions, and retrofire. After reentry, the cosmonaut ejected from the capsule at an altitude of seven kilometers. The craft and the pilot landed on separate parachutes.⁷⁰ Yuriy Alekseevich was later the backup pilot for Soyuz-1,

but never made a second space flight. He died in 1968 in the crash of a jet trainer.

The second manned orbital flight took place on 6 August 1961, when Major German Stepanovich Titov became the fourth human to experience space flight (the American astronauts Alan Shepard, Jr. and Virgil Grissom had made sub-orbital flights in the interim). Titov, who had been the backup pilot for Gagarin, flew 17 orbits, spending a full day in space.

It was a year later that the next manned flights were made from the "Baykonur Cosmodrome." Vostok-3, piloted by Major Andriyan Grigor'evich Nikolayev, and Vostok-4, piloted by Lt. Colonel Pavel Romanovich Popovich, were launched on 11 and 12 August, respectively. The close co-orbit of these two craft (which came within 6.5 kilometers of one another) required great accuracy in launch timing and flight parameter control and either an impressively rapid turnaround of the launch pad or the use of two pads. The "group flight" was heralded as a prelude to future docking efforts.⁷¹

Another ten months passed before the last two flights in the Vostok series. On 14 June 1963, Lieutenant Valeriy Fedorovich Bykovskiy took off in Vostok-5. Two days later, Valentina Vladimirovna Tereshkova, a former textile factory worker, became the first (and, so far, only) woman to fly in space. The fact that the Vostok-6 lift-off was on 16 June, rather than on 15 June, and therefore was in an orbit which did not permit a sustained rendezvous, but only a close pass at a five-kilometer separation, may indicate some delay from the planned launch time. One emigre author claims that Valentina Vladimirovna was originally to be the backup pilot, but the primary pilot had to be grounded because her

menstrual period had begun. Tereshkova flew instead, but suffered greatly during the three-day flight -- according to this emigre -- because her period began some time after lift-off. The fact that Tereshkova was not a pilot emphasized the design philosophy of Vostok, which maximized automation and provided manual override only for emergencies and experimentation. This automation, in the view of the Library of Congress, strengthens the supposition that military photographic satellites of the Kosmos series were based on the Vostok design.⁷²

SUNRISE IN SPACE: THE FIRST MULTIPLACE SPACECRAFT

We are pleased, of course, that our country is ahead in the exploration of space. But we Soviet people do not regard our space exploration as some kind of race. The spirit of reckless gambling in the great and serious matter of exploring and mastering space is deeply alien to us.

-- Leonid Il'ich Brezhnev, after⁷³
the flight of Voskhod-1

In late 1963, the United States announced that both the Gemini and the Apollo programs would begin immediately with unmanned launches of Gemini-1 and Apollo-1 by the spring of 1964. The first manned Gemini flight and the first American extravehicular activity (EVA) -- or, as the press called it, "spacewalk" -- were to occur in late 1964 or early 1965. According to Leonid Vladimirov, this impending launch of a two-man spacecraft from Florida prompted Khrushchev to instruct Korolev that, not two, but three Soviet cosmonauts were to be launched in one craft not later than 7 November 1964 (the anniversary of the October Revolution).⁷⁴ Thus, despite the public Soviet attitude that the "Space Race" was an American myth, the goal of political prestige pushed the Kremlin into rushing a multiple spacecraft into operation.

The Chief Designer and his organization accomplished this feat by making a number of modifications to the Vostok capsule and vehicle. The upper stage of the launch vehicle was improved to give greater thrust. The increased load of three, rather than one, humans was compensated for by replacing a number of the Vostok's instruments with lighter miniaturized versions, eliminating a number of instruments, and reducing to a minimum the weight of supplies for the LSS. In addition, the heavy ejection seat

and its guide rails were removed and replaced by three lighter couches in a triangular arrangement. An improved parachute system and a small braking rocket were installed to ensure a soft landing. Last but not least, the cosmonauts were to wear coveralls rather than cumbersome, heavy spacesuits.⁷⁵

An apparent precursor to the modified spaceship was launched in early October. Designated Kosmos-47, this spacecraft was put into an orbit with an apogee of 413 kilometers and a perigee of 177 kilometers, and was returned to Earth after one day. Six days later, on 12 October 1964, the new spacecraft, designated Voskhod (Sunrise) was placed into an orbit with an apogee of 409 kilometers and a perigee of 178 kilometers. The commander was Engineer Colonel Vladimir Mikhaylovich Komarov, who had been backup pilot for Vostok-4. The other crew members were Medical Lieutenant Boris Borisovich Yegorov, who had become a cosmonaut only in 1964 and who returned to medicine after his one spaceflight, and civilian engineer Konstantin Petrovich Feokistov, who had played a major role in designing the craft and who also made only this one spaceflight.⁷⁶ During their 16 orbits, the cosmonauts transmitted greetings to participants in the Tokyo Olympic games and had a radiophone conversation with Khrushchev and Anastas Mikoyan, besides testing ion rockets for attitude control use, making navigational tests, and making medical observations. Drosophila and plant specimens were carried on board to help determine the biomedical effects of spaceflight. The three cosmonauts landed near Kustanay in Kazakhstan one day after liftoff. By the time they reached Moscow for the traditional official reception and award ceremony, Khrushchev had been ousted and it fell to Brezhnev to give the speech cited above.⁷⁷

Five months later, on 18 March 1965, a second Voskhod was launched. This time there were only two cosmonauts -- Lt. Colonel Pavel Ivanovich Belyayev, the commander, and Lt. Colonel Aleksey Arkhipovich Leonov -- but they wore spacesuits. In addition, an extendable airlock chamber was affixed to the outside of the craft, which was used by Leonov to leave the capsule for a ten-minute EVA -- the first in history. During the spacewalk, Leonov depended on a completely self-contained back-pack LSS. The airlock made depressurization of the entire capsule -- as was done during the American Gemini EVA's -- unnecessary. After 16 orbits, the automatic orientation equipment malfunctioned, preventing the planned retrofire. Belyayev and Leonov manually controlled their reentry on the next orbit and landed in the Tayga near Perm.⁷⁸

Voskhod-2 had one other distinction: it was the last manned Soviet spaceflight to be witnessed by Sergey Korolev. The Chief Designer of Spacecraft died ten months later, on 15 January 1966, of heart failure following surgery. His work was of continuing importance to the Soviet space program, however. His design bureau had already designed the next generation of spaceships: the Soyuz.⁷⁹

UNION: ONE SPACECRAFT FOR MANY PURPOSES

Only the active work of man in space was able to sharply expand the frontiers of scientific research...

-- General-Lieutenant of Aviation ⁸⁰
Vladimir Aleksandrovich Shatalov

The first Soviet spacecraft which could alter their orbits after orbital insertion were the unmanned Polet-1 and Polet-2 ("Flight"-1 and -2) satellites launched on 1 November 1963 and 12 April 1964. Although they preceded the Voskhod launches, these flights were apparently part of a longer-term project, as they maneuvered several times from one orbit to another, a capability not demonstrated by Voskhod. Almost two years after Voskhod-2, on 28 November 1966, another satellite, Kosmos-133, aroused interest by flying a low-perigee, nearly circular orbit, using radio frequencies usually associated with manned flights, and being recovered after two days instead of the eight days typical of recoverable military satellites. When Kosmos-140 was launched into a similar orbit on 7 February 1967 and likewise recovered after two days, rumors of an impending manned space shot spread.⁸¹

For once, the rumors were correct. On 23 April 1967, Colonel Komarov, the commander of Vostok-1, became the first Soviet citizen to make a second orbital flight. He flew a new spaceship called Soyuz (Union), for which the Polet-1, Polet-2, Kosmos-133, and Kosmos-140 missions were apparently precursors. The launch vehicle, the Raketa-nositel' "Soyuz", has an improved upper stage and is capable of lifting larger payloads than previous versions.

The Soyuz spacecraft has three modules mechanically linked via pyrotechnic units. The aft section is the service module ("priboro-agregatnyy otsek" -- instrument and assembly compartment). The aft end of this module, the assembly section, has the form of a cylinder connected to a conical region which ends in a framework, which is used to assemble the ship to the launch vehicle. On the exterior of the assembly section are radiators for the thermal regulation system; four docking and orientation motors, each with a thrust of 100 newtons; eight orientation motors of 10 newtons thrust each; and the lower attachment points for the solar batteries. Inside the section is the approach and correction engine complex ("sblizhayushche-korrektiruyushchaya dvigatel'naya ustanovka"), consisting of main and reserve engines of 4,000 newtons thrust each, fuel tanks, and feed systems for the fuel and oxidizer. Communications and telemetry and antennae, ionic sensors ("ionnyye datchiki") for the orientation system, and part of the ship's storage batteries are located in the area of the base framework ("bazovyy shpangout"). The middle portion of the service module is the airtight cylinder of the instrument section which contains instrumentation for the orientation and guidance systems, for control of onboard equipment, for communications and telemetry, for the common power supply, and for the program and timing mechanism ("programno-vremennoye ustroystvo"). Forward of this is the transition section, a truss construction connecting the rest of the service module to the command module and carrying 10 docking and orientation engines of 100 newtons thrust each, as well as fuel tanks and a feed system for the monopropellant used by these motors.

The bell-shaped command module, called the descent apparatus by the Soviets, is a pressurized compartment providing accommodations for the

cosmonauts and containing the primary controls, instruments, basic and auxiliary equipment, consumables, and communication systems. It has two observation ports and a third port with an optical sight orientation system. Underneath the "decorative sheathing" of the interior is a layer of thermal insulation, and a thermal protective coating covers the exterior of the 2.2-meter-diameter module.

Forward of the descent apparatus is the orbital compartment, which has the form of a partial sphere with a cylindrical insert. Used as a workshop for scientific experiments, a space in which to relax during rest periods, and an airlock for transfer to other craft or for EVA, this module has three view ports, one of which is in the hatch of the docking unit at the bow. There is also a hatch to the command module and a side hatch through which the cosmonauts board prior to launch. Additional control panels and equipment are located here as well.

Solar-powered versions have two "wings" of three panels each for a total useful area of 14 square meters and a span of 8.37 meters. The life support system absorbs carbon dioxide, releases additional oxygen into the cabin's sea-level pressure oxygen-nitrogen atmosphere, provides ventilation for the cosmonauts' spacesuits, and maintains living area temperature at 15-25°C and relative humidity at 20-70 percent. The instrument section of the service module is maintained at 0-40°C. With a total (internal) volume of 10 cubic meters, the Soyuz has a maximum diameter of 2.72 meters, a maximum length of 7.5 meters, and a maximum mass of 6.8 tons. It is capable of autonomous flights of up to 30 days duration at altitudes of as much as 1300 kilometers. The descent apparatus makes an aerodynamic reentry, thereby reducing deceleration loads from the 8-10g typical of ballistic reentry to 3-4g. A drogue parachute

is deployed at an altitude of nine kilometers, and a gunpowder rocket fires at about one meter to further soften the landing.⁸²

Unfortunately, Komarov's reentry and landing did not proceed as planned. Attitude control problems arose during orbits 15 and 16. An attempted manual landing during the next orbit failed because of the defective orientation system. Komarov finally succeeded in stabilizing the craft for the retrofire on orbit 18 and reentered the atmosphere, although with the descent module revolving on its axis. This spin caused the parachute lines to tangle and Komarov became the first man to die in the course of a spaceflight. Another 18 months were to go by before the Soviets attempted another manned flight.⁸³

Before the next manned Soyuz was launched, at least five unmanned precursors were flown. On 27 October 1967, Kosmos-186 was inserted into a low circular orbit. Three days later Kosmos-188 made a direct-ascent first orbit rendezvous, coming within 24 kilometers from Kosmos-186. The two craft oriented themselves head-on to one another and Kosmos-186 actively approached and docked with Kosmos-188 on the other side of the globe from the USSR. After 3 1/2 hours and 2 1/2 orbits, the craft automatically undocked over the USSR and were recovered one and two days later. On 14 and 15 April 1968, Kosmos-212 and Kosmos-213 were launched for a similar mission, except that the direct-ascent rendezvous was closer (within five kilometers), the docked configuration was maintained for slightly longer time (230 minutes), and both craft remained in orbit for five days. Kosmos-238, launched on 28 August 1968, remained in orbit for four days and had orbital and radio parameters associated with manned flights. It apparently was a final test of on-board systems prior to a second man-rating of the Soyuz.⁸⁴

The second Soyuz craft was launched unmanned and put into a low parking orbit on 25 October 1968 for a three-day flight. The next day, Colonel Georgiy Timofeyevich Beregovoy lifted off as the pilot of Soyuz-3. His spaceship made an automated approach to within 200 meters of Soyuz-2. Georgiy Timofeyevich then took manual control and made repeated approaches to the unmanned target, although no docking was accomplished. After a 94-hour, 51-minute flight, Beregovoy landed safely near Karaganda, Kazakhstan.⁸⁵

Less than three months later, four cosmonauts were launched in two Soyuz craft. Colonel Vladimir Aleksandrovich Shatalov took off in Soyuz-4 on 14 January 1969. A day later, Soyuz-5, under the command of Lt. Colonel Boris Valentinovich Volynov, was launched with researcher-engineer Lieutenant Yevgeniy Vasilevich Khrunov and civilian flight engineer Aleksey Stanislavovich Yelisseyev on board. On 16 January, after an automated approach to within 100 meters, the two ships were docked and Khrunov and Yelisseyev -- using the orbital compartments as airlocks -- transferred from Soyuz-5 to Soyuz-4 by an EVA. (This suggests that the docking apparatus in these early Soyuz models may not have had a concentric hatch to facilitate such transfers.) The docking, hailed by the Soviets as the creation of the first space station and definitely representing the first docking of two manned spacecraft, lasted for 275 minutes. Each of the spaceships landed after three days in orbit.⁸⁶

In October 1969, another group flight, but no docking, was performed. Soyuz-6, with Lt. Colonel Georgiy Stepanovich Shonin as commander and civilian Valeriy Nikolayevich Kubasov as flight engineer, was launched on 11 October and made 80 orbits for a total flight time of 118 hours and 42 minutes. This crew tested Soyuz systems, gathered Earth resources

data, and experimented with welding techniques under weightlessness and vacuum conditions. A remote-controlled welding experiment named "Vulkan" (Volcano) tested low-pressure compressed arc, electron beam, and arc welding techniques. Reportedly, the only categorical success was the electron beam method. Soyuz-7 -- with commander Lt. Colonel Anatoliy Vasil'yevich Filipchenko, researcher-engineer Viktor Vasil'yevich Gorbatko (who held the rank of Colonel by late 1975), and flight engineer Vladislav Nikolayevich Volkov (a civilian) -- was launched for an 80-orbit, 118-hour, 41-minute flight on 12 October. Besides gathering Earth resources data, this spaceship carried docking gear and served as the passive target during joint maneuvers with Soyuz-8, which was launched the next day. Although Colonel Shatalov and his flight engineer on Soyuz-8, civilian Aleksey Stanislavovich Yeliseyev, also had docking gear on their craft and although they did much joint maneuvering with Soyuz-7 during their 118 hours 50 minutes (80 orbits) aloft, there was no docking on this mission as there had been on Shatalov's previous flight. When asked about this, Soviet officials have denied that there were any plans for a docking, or else simply evaded the issue.⁸⁷ Optimal communications and visibility tests were also performed by the three spaceships.⁸⁸

In mid-1970, the Soviets broke the record for the duration of a manned space flight which had been set in December 1965 by Frank Borman and James Lovell, Jr., in the U.S. spaceship Gemini-7. On 1 June 1970, Colonel Andriyan Nikolayev (who, as a Major, had flown on Vostok-3) and his civilian flight engineer Vitaliy Ivanovich Sevast'yanov took off from Tyuratam for a flight which was to last for 424 hours and 59 minutes (almost 18 days). Although their Soyuz-9 craft lacked docking equipment, its capacity for orbital maneuvering was demonstrated when the orbit was

raised on each of the fifth and seventeenth revolutions and lowered again on day 14 of the mission. Scientific work during the flight included Earth resources studies by way of monochrome and multi-spectral color photography, photographic studies of the Moon, biological experiments concerning the propagation and development of insects, bacteria and plants (including both algae and flowering plants), and medical studies of the cosmonauts (including cardiovascular and neurological tests, measurement of maximum hand strength, sampling of expired air, and mental testing of Sevast'yanov on day 13). Tests of navigation techniques and of adaptations to living conditions (such as trying both electric razor and lather-and-blade shaving techniques) were also conducted.⁸⁹

THE MAIN ROAD TO SPACE: THE SPACE STATION

Soviet science looks at the creation of orbital stations with replaceable crews as the main route of Man into space. They can become 'cosmodromes in space', launch sites for flights to other planets. Large scientific laboratories will arise for the study of space technology and biology, medicine and geophysics, astronomy and astrophysics.

— Leonid Il'ich Brezhnev, after the completion of the Soyuz-6/90 Soyuz-7/Soyuz-8 group flight.

Many sources have pointed out that, prior to the mid-1960's, public statements of Soviet officials indicated that a major goal of the USSR's space program was a manned lunar landing. In the latter half of the 1960's, such statements were made less often, and Academician Mstislav V. Keldysh, then President of the Academy of Sciences of the USSR, indicated in October 1969 that the Kremlin had set aside manned lunar plans, although they were not precluded for the future, and spoke of ambitious space station plans.⁹¹ Leonid Vladimirov, in fact, claims that Khrushchev had pushed for a manned lunar landing and that, after he was ousted, Sergey Korolev convinced the new leadership that the USSR was not yet capable of sending a man to the Moon and should instead concentrate on other aspects of space travel.⁹² Tsiolkovskiy himself had held that manned excursions to the Moon and the planets must be preceded by the construction of a space station.⁹³ In a 1963 interview, Korolev pointed to a need for orbital stations to act as "docks" for spacecraft, which could then travel in higher orbits and widen their sphere of activities, to include lunar missions.⁹⁴ In New Year's Day articles in Pravda in 1964 and 1965, the Chief Designer of Spacecraft, writing under the

pseudonym Professor K. Sergeyev, again emphasized the value of such "cosmic docks". A similar article on 1 January 1966, shortly before the death of Sergey Pavlovich, emphasized the difficulty of a manned lunar landing.⁹⁵

Whether the Soviet Union was ever really intent on "beating" the U.S. to the Moon may never be known. It is clear, however, that since at least the mid-1960's (and perhaps earlier) a major goal of the Soviet space program has been the creation of a permanent space station.

The first steps toward this goal were taken in 1967. In October of that year Kosmos-186 and Kosmos-188 automatically approached and docked with one another, a procedure absolutely vital to the utilization of a space station. Less than a week later, on 5 November, Dr. German Manovtsev, biologist Andrey Bozhko, and technician Boris Ulibishev entered a space station mockup in which they were to spend a full 12 months. During that year, they survived on recycled water and air, dehydrated food and vegetables grown in a greenhouse that was part of their 12-square-meter closed environment.⁹⁶ The successful conclusion of this test demonstrated the feasibility of a manned orbital station.

The next phase of the space station program involved the docking of two spacecraft and the transfer of personnel from one to the other. This sine qua non was accomplished in January 1969 with the joint mission of Soyuz-4 and Soyuz-5. In fact, the Soviets described the docked configuration as the world's first orbital space station, despite the fact that one could not pass from one half to the other without exiting the pressurized spacecraft. The joint flight of Soyuz-6, Soyuz-7, and Soyuz-8 nine months later provided additional maneuvering experience, as well as testing welding techniques which might be needed for the

construction of large space stations. It was this group mission which prompted Brezhnev's "cosmodromes in space" comment.

One week after the tenth anniversary of Yuriy Gagarin's flight, a Proton lifted off from the Baykonur Cosmodrome carrying an 18.9-ton object to an initial orbit of 200-222 kilometers altitude at a 51.6° inclination to the plane of the equator. The object was, as the Soviets describe it, "the first long-term piloted orbital station",⁹⁷ known as Salyut ("Salute"). The 16-meter long station had a maximum diameter of 4.15 meters, solar panels spanning 11 meters (two sets of two panels each at opposite ends of the station), and a pressurized volume of 100 cubic meters.

The forward three meters of the station was the pressurized transfer compartment, having a diameter of two meters. This compartment was used for scientific observations and experiments and contained scientific, life support, and thermal regulation equipment as well as the docking apparatus and transfer lock. Arrayed on the exterior of the transfer compartment were such devices as one set of solar panels, various antennae, a stellar telescope and sensors for various instruments.

The central portion of the Salyut comprised the work compartment and was formed of a cylinder of 2.9 meters diameter forward connected by a conical segment to a 4.15-meter cylinder aft. The basic control, life support, communications, and power supply equipment was in this module, as was much of the scientific equipment. Overall length of the work compartment was 9.1 meters.

The remaining 3.9 meters of the station's length were taken up by the assembly compartment ("agregatnyy otsek"), which is open to vacuum. Among the devices in this equipment module were fuel supplies, low thrust orientation motors, and the orbital correction engine.

There were seven work stations at various locations in the pressurized compartments, including the central control panel (which controls all basic on-board systems, including most of the scientific apparatus, and was designed for operation by two cosmonauts), an observation post for manual stellar orientation and navigation by one of the 15 portholes in the work compartment, a control panel for scientific apparatus, a medical experiment station, a control station for the "Orion" stellar telescope, a second orientation and navigation post which could be closed off to form a photographic darkroom, and an experimental and observation station for studies of near-Earth space. Electrical power was supplied by the solar panels with nickel-cadmium batteries bufferring the system. Temperature was maintained between 15° and 25°C; humidity, 20 and 80 percent; and air movement, 0.1 and 0.8 meters per second.⁹⁸

On 21 April 1971, Colonel Vladimir Shatalov, flight engineer Aleksey Yeliseyev, and Salyut systems specialist Nikolay Nikolayevich Rukavishnikov lifted off from Tyuratam in Soyuz-10. After rendezvous with Salyut, Shatalov manually docked the Soyuz craft to the station. Five and one half hours later, the craft separated and Shatalov flew around the station while photographs were taken, then returned Soyuz-10 to earth for the first nighttime landing of the USSR's manned space program. The crew, despite the inclusion of a Salyut systems specialist, did not enter the space station. This fact, combined with the fact that Soyuz-10 was the first Soviet spaceship to have a docking apparatus in the form of a collar around a hatch⁹⁹ (which allows intervehicle transfers without EVA), imply that the mission may have fallen short of accomplishing all of its goals. Official Soviet commentary, however, cites the mission goals as "...joint experiments with the station 'Salyut', checking of the

improved on-board systems of the transport craft, further development of the control, orientation and stabilization systems, [and] conducting of biomedical investigations..." and claims that the undocking operation came only "After fulfillment of [the] intended experiments..."¹⁰⁰

Soyuz-11 was launched on 6 June 1971 with Lt. Colonel Georgiy Timofeyevich Dobrovolskiy, flight engineer Vladislav Volkov, and Salyut test engineer Viktor Ivanovich Patsayev as crew. After docking with Salyut, the crew transferred to the station for a five-fold mission: testing of station systems, testing of maneuvering and navigation systems of the ship/station complex, study of the Earth's surface and atmosphere with the aim of developing economic uses of such data, study of atmospheric and near-Earth space phenomena in various spectral ranges, and biomedical studies on the effects of space flight on the human organism. Besides cardiovascular, respiratory, vision and muscular testing of the cosmonauts, the biomedical studies included the cultivation of higher plants in the "Oasis" (Oasis) apparatus; the exposure of frog embryos, seeds, yeast, lower plants and microorganisms to weightlessness followed by ground studies of how the organisms were affected; and observation of the development of *Drosophila* fruit flies under weightless conditions. Physical and astronomical studies included ultraviolet astronomy with the "Orion" telescope, gamma ray studies with the "Anna-III" gamma telescope, measurement of charged particle fluxes with Cerenkov and scintillation counters, study of multiply charged particles in primary cosmic rays with the FEK-7 nuclear emulsion chamber, Earth photography and spectrography, study of electronic resonances, etc. On 29 June, at 1828 Greenwich Mean Time (GMT), Soyuz-11 undocked from Salyut. Retrofire took place at 2234 GMT and 13 minutes later, at the moment that the descent module separated from the orbital compartment for

reentry, radio communication was lost. One of the two valves designed to vent cabin pressure at 5300 and 4350 meters during the descent had failed when the orbital compartment separated. In less than a minute the cabin atmosphere could no longer sustain life. After the descent module landed at 2317 GMT, all three crew members were found dead in their seats. They had died of pulmonary embolism.¹⁰¹

It was 27 months after this tragedy before the Soviets launched another manned spacecraft. A number of unmanned launches made in the interim were related to the manned program, however. Kosmos-496, for example, was launched on 26 June 1972 and recovered after six days. It transmitted on two frequencies commonly used by manned flights and is believed to have been a test of an improved Soyuz designed to correct the problems suffered by Soyuz-11. On 3 April 1973, Salyut-2 was launched, but no Soyuz flight was launched to link up with it. Reportedly, a catastrophic failure of the station took place on 14 April and solar panels, rendezvous radar and radio equipment were torn off of the craft. On 28 April, TASS reported that Salyut-2 "had concluded the programme of flight", omitting the word "successfully". The station's orbit decayed and it reentered the atmosphere on 28 May 1973. Telemetry characteristics noted prior to 14 April suggest that this station was intended for a military mission. On 11 May 1973, a launch took place which the Soviets announced as Kosmos-557. Telemetry characteristics were similar to those of Salyut-1 and the satellite may have been a failed civilian Salyut. Kosmos-573, launched on 15 June 1973 for a two-day flight, transmitted on man-related frequencies and may have been a precursor to Soyuz-12.¹⁰²

Soyuz-12, commanded by Lt. Colonel Vasiliy Grigor'yevich Lazarev and crewed by civilian flight engineer Oleg Grigor'yevich Makarov, was launched on 27 September 1973 at 1218 GMT and landed on 29 September at 1134 GMT. Both days of the flight were dedicated to checking out on-board systems and to Earth photography with a nine-objective camera.¹⁰³ On this and all subsequent Soyuz flights, the cosmonauts wore spacesuits during the reentry procedures. The extra weight and room occupied by the spacesuits limited the standard Soyuz to no more than two crew members.

From 18 December to 26 December 1973, Major Petr Il'ich Klimuk and flight engineer Valentin Vital'yevich Lebedev aboard Soyuz-13 conducted astrophysical observations using the Orion-2 telescope, research in bacterial protein production using the "Oasis-2" apparatus, experiments with higher plants, Earth observation, measurement of blood circulation to the brain during weightlessness, and navigation tests.

On 25 June 1974, a new space station, Salyut-3, was boosted into orbit. Design changes incorporated into the new orbital platform included miniaturized circuitry in control loops, three large sun-following solar panels rather than the four fixed panels of Salyut-1, more efficient life support systems which kept air pressures at 835-850 millimeters of mercury (mmHg) and temperatures at 21° to 22°C, and an interior redesign. The station was kept oriented toward the Earth using both stabilization and orientation rockets and an "electromechanical system", with tracking and correction calculations provided by a "ground-based analog complex". Salyut-3 also carried the first space-borne water regeneration system. Called "Priboy" (Surf), the syst. collected moisture in the air, purified it, and added salts to prepare it for drinking purposes.¹⁰⁴

Colonel Pavel Romanovich Popovich and his flight engineer Lt. Colonel Yuriy Petrovich Artyukhin took off on 3 July 1974 in Soyuz-14. Soft docking (i.e., initial capture of the docking probe) occurred at 2100 GMT on 4 July, and the crew entered the station four and a half hours later. After docking, Popovich and Artyukhin began transmitting on a frequency of 143.625 megahertz instead of the usual Soyuz frequency of 121.75 megahertz. Station telemetry was on 19.946 megahertz, a frequency previously used by Salyut-2. The work done by Pavel Romanovich and Yuriy Petrovich aboard Salyut-3 included blood circulation tests with the apparatus "Polinom-2M" (Polynomial-2M), sampling of expired air for testing on the ground, bacterial growth tests, polarization and spectrographic studies of the Earth's atmosphere using an RSS-2 spectrograph, navigational tests using a system called "Vzor" (Gaze), station system checks, television transmission, vibration measurements, conditioning exercises using a treadmill and elastic tethers, and Earth photography using a high resolution camera with a 10-meter focal length lens. The Soviets claim that the photography was for Earth resources work. On 19 July, Popovich and Artyukhin returned to Earth.¹⁰⁵

On 26 August, Lt. Colonel Gennadiy Vasil'yevich Sarafanov, as commander, and Engineer Colonel Lev Stepanovich Demin, as flight engineer, lifted off from Tyuratam aboard Soyuz-15. Failure of the automatic reaction control system caused excessively high closure rates and, therefore, repeated failures of docking attempts. Limited battery life forced a night landing on 28 August 1974. The station continued orbiting in the unmanned mode, releasing a module which reentered and was recovered two months after the Soyuz-14 mission. In January 1975, it was deorbited by commands from the ground control center.¹⁰⁶

Despite Moscow's insistence on the non-military nature of its space program and despite Artyukhin's comment during a visit to India that the USSR would not use satellites for any military purposes,¹⁰⁷ several aspects of the Salyut-3 flight indicate a military mission. These include the fact that no civilians were among those sent to man the station, the shift in transmission frequencies by Popovich and Artyukhin, the constant orientation relative to the Earth's surface, the resolution and focal length of the camera on board, and the separation of a recoverable module, which suggests that photography had continued automatically while the station was unmanned.

The next Soyuz mission was not directly related to the space station program. Soyuz-16, launched on 2 December 1974, was an announced precursor to the Apollo-Soyuz Test Program (ASTP) and carried modified docking, communications, life support, and control equipment to meet the needs of that program. During this flight the prime ASTP backup crew, Colonel Filipchenko and flight engineer Rukavishnikov, conducted Earth resources and atmospheric studies, solar and stellar photography, docking exercises, and studies of microbial growth and transfer, fungi growth, sprouting of seeds, and orientation of fish under weightless conditions.¹⁰⁸

The next space station of the Salyut series was launched on 26 December 1974.¹⁰⁹ Two weeks later, Lt. Colonel Aleksey Aleksandrovich Gubarev and civilian flight engineer Georgiy Mikkaylovich Grechko flew Soyuz-17 to rendezvous and dock with Salyut-4 at 0125 GMT on 12 January 1975. Their work on board the station included medical studies using a veloergometer (apparently part of the "Polinom" unit), a special decompression suit called "Chibis" (Lapwing), a bone density unit designated

"Plotnost" (Density), and other medical devices. Biological experiments with microorganisms, higher plants, *Drosophila*, and frog embryos were conducted. Studies of the Earth included a small amount of resources photography, spectrography of the atmosphere and of the atomic oxygen red emission line at altitudes of 250 to 270 kilometers, and measurement of the Earth's radiation in the infrared region. Solar photography, x-ray telescoping to identify emitters, and tests of the "Stroka" (Line) teletype system were also conducted, as were tests of the "Kaskad" (Cascade) and "Del'ta" (Delta) navigation systems. Gubarev and Grechko departed the station on 9 February, ending their 30-day mission with a landing in a snow storm at 1103 GMT.¹¹⁰

The next Soyuz flight intended to dock with Salyut-4 was launched on 5 April 1975. A stage separation malfunction forced the mission to be aborted and the crew, Colonel Vasilii Lazarev and Oleg Makarov landed only 320 kilometers north of the Chinese border. To alleviate American worries about the upcoming ASTP mission, Moscow assured NASA that this "April 5th Anomaly", as it came to be known, had been launched using an older version of the launch vehicle and that the new version would be used for ASTP. This explanation itself caused some consternation as it had not previously been known that there were two versions of the booster; neither was it clear why the older version should have been used for the 5 April launch.¹¹¹

Soyuz-18, crewed by Colonel Petr Klimuk and Vitaliy Sevast'yanov, took off on 24 May and docked with Salyut-4 on 25 May 1975. The mission included work with 90 scientific and experimental installations. The "Polinom" and "Chibis" medical experiments continued, as did atmospheric spectography with the "Emissiya" (Emission) apparatus and communications

sessions with the "Stroka" device. The development of *Drosophila* was studied and onions and peas were grown in the "Oasis" unit. Under the name "Spektr" (Spectrum), measurements of particles striking the space station were made to determine their effect on orbital decay. A great deal of Earth photography was performed, as were a number of navigation tests. X-ray astronomy work concentrated on observation of X-1 Scorpio and X-1 Cygni. The behavior of liquids in space was studied, with an eye to designing space-going hydraulic systems.¹¹²

During the 63-day mission of Klimuk and Sevast'yanov, Soyuz-19 was launched (at 1220 GMT on 15 July). The Apollo half of ASTP was launched at 1950 GMT on the same day and the two spacecraft docked to one another on 17 July 1975. For nearly two days the Soviet and American craft were docked together or performing undocking and docking maneuvers. Joint experiments included an artificial solar eclipse (using Apollo as the occulting body), measurements of atomic oxygen and nitrogen at the mission altitude, cultivation of *Actinomyces levories* fungi to study the effects of spaceflight on biological rhythms, investigation of the exchange of microorganisms between men in a sealed environment, and measurements of the properties of metals and semiconductors under weightless conditions. Purely Soviet experiments involved solar photography, studies of the optical properties of the upper layers of the atmosphere, and additional biological studies. The Soviet crew, commander Colonel Aleksey Arkhipovich Leonov and flight engineer Valeriy Nikolayevich Kubasov, and the American crew, commander Brigadier General Thomas P. Stafford, command module pilot Vance D. Brand, and docking module pilot Donald K. Slayton, spoke to each other using the other crew's language and exchanged visits to each other's capsules (although no more than three persons were in either

spacecraft at any one time). The Soyuz-19 crew communicated with Klimuk and Sevast'yanov twice before they landed on 21 July. The Apollo craft landed near Hawaii on 24 July. Klimuk and Sevast'yanov departed Salyut-4 and landed on 26 July.¹¹³

On 17 November 1975, an unmanned spacecraft, Soyuz-20, docked with Salyut-4. On 4 December, Moscow announced that this mission carried biological specimens for studies parallel to those on Kosmos-782, but in a different microclimate. Kosmos-782 was launched on 25 November and recovered on 15 December. It carried U.S., French, Czechoslovak, Hungarian, Romanian and Polish experiments as well as Soviet ones.¹¹⁴

Figure 3

SOVIET SPACE STATION CHRONOLOGY

<u>Date</u>	<u>Event</u>
October 1967	Rendezvous and docking of Kosmos-186 and Kosmos-188.
November 1967	Three Soviets enter a space station mockup to test the feasibility of living in a closed environment.
April 1968	Rendezvous and docking of Kosmos-212 and Kosmos-213.
November 1968	Space station mockup experiment ends successfully.
January 1969	Rendezvous, docking, crew transfer, and experimental program of Soyuz-4 and Soyuz-5.
October 1969	Welding experiments on Soyuz-6.
April 1971	Launch of Salyut-1; rendezvous and docking of Soyuz-10 with Salyut-1.
June 1971	Soyuz-11 crew spends over 23 days on Salyut-1.
April 1973	Failure of Salyut-2.
May 1973	Kosmos-557 launch, apparently intended as a Salyut but failed as it reached orbit.
June 1974	Salyut-3 launched, apparently a military mission.
July 1974	Soyuz-14 crew spends two weeks on Salyut-3.
August 1974	Soyuz-15 fails to dock with Salyut-3.
December 1974	Salyut-4 launched.
January-February 1975	Soyuz-17 crew spends four weeks on Salyut-4.
April 1975	Soyuz mission to Salyut-4 aborted, "April 5th Anomaly".
May-July 1975	Soyuz-18 crew spends two months on Salyut-4.

SOVIET SPACE STATION CHRONOLOGY (cont.)

<u>Date</u>	<u>Event</u>
November 1975	Unmanned Soyuz-20 docks with Salyut-4; biological studies.
June 1976	Salyut-5 launched, apparently a military mission.
July-August 1976	Soyuz-21 crew spends 48 days on Salyut-5.
October 1976	Soyuz-23 docking attempt fails.
February 1977	Soyuz-24 crew spends 17 days on Salyut-5.
September 1977	Salyut-6 launched.
October 1977	Soyuz-25 docking with Salyut-6 cancelled.
December 1977	Romanenko and Grechko board Salyut-6 from Soyuz-26.
January 1978	Dzhanibekov and Makarov arrive in Soyuz-27, forming complex of station and two ships, depart five days later in Soyuz-26.
January-February 1978	Progress-1 freighter resupplies Salyut-6.
March 1978	First international crew: Gubarev and Remek visit Salyut-6 for one week in Soyuz-28; Romanenko and Grechko later return to Earth in Soyuz-27 after 96 days on board the station.
June 1978	Kovalenok and Ivanchenko board Salyut-6 from Soyuz-29.
June-July 1978	Second international crew: Klimuk and Germashevski, in Soyuz-30, visit Salyut-6 for seven days.
July-August 1978	Progress-2 and Progress-3 freighters resupply Salyut-6.
August-September 1978	Third international crew: Bykovskiy and Jen arrive in Soyuz-31, spend one week on Salyut-6, return to Earth in Soyuz-29.
October 1978	Progress-4 freighter resupplies Salyut-6.
November 1978	Kovalenok and Ivanchenkov return to Earth in Soyuz-31 after 140 days in space.

SOVIET SPACE STATION CHRONOLOGY (cont.)

<u>Date</u>	<u>Event</u>
February 1979	Lyakhov and Ryumin board Salyut-6 from Soyuz-32.
April 1979	Fourth international crew: Rukavishnikov and Ivanov in Soyuz-33 aborted docking with Salyut-6 and returned to Earth.
August 1979	Lyakhov and Ryumin, who had been resupplied on Salyut-6 by three Progress freighters and the unmanned Soyuz-34, returned to Earth on Soyuz-34 after 175 days on board the station.
December 1979	Unmanned Soyuz-T docks with Salyut-6.
March 1980	Soyuz-T separates from station in Soyuz-35, unload Progress-8; Progress-9 brings additional supplies.
May-June 1980	Fifth international crew: Kubasov and Farkas arrive in Soyuz-36, spend one week on Salyut-6, return to Earth on Soyuz-35.
June 1980	Malyshev and Aksenov in Soyuz T-2 visit Salyut-6 for three days.
June-July 1980	Progress-10 freighter resupplies station.
July 1980	Sixth international crew: Gorbatko and Tuan arrive on Soyuz-37, spend seven days on Salyut-6, return to Earth on Soyuz-36.
September 1980	Seventh international crew: Romanenko and Tamayo, flying Soyuz-38, spend seven days on board the station.
September-October 1980	Progress-11 resupplies the station.
October 1980	Popov and Ryumin return to Earth aboard Soyuz-37 after 185 days in space. Ryumin has spent 360 of the past 594 days in orbit.
November-December 1980	Kizim, Makarov, and Strekalov visit Salyut-6 for 12 days, flying Soyuz T-3.
January 1981	Progress-12 docks with Salyut-6.

THE TENTH FIVE-YEAR PLAN: SPACE AND ECONOMIC APPLICATIONS

The Soviet Union foresees the completion and utilization of new orbital stations manned by crews working in shifts. Our leading scientists consider such projects the main cause for man in space. These bases will increase in size to become large astro-stations in the universe and these will be used as the starting points for flights to other planets. Large scientific stations will be created there (in outer space) for far reaching research in space technology and biology, medicines, geophysics, astronomy and astro-physics.

-- Guidelines for the Development of
the National Economy of the U.S.S.R. 115
1976-1980

The XXV Congress of the CPSU in early 1976 confirmed the intention of the Soviet Union to continue its extensive space program with an emphasis on economic applications (see text at footnotes 55, 56 of this paper). During the five years since that session (corresponding to the Tenth Five-Year Plan), there have been 19 manned space flights, with 22 cosmonauts making their first flight and one making his fourth (see also Table 4, Summary of Soviet Manned Space Flights by Five-Year Plan next page). Of those flights, 18 were visits or attempted visits to Salyut space stations.

Salyut-5 was launched on 22 June 1976. Two weeks later, on 6 July, Colonel Boris Valentinovich Volynov and his flight engineer Lt. Colonel Vitaliy Mikhaylovich Zholobov departed Tyuratam on Soyuz-21. During their mission on the new space station, which lasted until 24 August, the two cosmonauts performed a number of experiments. The "Sfera" (Sphere) device was used to investigate the melting of a low-melting-point alloy and its resolidification into spherules under weightless conditions for

Figure 4

SUMMARY OF SOVIET MANNED SPACE FLIGHTS BY FIVE-YEAR PLANS

<u>Party Congress</u>	<u>Five-Year Plan</u>	<u>Years</u>	<u>Number of Manned Flights</u>	<u>Number of Cosmonauts Making Their</u>		
				<u>First</u>	<u>Second</u>	<u>Third Spaceflight</u>
XXII (October 1961)	VII	1961-1965	8	11	0	0
XXIII (March-April 1966)	VIII	1966-1970	8	11	4	0
XXIV (March-April 1971)	IX	1971-1975	10 + "April 5 Anomaly"	12	10	2
XXV (February-March 1976)	X	1976-1980	19	22	9	7
				(7 non-Soviet)		(1 made a fourth flight)

Adapted and updated from Houtman, pp. 7-8.

comparison with bearings made on Earth. The "Kristall" (Crystal) constant temperature chamber was used to grow alumino-silicate alum crystals from aqueous solution. Fluid flow by capillary action was studied in the "Potok" (Flow) device, while the "Reaktsiya" (Reaction) unit was used for welding experiments. The "Sfera", "Potok", and "Diffuziya" (Diffusion) units were parts of an experimental complex called "Fizika" (Physics). ("Diffuziya" studied the diffusion of two hydrocarbon fluids into one another under weightless conditions.)¹¹⁶

The next Soyuz craft, with Colonel Valeriy Fedorovich Bykovskiy as commander and Vladimir Viktorovich Aksenov as flight engineer, made no attempt to dock with the space station. The 15-23 September 1976 flight of Soyuz-22 had the mission of "final adjustment" of Earth resources techniques using a multi-band, six-objective camera designated MKF-6 in an experiment called "Raduga" (Rainbow). The camera, made by the Karl Zeiss Jena plant in the GDR, took simultaneous pictures in four visible and two infrared spectral bands and achieved a resolution of 10-20 meters from altitudes of 250 to 280 kilometers. The camera was carried in a photographic module which replaced the docking apparatus on this flight.¹¹⁷

Soyuz-23, launched on 14 October 1976, had as its mission the continuation of "scientific-technical researches and experiments with the orbital station 'Salyut-5'". The mission commander was Lt. Colonel Vyacheslav Dmitriyevich Zudov; the flight engineer, Lt. Colonel-Engineer Valeriy Il'ich Rozhdestvenskiy. Attempts to dock with the space station were cancelled due to deviation of the ship's approach control system from the designed operating regime. The craft made the first water landing of the Soviet program on the night of 16 October on Lake Tengiz, 195 kilometers southwest of Tselinograd.¹¹⁸

Soyuz-24 met with more success. After a 7 February 1977 take-off, Colonel Viktor Vasil'evich Gorbatko and flight engineer Lt. Colonel Yuriy Nikolayevich Glazkov entered the Salyut station on 9 February. They performed biomedical and technological experiments, observations of the Earth and its atmosphere, and Salyut systems tests, including partial replacement of the station's atmosphere, before returning to Earth on 25 February.¹¹⁹

The station, which remained in orbit until late August 1977, returned at least one data capsule to the Earth automatically. This fact, plus the all-military nature of the three crews sent to occupy it, tends to indicate that Salyut-5, like Salyut-3, had a primarily military mission. It should be noted that a number of the technical experiments on board were of significant military interest (for example, "Sfera" produced bearings more precise than those made on the ground).

The USSR was not without a station in orbit for long. On 29 September 1977, a new improved civilian station, Salyut-6, was launched. Among the improvements are a new engine system and a second docking module and personnel transfer lock in the assembly compartment. Salyut-6 retains the three-compartment configuration of its predecessors, along with the total pressurized volume of 100 cubic meters. It carries about 1500 kilograms of scientific apparatus, is penetrated by more than 20 double-glazed portholes, has improved orientation and navigation systems and an electro-mechanical stabilization system, and can be refueled by transport craft.

The transfer section has three hatches: one in the docking module for ship to station transfers, one opposite the docking module leading into the work compartment and one in the side of the compartment. For EVA, the hatch to the work compartment can be sealed, pressure vented

into space and the side hatch used for egress. On returning to the interior, the cosmonaut can seal the side hatch and let air back into the transfer compartment via a valve to the work compartment or via a valve to externally mounted air tanks. Thus the entire compartment can act as an airlock. In addition, this portion of the station carries "radio-technical" and radiotelemetry antennae, ion sensors for the orientation and stabilization systems, micrometeorite sensors, sun position sensors, thermal regulation equipment, flashing beacons ("problekovyye mayaki"), and other equipment. Two of the station's seven work stations -- one for photography and astronomy and other for manual orientation control -- are located in the transfer compartment.

The work compartment includes, in the large diameter portion, a conical volume open to vacuum in which various scientific equipment is mounted. On the exterior of the compartment are mounted three sun-tracking solar panels, giving a total of four kilowatts of electrical power. The central control panel for the station, which is the primary work station for both the mission commander and the flight engineer, remains in the small diameter section of the nine-meter-long volume. Medical equipment and a work station of Earth observation photography and spectrography are in the transition region, while physical training, veloergometer, and partial pressure ("Chibis") equipment is at the forward end of the large cylinder. Moving aft, one finds sleeping positions arranged along the walls, special airlocks for trash ejection, a scientific work station at the vacuum-exposure cone, and the sanitation and hygiene complex, which is separated from the rest of the compartment by a set of blinds. Aft of this area's bulkheads are the station's electronics modules and supplies of such consumables as oxygen, food and water.

Bolted to the aft of the work compartment is the assembly module. The unified engine complex -- including fuel tanks, compressors, valves, correction motors, and orientation and stabilization motors -- and sun position motors are located in or on this region. Movie equipment (for the cosmonauts' recreation time), ventilators, heating tubes and other equipment are kept in the personnel transfer chamber which penetrates the assembly compartment linking the work compartment with the second docking unit.¹²¹

On the morning of 9 October 1977, Colonel Vladimir Vasil'evich Kovalenok, mission commander, and civilian Valeriy Viktorovich Ryumin, flight engineer, blasted off in Soyuz-25 with the intention of performing "joint experiments with the scientific station Salyut-6". However, when they had approached the station to within 120 meters, docking was cancelled "due to deviation from the foreseen regime of mooring."¹²² (Western sources disagree with this description to some extent, claiming that the problem was a failure to achieve "a hard lock on docking".)¹²³

The next crew sent to visit Salyut-6 was that of Soyuz-26, launched on 10 December 1977. Yuriy Romanenko and Georgiy Grechko boarded the space station on 11 December for a stay which not only set a new record for space flight duration, but also involved at least three "firsts" for space travel. The first month of the mission was occupied primarily by Earth observations. Then, on 11 January 1978, Lt. Colonel Vladimir Aleksandrovich Dzhaniybekov and civilian flight engineer Oleg Makarov docked with the station in Soyuz-26, thus forming the first complex of three separately launched spacecraft in history. The four cosmonauts spent five days performing joint experiments, including a Franco-Soviet experiment designated "Tsitos" ("Cytos" -- apparently a cytological study of some

sort). Dzhaniybekov and Makarov then returned to Earth on Soyuz-26, leaving the "fresher" ship at the station.¹²⁴

On 22 January, the first docking of an automated cargo resupply ship with a space station occurred. The new ship, Progress, is based on the Soyuz manned ship, but the descent module has been converted to a fuel compartment, containing two fuel and two oxidizer tanks and capable of delivering 1000 kilograms of fuel and oxidizer to the station through pipes in the docking modules. The orbital work compartment has become a cargo compartment with 6.6 cubic meters available for up to 1300 kilograms of dry cargo stored at normal atmospheric pressure and +3 to +30°C. After Progress is unloaded, equipment and materials no longer needed aboard the station and not intended for return to Earth are loaded into the cargo compartment for destruction on reentry. (Progress lacks thermal protection or parachutes, thereby allowing an increased payload.) The cargo vessel is capable of three days autonomous flight and of 30 days flight while docked to a station. Progress-1 was separated from Salyut-6 on 6 February and deorbited on 8 February 1978.¹²⁵

Another "first" took place on 2 March 1978, when Soyuz-28 carried the first international crew into orbit. Under the auspices of the Interkosmos program, Soviet cosmonaut Aleksey Gubarev and Czechoslovak Captain Vladimir Remek spent 3-10 March with Romanenko and Grechko on Salyut-6. The four conducted astronomical and Earth observations and a number of technical and biomedical studies including the growth of silver chloride-lead chloride and copper chloride-lead chloride crystals, studies of dust at altitudes of 80 to 100 kilometers, tests of the ability of Chlorella algae to provide water, air and protein to space travelers, and studies of

oxygenation and heat exchange in the human body.¹²⁶ Romanenko and Grechko returned to Earth six days after their visitors, setting a flight duration record of 96 days.¹²⁷

Kovalenok made a second, and more successful, trip to the orbital station in mid-June 1978 as commander of Soyuz-29. Aleksandr Sergeevich Ivanchenkov was flight engineer for this mission which docked with Salyut-6 on 17 June. The research work of the two cosmonauts included atmospheric, materials, biomedical, and station systems studies. Eleven days after Vladimir Vasil'yevich and Aleksandr Sergeevich entered Salyut through the transfer compartment, Petr Klimuk docked Soyuz-30 to the port in the assembly compartment. The "Cosmonaut-researcher" on this second Interkosmos mission was Major Miroslav Germashevski of Poland. For seven days, the four cosmonauts conducted station systems tests, Earth observation and photography, biomedical studies and experiments on semiconductor production. Klimuk and Germashevski returned to Earth in Soyuz-30 on 5 July. After this visit, the station was resupplied by Progress-2, which arrived on 9 July. On 29 July Kovalenok and Ivanchenkov performed a 125-minute EVA to dismantle experiments studying micrometeorites and the effects of space exposure on various materials. Progress-2, presumably carrying the dismantled components, was separated from the docking port on 2 August for destructive reentry on 4 August. Another resupply mission, Progress-3, was docked with Salyut-6 from 10-21 August. The cargo ship's engines were used during this period to correct the orbit of the complex. From 27 August to 3 September, Kovalenok and Ivanchenko were again visited by an international crew: Colonel V. F. Bykovskiy and Colonel Sigmund Jen of the East German National Volksarmee, who arrived aboard Soyuz-31 and returned to Earth aboard Soyuz-29. Progress-4 brought still more cargo to Salyut-6, docking with the

station on 6 October. On 19 October, the Progress craft's engines were used to make another orbital correction. Nine days after Progress-4 departed Salyut-6, Kovalenok and Ivanchenkov used Soyuz-31 to return to Earth on 2 November 1978. The pair had set still another duration record by remaining in space for 140 days.¹²⁸

Valeriy Ryumin, who had flown with Kovalenok on the unsuccessful Soyuz-25 mission, got his second chance to visit the space station on Soyuz-32, commanded by Lt. Colonel Vladimir Afanas'yevich Lyakhov. The pair lifted off on 25 February 1979 and chalked up another duration record -- 175 days -- before landing again on 19 August. Only one crew -- Soviet civilian Nikolay Rukavishnikov and Bulgarian Engineer-Major Georgiy Ivanov on Soyuz-33 -- attempted to visit during this period. Soyuz-33 departed Baykonur Cosmodrome on 10 April, but on its approach to the station there occurred a "deviation from the regular regime in the operation of the approach and correction engine complex of Soyuz-33, as a result of which its docking with the station was cancelled."¹²⁹

During their 175-day stint in orbit, Lyakhov and Ryumin carried out repairs to and preventive maintenance of the station, took part in five dockings and undockings (Soyuz-32, Soyuz-34, and three Progress vehicles), unloaded more than 4500 kilograms of cargo from the automatic freighters, made three orbital corrections, produced more than 50 alloy samples, performed a "unique" EVA, and erected the first orbital radiotelescope. The research program included Earth observations aimed at locating oceanic plankton concentrations (the locations were reported to the Soviet fishing fleet to help increase their catch), mineral outcroppings, and ring structures which might yield oil and gas. Astronomical observations using the BST-1 submillimeter band telescope, spectrography of the Earth's surface

and atmosphere and the station's portholes using the Bulgarian-made "Spektr-15" spectrometer, and ionospheric studies using the Bulgarian electrophotometer "Duga" (arc) were also performed. The "Isparitel" (Evaporator) device was used to investigate deposition of thin films under orbital conditions. Of major significance to the research program was the delivery to Salyut-6 of the KRT-10 radiotelescope. After the separation of Progress-7 from the station, Lyakhov and Ryumin deployed this 10-meter dish, which was intended to work with the 70-meter dish at the Crimean observatory to form a long-baseline radio interferometer equivalent to a single radiotelescope the size of the entire planet. In the initial stages of its deployment in July the KRT-10 became entangled with one of the docking targets. It was this which prompted the EVA, the uniqueness of which lay in its unplanned nature. At one point in the flight, Vladimir Afanas'yevich and Valeriy Viktorovich returned experimental samples to Earth, using their Soyuz-32 craft in the automatic mode. At the end of their mission, they returned to Earth in Soyuz-34, which had carried cargo to the station in the automatic mode.¹³⁰

The next visit to Salyut-6 was made by a robot. On 15 December 1979, an unmanned craft with the designation Soyuz T was launched. The TASS announcement of the lift-off reported that improved communications, computer, and orientation and guidance control equipment had been installed on this craft. The robot spaceship remained docked to Salyut-6 until 24 March 1980, when it returned to autonomous flight for final tests of the new on-board systems. The conclusion quickly reached in the West was that the new equipment was intended to overcome the docking difficulties which had beset the Soyuz ferry version (in particular, Soyuz flights 15, 23, 25, and 33 and -- possibly -- 10).¹³¹ Of interest in this regard is the fact

that the Soviet leadership will only allow the basic Soyuz ferry version to remain in orbit for 90 days in manned applications, yet the automated Soyuz T flight continued for more than 100 days.

Later reports verified that the Soyuz T is a highly modified version of Soyuz: "almost all on-board systems have been renovated"; a "perfected" computer (digital, rather than the previously used analog devices) allows on-board control and computation functions previously performed on the ground; the control panels now feature cathode-ray tube and annunciator panel displays, as opposed to dial read-outs; a new platformless orientation system has done away with the requirement for gyroscope platforms; higher quality communications equipment has been installed; carbon dioxide scrubbers and oxygen supplies have been added to the life support system; and new solid fuel rockets are used to soften the landing and as protective measures in case of launch accidents. New solar panels and a unified fuel system for all spacecraft motors are other innovations relative to the older ferry version. The Soviets refer to the T series as a new generation of transport ships for both autonomous flights and space station ferry missions, and claim that flight duration is now limited only by the consumables in the life support system.¹³²

Although Moscow claims the new ship requires less preparation time, four of the six manned spaceflights of 1980 were on the older Soyuz ferry. The first of these, Soyuz-35, was launched on 9 April for: docking with the Salyut-6/Progress-8 complex (the Progress-8 freighter had been docked to the station on 29 March), preventive maintenance and repair work on the station, and continuation of scientific and technical experiments, of Earth resources studies, and of biomedical research. The mission

commander was Lt. Colonel Leonid Ivanovich Popov and the flight engineer, once again, was Valeriy Ryumin.¹³³

After boarding the station on 10 April, Leonid Ivanovich and Valeriy Viktorovich began unloading Progress-8, powering up systems which are turned down or off for autonomous flight, and initiating experiments. On 12 April, the "Oazis", "Vazon" (Flowerpot), and "Malakhit" (Malachite) installations -- all used to study plant growth under spaceflight conditions -- were put into operation. "Malakhit" had been brought to the station aboard Soyuz-35 and contained growing orchids. By 18 April, all station systems were operating, Progress-8 was unloaded, the air in the living compartments had been replenished and refreshed with air from tanks on the transport ship, and the reloading of the station's cameras was underway. Progress-8 was deorbited on 26 April, and Progress-9 docked to the station three days later. This transport robot was unloaded by mid-May, used to make an orbital correction on 16 May, and deorbited on 22 May. The cosmonauts' experimental program during this period included semiconductor refining in the "Kristall" unit and the "Splav" (Alloy) installation, gamma-ray and charged particle measurements using the small gamma telescope "Elena", production of phenopolyurethane structural components with the "Lotos" (Lotus) device, Earth resources studies with the aid of multispectral cameras and the MSS-2 spectrometer, Earth surface and oceanic observations for environmental and meteorological research and to aid the Soviet fishing fleet locate schools of fish, cardiovascular and oxygen economy studies, and measurements of gas exchange dynamics.¹³⁴

On 27 May 1980, Soyuz-36 -- which had taken off the previous day -- docked with Salyut-6 and civilian mission commander Valeriy Nikolayevich Kubasov and Hungarian cosmonaut Captain Bertalan Farkas came on board.

The four spent a week performing Earth surface and atmospheric observations, semiconductor production and other materials science experiments, measurements of thermal deformation of the station and of optical characteristics of the stations portholes, biomedical tests, and measurements of radiation dosages. Kubasov and Farkas returned to Earth in Soyuz-35 on 3 June. Kubasov later reported having to cut back on sleep to only one to four hours a day in order to complete all the planned work.¹³⁵

Three days later, Popov and Ryumin had two more visitors, Lt. Colonel Yuriy Vasil'yevich Malyshev and civilian engineer Vladimir Viktorovich Aksenov. They arrived in the first manned version of the new generation of transport spaceship, Soyuz T-2, with the mission of further testing and development of their craft's on-board systems in the piloted mode and of conducting joint operations with the space station complex. Lighter, more comfortable space suits, using pure oxygen for the suit's atmosphere, have been designed for use with the Soyuz T series and these were also tested during the four-day flight.¹³⁶

Progress-10 was launched on 29 June for a resupply run to Salyut-6. After it was unloaded and had been used by Popov and Ryumin to correct the station's orbit, the cargo craft was undocked on 18 July, day 101 of Popov's and Ryumin's flight.¹³⁷ A new series of coating deposition experiments were run on the "Isparitel'" unit in early July. Soviet scientists were especially interested in the results of this series of tests, since some of the coatings produced during the 175-day flight of Lyakhov and Ryumin had properties not found in samples produced on the ground. After the tests were completed, Popov and Ryumin were to have removed the device from the airlock chamber (one of the small locks in the work compartment used for waste

disposal and scientific experiments) and to replace it with the "Splav" electric furnace. Experiments using "Splav" began on 11 July.¹³⁸

The fourth manned flight of the year, Soyuz-37, brought Colonel Gorbatko and Vietnamese Lt. Colonel Phan Tuan to visit the station from 24 to 31 July. During the visit the quartet of cosmonauts carried out a number of Earth observation, biological, medical, and materials science assignments including spectrographic observations of the SRV, measurements of the temperature profile of the "Kristall" device, and attempts to produce semiconductor mono-crystals. On 31 July, Gorbatko and Tuan landed Soyuz-36 in Kazakhstan.¹³⁹

During August, the highlights of the program aboard Salyut-6 included the repair of the "Elena" gamma telescope by Popov and Ryumin. The cosmonauts disassembled the unit, fashioned a substitute for a broken pin and reassembled it, thereby avoiding delays in the program and simultaneously "astonishing" ground personnel. In a materials processing experiment "large pure crystals" of a cadmium telluride-mercury telluride mixture were produced. The mixture has great potential as a semiconductor, but such crystals cannot be produced on the ground as the components are immiscible in a strong gravity field.¹⁴⁰

In mid-September, Soyuz-38 blasted off from Baykonur Cosmodrome under the command of Colonel Yuriy Romanenko. The cosmonaut-researcher on this Intercosmos mission was Lt. Colonel Armaldo Tamayo Mendez of Cuba. They docked with Salyut-6 on 19 September and spent a week conducting joint experiments with Popov and Ryumin. The work included studies of cardiovascular adaptation to spaceflight, studies of changes in the structure of the arch of the human foot under weightless conditions, central nervous system studies, investigation of multicellular processes in yeast,

growth of semiconductor crystals and, for the first time in orbit, of organic crystals, geophysical studies, and investigation of psychomotor coordination during adaptation to spaceflight. On September 26, Romanenko and Tamayo returned to Earth aboard Soyuz-38.¹⁴¹ The fact that they did not exchange capsules as previous visiting crews had done hinted that Popov and Ryumin might soon return as well.

A Progress freighter launched on 28 September docked with the station on 30 September. Unloading was completed by 6 October, and two days after that Popov and Ryumin were putting the finishing touches on their experimental program and beginning the "buttoning-up" process to prepare the station for unmanned flight. One of the last experiments to be completed, designed to study the effects of spaceflight on mutation in the seeds of higher plants, came to an end on 10 October. Popov and Ryumin ended their 185-day flight, landing Soyuz-27 180 kilometers southeast of Dzhezkazgan, on 11 October 1980.¹⁴² Ryumin had spent 360 days in space in two consecutive flights.

The last manned flight of 1980 was the third vehicle in the Soyuz T series. The mission commander was Lt. Colonel Leonid Denisovich Kizim; the flight engineer, Oleg Makarov (making his fourth attempted, and third successful, flight); the cosmonaut-researcher, Gennadiy Mikhaylovich Strekalov. This was the first three-man Soyuz crew since the disaster of Soyuz-11. Apparently the smaller, lighter spacesuits and the extra room in the descent module allowed the return to a crew of three. The third crewmember is not involved in running the ship and therefore can be a specialist in any field whatever, with no pilot training necessary, or can be replaced with a cargo module for two-man missions. The Soyuz T-3, having taken off at 1418 GMT on 27 November, docked with Salyut-6 on 28

November. Medical, biological and materials research was conducted, as were repairs and preventive maintenance. One repair, the replacement of a hydraulic unit in the thermal regulation system, required the opening and resealing of a closed hydraulic system and marked the first time such work has been conducted under weightless conditions. Progress-11 was separated from the station on 9 December, one day after being used to make an orbital correction. The next day, 10 December 1980, Soyuz T-3 returned its three crew members safely to Earth.¹⁴³

Yet another manned flight to Salyut-6 is apparently being prepared as this paper is being written. On 24 January 1981, Progress-12 was launched to dock with the station.¹⁴⁴ The manned flight to unload the cargo will probably be timed to coincide with the XXVI Party Congress which convenes in February 1981.

GREENHOUSES, BOOSTERS, AND SPACE PLANES:

SOVIET SPACE-RELATED RESEARCH AND DEVELOPMENT

Just as on the Earth's surface an endless mechanical and chemical cycling of materials is achieved, so it can be achieved in our little worldlet...Just as on Earth plants consume the unclean in their leaves and roots and give food in exchange, so can the plants taken by us on the trip work unceasingly for us.

-- Konstantin Eduardovich¹⁴⁵
Tsiolkovskiy

Having an extensive manned space program, the USSR has done a large amount of research aimed at perfecting life support systems (LSS). For each 70 kilogram cosmonaut aged 25-40, such a system must supply each day 600 liters of oxygen, 600-800 grams of food, 2.0-2.5 liters of drinking water, and 5.0-10 liters of water for sanitation and hygiene. The LSS must also remove 400-500 liters of carbon dioxide, 2.5-3.0 liters of water in the form of urine and perspiration and 100-200 grams of solid waste. For Soviet spacecraft, this means, in part, maintaining an oxygen-nitrogen atmosphere at pressures of 710-900 mm Hg, oxygen contents of 19-29 percent (164-199 mm Hg partial pressure), carbon dioxide contents of 0.1-0.6 percent (3.0-8.5 mm Hg), relative humidities of 35-80 percent, and temperatures of 13-30°C.¹⁴⁶

As of 1975, atmospheric quality on Soyuz and Salyut spacecraft was maintained by regeneration: alkali metal oxides and superoxides were used to absorb carbon dioxide and release oxygen into the cabin air. Four kilograms of potassium superoxide is sufficient for one cosmonaut for one day. Impurities such as carbon monoxide, ketones, alcohols, aldehydes, aliphatic acids, methane, unsaturated hydrocarbons,

dust, bacteria, and viruses were removed from the air by activated charcoal, dust precipitation, hypocalite, zeolite, and special bacterial filters and by chemical catalytic processes. Thermal regulation was provided by air-liquid heat exchangers which radiated excess heat into space, while dehumidification was accomplished by condensing atmospheric moisture on a cooled surface, from which wicks passed the water into a purification and recycling system.¹⁴⁷

Research on closed or semi-closed LSS design began in the 1960's. A test of one such design was described above, in which three men spent a full year in a space station mockup containing a closed LSS. Continuing research is aimed at perfecting a 100 percent closed system. It is to this end that so much of the research program on Salyut stations and Soyuz transports has been dedicated to investigations of plant growth -- whether bacterial, as in the experiment "Oazis-2" on Soyuz-13; fungi, as in the Soyuz-16 experiment "Ritm" (Rhythm); algae, as in the joint Soviet-Czechoslovak experiment "Khlorella" (Chlorella) on Salyut-6; ferns, as in the Soviet-Vietnamese experiment "Azolla" (Asola) on Salyut-6; peas and onions, as in Salyut-4's "Oazis-1M"; or orchids, as in the "Malakhit" unit on Soyuz-35 and Salyut-6. During the two-week Soyuz T-3/Salyut-6 mission, one project studied the possibility of replacing gravity-induced geotropism (the absence of which disrupts the development of plants in orbit) with tropisms reacting to directional lighting and applied electrical fields.¹⁴⁸

Another area of Soviet research concerns protection of cosmonauts from ionizing radiation. An experiment on Kosmos-605 in 1973 found that radiation dosages inside the spacecraft could be decreased by the application of electrostatic fields.¹⁴⁹

As has been noted above, the Soviet Union has also conducted extensive research into the physiological effects of space flight. Cardiovascular, respiratory, neurological, muscular, neuromotor, osteological, psychological, and metabolic processes have been investigated, and means of combating some of the harmful effects have been devised -- for example, the "Chibis" partial pressure device used to imitate circulatory effects of gravity. As cosmonaut Lyakhov has commented: "...And man is studying his 'compatibility' with unusual space conditions and is aiming at flying farther and longer. For example, a trip to Mars demands, as a minimum, two years. An increase in the periods [of flights] on orbital stations is being conducted systematically, since scientists are trying to find reliable methods guaranteeing rapid readaptation after landing..."¹⁵⁰ The methods found to date are sufficiently effective that, after 185 days in free fall, cosmonauts Popov and Ryumin had readapted well enough to take a short walk within 24 hours of their landing in October 1980.¹⁵¹

The USSR began planetary and lunar studies early in its space program. The first Soviet lunar probe was launched on 2 January 1959, and the first probe of the Venera series was launched on 12 February 1961. The launch date of the first Soviet Mars probe was 1 November 1962. The Luna, Venera, and Mars series, together with the "Zond" (Probe) series of 1964-1970, returned significant amounts of data on planetary geology, atmospheres, and weather. To date, however, Soviet spacecraft have been sent only to the terrestrial planets; none have been sent either to Mercury or to the gas giants. Future planetary probes planned by the USSR include two Venus landers to be launched

in November 1981 and a possible 1984 launch of a Venera probe which would also fly by Halley's Comet in 1986.¹⁵²

In any extensive space program, of course, there will be a certain amount of research and development devoted to rocket engines and to spacecraft. While the Soviets are reticent about their future plans, evidence of past developmental work is clear. The standard A launch vehicle was first introduced in 1957, then modified with various upper stages as they were developed. The A-1, or Vostok launch vehicle, was used as early as 1959, while the A-2 (Soyuz launch vehicle) was flown as early as 1960. The B, or Kosmos, launch vehicle came into use in 1962, the C vehicle in 1964. The D, or Proton, launch vehicle was first used in 1965. A modified version has been used to launch Salyut space stations since 1971. The F vehicle was in use prior to 1971.¹⁵³

An evolution in spacecraft has also been apparent, from the simple sphere of Sputnik-1 through Salyut-6 and Soyuz T. The first manned spacecraft, Vostok, appeared in 1961 and was replaced by Voskhod in 1964. The first Soyuz flight in 1967 ended in disaster and modifications were made by late 1968 when Soyuz-2 and Soyuz-3 were launched. By early 1976, there were, according to a Western report, six different versions of the basic Soyuz craft.¹⁵⁴ In January 1978 yet another version was introduced -- the Progress freighter. A major redesign created the Soyuz T, first flown in 1980. The first of the Salyut space stations appeared in 1971. In 1974, the first successful military version of Salyut was flown, as was a modified civilian version, Salyut-4. Salyut-6, apparently a significantly improved version, was launched in September 1977 and is still in use.

Of more interest than past developments, however, is current and future research and development. What innovations can be expected in the next few years? A Soviet report has predicted that there will be significant increases in the specific impulse of upper stages as a result of the adoption of nuclear rockets (in which a reactor heats a working fluid, such as hydrogen, which is used as the exhaust) or of ion rockets, such as the "Yantar'" (Amber) motors tested on some Soviet flights which achieved exhaust velocities as high as 120 kilometers per second.¹⁵⁵ Nuclear rockets, though, are not likely to see use at any time in the near future because of technical difficulties such as the weight penalties imposed by shielding requirements. Ion rockets, while they have high exhaust velocities and high specific impulses, tend to have very low mass flow rates, and therefore low thrusts. As a result, they will probably be restricted to use as orientation motors for some time to come.

Another question arises as well: Why has the USSR not introduced a single new launch vehicle into service since 1971? After all, five basic vehicles and several modifications were introduced during the preceding decade and a half. Western sources have several times reported that development work on a very heavy launch vehicle is under way, and have even given it the designation "G". In 1967, representatives of the National Aeronautics and Space Administration (NASA) testified before Congress that development of a vehicle with greater thrust than the Saturn V was under way in the Soviet Union. By late 1969, reports of catastrophic launch failures of the new vehicle began appearing in the Western press. According to one report the first attempted launch resulted in an explosion on the pad. A second attempt was destroyed

immediately after lift-off, while the third rose several thousand feet before failing. As a result, a test stand was modified to accomodate "full upright dynamic testing of the booster stack". A later report, claiming that the first stage would have from 24 to 36 engines with a total thrust of 4,500-6,300 tons, predicted that a successful launch of this vehicle could come as early as 1983. The closest the Soviets themselves have come to commenting on the hypothetical G vehicle was the response of cosmonaut Popovich when asked in a 1977 interview whether Moscow had a launch vehicle as powerful as the Saturn V. "We have everything! Like the U.S.A., the Soviet Union has very large and powerful carrier rockets which can launch very large spacecraft, including launchings toward Mars and Venus."¹⁵⁶ (This comment was probably an evasion, however, since Venus and Mars probes have been launched on the A and D vehicles.)

The Soviets have been slightly less reticent about possible future manned spacecraft. In 1976 a German report quoted General-Lieutenant Shatalov as saying: "In the near future, air travel and space travel will come closer together."¹⁵⁷ Likewise, Soviet guidance system designer Nikolay Alekseyevich Pilyugin was cited in 1980 as having said: "...and in the future, possibly, the airplane and the rocket will again be united. Such projects exist..."¹⁵⁸ Both quotations point to Soviet plans paralleling the American Space Shuttle project.

Indications of Soviet plans for a reusable manned spacecraft have been appearing since the early 1960's. In 1962, aircraft designer Dr. Artem Mikoyan introduced the term "Kosmolet" (an apparent ellision of the words "kosmicheskiy samolet" ["space airplane"] to refer to such a project.¹⁵⁹ According to one Western writer, Chief Designer of

Spaceships Korolev and Chief Designer of Rocket Engines Glushko were instructed to study design options for a reusable upper stage in 1965 and preliminary estimates were ready by 1967, under the project name "Raketoplan" (Rocket plane).¹⁶⁰ (This was the only source which referred to the project by this name, which was also used for an early rocket-powered aircraft that flew to a maximum altitude of three kilometers in a 1940 test.)

In late 1973, a German radio broadcast reported that the "transporter" being planned in the USSR would first be used for long distance terrestrial flights and only later be used as an Earth-to-orbit shuttle. The report cited plans for a horizontal takeoff with a flyback booster lifting the "space glider" to an altitude of 30 kilometers. The upper stage would then ignite its rocket engines and rise to 100 kilometers, achieving a speed of 28,000 kilometers per hour. The "space glider" would carry passengers or freight to any point on the globe and land like an aircraft. The second phase of the project would develop the system into "a commercial means of transport operating between Earth and space" with a 300 flight capability.¹⁶¹ A later German report specified that the booster would be about the size and shape of a TU-144 and have air-breathing engines which would give it a speed of 7,920 kilometers per hour, while the upper stage would be about the size of a Yak-40. Each would have a crew of two or three.¹⁶²

Apparently, both vertical and horizontal launch techniques were studied for the Soviet MTKK ("Mnogorazovyy transportnyy kosmicheskiy korabl'" -- multiple [use] transport spaceship). Shatalov, in 1976, voiced the opinion that the horizontal variant, while more costly, was

preferable and claimed, "We have perfected the more advanced second shuttle device, which proceeds from a horizontal launching."¹⁶³

Popovich, in a 1977 interview for a West German periodical, was asked if the USSR was "...building a reusable orbital transport..." He replied that "...such a project is currently being developed and worked on..." as a "...vital economic question of space travel..." Popovich further commented that such a transport would be three times as economical as disposable launch vehicles, and that systems of two, three, and four stages had been considered by Moscow, with the two-stage version being selected as the most advantageous. He refused to say when such a system might become operational, however. (Interestingly, although the interviewer repeatedly referred to the system as "Kosmolet", Popovich neither used this term nor corrected the interviewer.)¹⁶⁴

A U.S. journalist claims that the delta-winged upper stage prototype was spotted at a "secret Soviet flight test facility" in 1978, at which time it was undergoing atmospheric flight tests. It was carried aloft for these tests by a TU-95 bomber. According to this and other U.S. reports, manned missions in this vehicle could come before 1985, with initial launches using an expendable booster and a vertical lift-off. A large runway for landing the vehicle has also reportedly been built at the launch site near Tyuratam. Whether the Soviets could design a flyback booster and "...put one into operation before the year 2000 is an open question."¹⁶⁵ The various reports compare the Soviet MTKK with the now defunct U.S. experimental X-20 Dynasoar craft and say it will have much smaller capabilities than the American Space Shuttle.¹⁶⁶

In addition, during the latter half of the 1970's, the USSR made three double Kosmos launches in which both payloads returned to Earth

after one orbit. Dr. Charles S. Sheldon II, Senior Specialist in Space and Transportation Technology of the Congressional Research Service of the Library of Congress, feels that: "The implication is that they were reentry tests, and the first thought immediately is a space shuttle."¹⁶⁷

Other evidence, however, suggests that no reusable Soviet spacecraft will be flown in the near future. In November 1980, an article appeared in Aviatsiya i kosmonavtika (Aviation and cosmonautics) which discussed the transfer of cargoes between the Earth and orbital facilities. The author, Academician V. P. Mishin, was identified as a Hero of Socialist Labor and Lenin Prize laureate. The article points out the need for delivering various freight to craft on long-term orbital flights and states that "scientists and designers of various countries" are working on the development of a "high-productivity transport bridge" between the surface and near-Earth orbits. However, the general tone of the article seems to oppose the use of manned craft, such as the Space Shuttle or the so-called Kosmolet. Mishin points out that the systems associated with human occupation of a spacecraft -- such as life support, manned control devices, instrument displays, and seating accommodations -- take up weight and volume and thereby cut down on the payload. Since the amount of cargo to be returned to Earth will be small for some time to come, the freight vehicles can be made for one-way trips only, as is the Progress cargo robot. This allows a further increase in cargo capacity by eliminating the weight and volume penalties incurred by thermal protection and soft-landing systems. Experimental results and items manufactured in orbit can be returned to Earth by other means -- notably by recoverable capsules such as those returned from Salyut-5 (and Salyut-3, as well as from a number of reconnaissance satellites in the Kosmos series).¹⁶⁸

Soviet criticism of the American shuttle during the past few years may also be a sign of either disenchantment or, more likely, problems with their own development program. The USSR has accused the Space Shuttle of being a source of air pollution, of causing disruption of the ozone layer, of being primarily military in nature, and of being an attempt to influence international relations and regain prestige for the U.S. The Shuttle has also been attacked for being too costly, for not being capable of long-term flights, and for being an anti-satellite development.¹⁶⁹ Such criticisms could be used as an "explanation" for the lack of a Soviet-made reusable manned vehicle.

Perhaps the most convincing evidence that the USSR is not ready to fly a shuttle-type craft, however, is the unveiling of the Soyuz T. This extensively re-engineered Soyuz craft, as noted above, has been announced as being intended specifically for the role of an Earth-to-orbit ferry, especially in connection with space station crew replacement. This is one of the major roles that a Soviet shuttle could be expected to play. If such a shuttle were imminent, it would not make a great deal of sense for Moscow to expend the resources needed to create a new expendable craft.

R.U.R. REVISITED: MANNED VERSUS ROBOT SPACE CRAFT

Each member of an orbital station's crew should be not only an operator-tester, able to exploit space technology and equipment and to act skillfully in irregular situations and under the extreme conditions of space flight, but also an ambitious ["mnogoplanovym"] experimenter, a researcher with deep theoretical knowledge, capable of independently accumulating, summarizing, and interpreting the results of experiments, investigations and observations.

-- General-Lieutenant of Aviation 170
Vladimir Aleksandrovich Shatalov

In the Soviet space program, as in the American, there has been debate as to the relative value of manned and automated space craft. For planetary missions, to date, unmanned probes have been the only choice in either program -- one need not provide a robot with a return trip. For exploration of near earth space the prime argument favoring robots is that they can be made simpler, smaller, lighter, and therefore, cheaper than manned vehicles. (See also Academician Mishin's arguments summarized above.) As Aleksey Stanislavovich Yeliseyev, a former cosmonaut and ground controller for Salyut-6, has pointed out, however: "Each of these assignments can be accomplished with the aid of automatic satellites. But before they come into use...a great deal of preparation is necessary. It is necessary to study in detail each of the controlled natural objects, to develop apparatus which can be used aboard automatic researchers, to create powerful computing complexes for rapid processing of information arriving from space, and to set up a system for its distribution among the users."¹⁷¹

Although the very presence of man on a space flight "is the source of many problems", men can use their initiative to improve the productivity of a mission, often by modifying procedures in progress. Automated devices "work according to a given program" and cannot deviate from it.¹⁷² Robots can only react to a limited set of circumstances. "Therefore in order to ensure the operation of the entire system as a whole, it is absolutely necessary to include in it the component which accomplishes integration of all remaining components. This integral component of contemporary systems...is man..."¹⁷³

These considerations have led the USSR to pursue an extensive manned space program. Since the launch of Soyuz-1 in 1967, 37 Soviet crews have traveled in space, many of them on one of five space stations. For the Soviet Union, "The creation of orbital stations with replaceable crews is man's principle path into space."¹⁷⁴ (Of course, the unmanned program is also extensive. The average number of payloads, both manned and unmanned, launched to orbit or beyond each year during the last decade was 104.)

Figure 5

MANNED SPACEFLIGHTS (M) AND PAYLOADS TO EARTH ORBIT OR BEYOND (P)

LAUNCHED BY THE USSR, BY YEAR

<u>Year</u>	<u>(P)</u>	<u>(M)</u>
1957	2	
1958	1	
1959	3	
1960	3	
1961	8	2
1962	26	2
1963	20	2
1964	39	1
1965	63	1
1966	42	
1967	65	1
1968	74	1
1969	70	5
1970	86	1
1971	93	2
1972	89	
1973	107	2
1974	94	3
1975	111	3
1976	121	3

Figure 5 (cont.)

<u>Year</u>	<u>(P)</u>	<u>(M)</u>
1977	105	3
1978	120	5
1979	102	2
1980	104	6

THEY ARE NOT ALONE: NON-SOVIET SPACE PROGRAMS

It is probable that, in the future, flights in space will become a common affair. I think that it will not be so far in the future...

-- Leonid Il'ich Brezhnev¹⁷⁵

At least seven nations and one international organization have launched one or more satellites of their own into Earth orbit. Still others have designed, built, and/or purchased satellites to be launched for them by one of the space powers.

The second nation to launch a satellite was the U.S. which launched 1,020 payloads to Earth orbit or beyond by the end of 1979 (the USSR had launched at least 1430). Four additional payloads were launched for the U.S. by Italy (in 1967, 1971, and 1974).¹⁷⁶ The U.S., like the Soviet Union, initiated manned launches in 1961 but, unlike the Soviets, began with suborbital flights. The first American to orbit the Earth was launched on 20 February 1962. The President had announced, in 1961, that an attempt would be made to land an American crew on the Moon by the end of that decade, a goal accomplished with the 16 July 1969 launch of Apollo 11. The lunar program ended with Apollo 17 in December 1972. In May 1973, the Skylab space station was launched. It was occupied by three Apollo crews over the next seven months. The final Apollo flight was the 15 July 1975 launch as part of the Apollo-Soyuz Test Project (ASTP).¹⁷⁷ Since that time, although active planetary and unmanned Earth orbital programs have been pursued, there have been no U.S. manned flights. Any plans for manned flights have been held in abeyance until the Space Shuttle comes on line. The Shuttle project has suffered a

number of delays and postponements -- some due to technical problems and others the ultimate result of budget cuts -- and the first Shuttle launch is now expected to be during 1981. Until recently the takeoff was slated for mid-March, but a leaky seal in the vehicle's external fuel tank has forced further delay.¹⁷⁸ The U.S. also maintains cooperative agreements with about 70 other nations, including the USSR, ranging from training of foreign scientists, through flying foreign experiments on U.S. spacecraft and having foreign nationals track U.S. spacecraft, to the European-designed and built Spacelab to be flown on the Shuttle.¹⁷⁹ Motivations for the American space program range from the commercial (communications satellites, meteorological and navigation networks, possible space manufacturing) and political prestige to the scientific (astronomy, astrophysics, geophysics, planetary studies, cosmology, et cetera) and national security (military communications, reconnaissance, missile early warning, et cetera). According to the Library of Congress, 48.2 percent of all U.S. space launchings through 1979 were of a "presumptively specialized military" nature. (The figure for the USSR was 68.6 percent.)¹⁸⁰

France became the third space power on 26 November 1965 when it launched the Asterix-1 satellite. Besides operating its own space program, with launch facilities at Kourou, Guinea, France participated in the European Space Vehicle Launcher Development Organization (ELDO) and is an active participant in the European Space Agency (ESA). France also has an active cooperation program with the Soviet Union and two French pilots, Lt. Colonel Jean-Loup Chretien and Commander Patrick Baudy, have entered cosmonaut training for a joint Franco-Soviet Soyuz/Salyut flight in 1982.¹⁸¹

On 11 February 1970, the Osumi satellite made Japan space power number four. The proposed three trillion yen (\$6.7 billion) space research program for the next 15 years would have Japan concentrate on planetary probes, including lunar orbiters in 1984, Mars and Mercury probes in the late 1980's and Venus probes in the early 1990's. It also foresees Japanese astronauts training for flights on the American Space Shuttle.¹⁸²

China joined the club shortly after Japan when it launched its first satellite on 24 April 1970. The PRC has also considered acquiring communications satellites from the West and is currently putting astronaut candidates through physical training programs and spacecraft simulator exercises.¹⁸³

The next space power, the United Kingdom, launched its first satellite, Prospero, on 23 October 1971 using a Black Arrow launch vehicle developed by Westland Aircraft. Other British firms produce various satellites and launch vehicle components. Both the first communications satellite (the third operational Intelsat IV) and the first military communications satellite (Skynet II) to be built outside of the USA and the USSR were made in the UK.¹⁸⁴

The first international organization to successfully launch a satellite was ESA, which launched the first of its new Ariane vehicles from Kourou in December 1979. A second flight test in May 1980 failed, causing some skippage in ESA's schedule. The third test flight is now scheduled for February 1981 with a fourth to follow in mid-1981. The first "operational" launch is now scheduled for late 1981. ESA has confirmed orders for launch services on Ariane boosters for most planned launches through 1985. Customers include Intelsat, France, Sweden, the

Federal Republic of Germany, India, and ESA itself. ESA satellite and space probe plans include meteorological, communications, and astronomy satellites and the Giotto probe of Halley's Comet.¹⁸⁵

On 18 July 1980, a four-stage solid-fueled launch vehicle designed and built in India lifted a 35 kilogram satellite named Rohini into orbit, making India the eighth space power. The launch site was the Sriharikota Range (SHAR) on Sriharikota Island north of Madras. India also operates the Thumba Equatorial Rocket Launching Station (TERLS), near Trivandrum on the magnetic equator, for sounding rockets. Previous satellites were launched for India by the Soviet Union under a bilateral cooperation agreement of May 1972.¹⁸⁶

A company headquartered in the FRG, Orbital Transport-und Raketen-Aktiengesellschaft (OTRAG) is working on the development of a launch vehicle and expects to launch its first payload in late 1982, with a capability for 10-ton loads to near-Earth orbit or two tons to geostationary orbit being available by 1984. If successful, OTRAG will have the first non-governmental funded orbital vehicles in history.¹⁸⁷

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THE SCENT OF THE FUTURE: MANNED SPACE TRAVEL AND THE SOVIET UNI--ETC(U)

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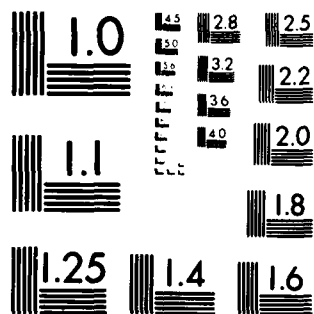
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GAZING INTO THE CRYSTAL BALL: CONCLUSIONS AND PREDICTIONS

"We cannot firmly tie the distant future of civilization solely to the Earth...setting forth into outer space, our generation must...seriously occupy itself with the problems of the cosmic future of mankind..."

-- Vitaliy Ivanovich Sevast'yanov¹⁸⁸

The Soviet space program, with its roots in the Russian Empire, germinated amidst the scientific excitement and scrambling for national prestige of the International Geophysical Year. The soil was fertile and well watered: the Cold War and American embarrassment over early failures created the "Space Race". Then the bud of the Soviet manned space program appeared and began to open. A new fertilizer was found to keep the growing flower healthy: space applications research and a solid program of development from individual spacecraft through docked spaceships to increasingly sophisticated space stations. The program is now bearing fruit in the form of economic benefits from Earth resources observations, military benefits from spaceborne reconnaissance and communications, scientific and engineering benefits from spaceborne astronomy, geophysical and meteorological observations, and materials science and biomedical experimentation, and political benefits from a highly visible, highly propagandized and continuous manned space program and from bilateral and multilateral cooperation agreements.

The current program is concentrating on the further development of space stations, but the Soviets have consistently described such stations not only as beneficial in and of themselves, but also as stepping stones to Lunar and planetary flights. Brezhnev spoke of "cosmodromes

in space"; the "Guidelines for the Development of the National Economy" referred to orbital stations as "starting points for flights to other planets". With this in mind, it becomes interesting to note that a launch window for a Mars flight is available during February and March 1981, approximately coinciding with the XXVI Congress of the CPSU.¹⁸⁹ A manned flight to Mars is likely to take 400 days, with 40 spent exploring the planet and the other 360, traveling through space.¹⁹⁰ Coincidentally (or perhaps not), Valeriy Ryumin spent a total of 360 days in space during his two stints on Salyut-6. Politically, considering Afghanistan, Poland, and Reagan, the USSR could use a space spectacular to improve their image. In addition, April 1981 marks the twentieth anniversary of Gagarin's flight.

With all these factors combined, what could prevent the Kremlin from launching a Mars expedition? The biggest obstacle seems to be booster availability. The Soyuz launch vehicle could not put a spacecraft into Mars transfer orbit if it were large enough to support a human crew for 400 days. The largest operational Soviet launch vehicle, the Proton, is probably still too small, and in any case has never been man-rated. The long awaited G vehicle has yet to be seen. Perhaps a multiple launch from Earth followed by assembly of components in orbit could be used to overcome the booster problem. The next obstacles to crop up are long-term equipment reliability and computing power. While Salyut-6 has displayed great longevity, it has been resupplied with fuel, life support consumables and spare parts at frequent intervals and has undergone repairs to a number of major units. Resupply would be impossible and repairs difficult on a Mars voyage. It was only in 1980 that the Soviets put aboard a spaceship a computer which was capable of handling a

docking procedure without the aid of ground-based computers. When the one-way transmission time lag is more than three minutes (at the closest approach of the two planets a radio signal takes about 190 seconds to go from the Earth to Mars), a ground-based computer could not respond quickly enough to the changing situation at spacecraft. The next obstacle is that of providing a vehicle capable of descending to Mars and then returning to Mars orbit -- an excursion module. This would probably require a winged craft to minimize fuel consumption in landing. Yet the appearance of the Soyuz T indicated that a winged reentry vehicle that could later take off again (i.e., a shuttle vehicle) would not be available in the near future.

These obstacles are formidable, but so are the political forces which make some sort of space display in early 1981 desirable to the Kremlin. Perhaps the creation of a larger space station is in the offing? Here, too, the lack of a larger booster and the lack of a reusable shuttle for resupply missions are hindrances. It would be possible, of course, to dock several Salyut modules together to form a larger station.

All of this is mere speculation. The only fairly certain predictions are that the USSR will continue its manned space program, that there will be continued and probably expanded use of space stations in that area, and that new vehicles will be developed. A great deal of effort will probably be put into completion of some sort of reusable manned spaceship and into development of some form of large (Saturn V class or larger) launch vehicle.

Yuriy Gagarin's comment about space marks the official attitude well: "In space is the scent of the future."¹⁹¹

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